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Research Paper

Exploring the Factors Accelerating the Electric Motorcycle Adoptions: Insights from Theory of Planned Behavior and Travel Behavior

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Abstract

Indonesia is a densely populated country where most people use motorcycles for mobility. With increasing carbon emissions, Indonesia plans to migrate conventional motorcycles toward electric ones by 2040. However, the adoption process of electric motorcycles is relatively slow, considering that the number of electric motorcycles is still far from the government's target. This study aims to investigate what factors influence the adoption process of electric motorcycles in Indonesia. Based on 906 samples, an analysis was conducted using a hybrid choice model on willingness to pay more, which considered three components: socio-demographics, Theory of Planned Behavior (TPB), and travel behavior patterns. The results showed that all three components significantly affect the willingness to pay more. Individuals who are older, highly educated, high-income, use public or environmentally friendly transportation, and have a low frequency of mobility for work purposes are more likely to purchase an electric motorcycle. The results of this study provide a new perspective in the unique context of electric motorcycle adoption in Indonesia and conditions that still need improvement when related to the government's long-term targets. This research will be helpful for governments and manufacturers by providing the characteristics of people who are more likely to purchase an electric motorcycle.

Keywords: Hybrid choice model; Theory of planned behavior; Travel behavior; Electric motorcycles; Willingness to pay more

1. Introduction

Indonesia is one of the world's major countries with a high population density [1]. Indonesian people are accustomed to using motorcycles as a mode of transportation to support their mobility. In 2022, the number of motorcycle vehicles in Indonesia reached 125 million units, or 84.5% of the total vehicles [2]. Motorcycles are a vehicle option that is relatively cheaper than other vehicles, such as cars. Apart from cost, the size of this vehicle makes it efficient in terms of space use and produces good maneuverability [3]. Gasoline-powered vehicles such as motorcycles are a significant source of environmental pollution due to greenhouse gas emissions [4]–[7], even associated with billions of years of lost life in India [8]. The government is trying to solve this problem by suppressing the use of electric motorcycles by issuing acceleration regulations, subsidies, and purchase incentives [9], [10]. However, electric motorcycles have not become the primary choice for users, so there are only 62,815 units, or 0.5% of the government's target in 2030 [11]. Using electric motorcycles is proven to be more environmentally friendly, can improve air quality locally, and reduce health risks caused by conventional motorcycle emissions [12], [13]. In addition, using electric motorcycles also reduces noise pollution because they produce a quieter sound than conventional motorcycles [14].

Several studies related to the adoption of electric motorcycles have been conducted in various countries to investigate what factors affect the intention to purchase electric motorcycles to

encourage the acceleration of the adoption process [15]–[17]. Research with this goal can be clustered into two main clusters. The first cluster seeks to explore the factors that determine individual choices. Researchers often use vehicle technical variables as explanatory variables [18]–[22]. Hermawan and Lee [18] researched factors influencing the use of shared e-scooters in Singapore and found that users are increasingly interested in using e-scooters as speeds increase. Balijepalli et al. [19] found that battery charging speed is crucial for consumers in Bandung, Indonesia. Scorrano et al. [20] conducted a similar study in Italy using shared e-scooters. They found that operating costs and technical factors of e-scooters were significant motivating factors. However, it was suggested that users preferred using conventional motors in the cteris paribus state. In Vietnam, Truong [21] stated that the battery charging time and scooter usage distance capacity were crucial for users. Finally, in India, the availability of infrastructure and increasing prices of fossil fuels, accompanied by decreasing electricity prices, are crucial factors in determining the selection of respondents' vehicles [22]. In addition, some researchers also considered user travel behavior in investigating factors driving the adoption of electric motors. Aguilera-García et al. [23] considered travel-related attributes, such as the frequency of trips using specific modes each week, public transportation modes, and two-wheeled vehicles. The characteristic of never traveling using specific modes of transportation, such as cars, motorcycles, and taxis, is a motivating factor for someone to use electric vehicles. Mitra and Hess [24] also investigated travel behavior, such as ownership of specific modes of transportation, commonly used modes, and the use time.

The second research cluster seeks to determine the driving factors based on technology acceptance theory, such as the Theory of Planned Behavior (TPB). TPB is one of the theoretical frameworks researchers often use to explain the driving factors of the intention to adopt a technology. Murtiningrum et al. [25] found that the three TPB variables, along with environmental and economic benefits, proved influential on the attitude toward electric motorcycle adoption in Indonesia. Still in Indonesia, Rahmawati et al. [15] found similar results, where the three TPB variables directly affected purchase intention, with attitude having a major impact. There were also consistent conclusions from research conducted regarding the intention of e-scooter adoption in developed and emerging economy countries, such as Taiwan, Malaysia, and China [26]–[28].

Based on our knowledge, we have yet to find any research that integrates the two clusters above by presenting the TPB framework and travel behavior to explore the factors that affect behavioral intentions. Scorrano and Rotaris [29] considered environmental attention and activism as latent variables to find their influence on the intention of using electric motors in Italy, along with the technical factors of electric scooters. The research was made possible using the hybrid choice model method. The method seeks to identify variables that cannot be observed (latent variables) and include them in the choice model analysis. According to TPB, purchase intention is determined by three latent variables: attitude toward behavior, subjective norms, and perceived behavioral control. This latent variable cannot be included in the ordinary choice model. Therefore, this research will use the hybrid choice model to investigate the purchase intention of electric motorcycles in Indonesia by integrating TPB's latent variables and travel behavior into the choice model. This research will focus on the willingness to pay more (WTP) for electric motorcycles, considering that Indonesian people use motorcycles most widely to support mobility. According to the previous explanation, this research aims to explore factors that support or weaken electric motorcycle purchase intention by using the hybrid choice model. This research may present several contributions. First, this research can provide a novelty by simultaneously combining latent factors and choice models for electric motorcycle objects. Second, this study will investigate whether there is a willingness to pay more for electric motorcycles and explore supporting or inhibiting factors. Third, this study will also reveal the results of the electric motorcycle adoption process in Indonesia. Finally, this study can provide some suggestions for governments and manufacturers because it can reveal the characteristics of people who are more intent on purchasing an electric motorcycle. This research can provide practical policy advice and

business strategies to help the growth of electric motorcycles in Indonesia, which will become the primary type of motorcycle in 2040.

2. Methodology

2.1. The Role of Travel Behavior

As research on electric motorcycle adoption increases, factors other than technical factors, such as travel behavior, are also considered in the analysis. Hierarchical structures often hint at daily travel patterns due to the user decisions. The hierarchy starts with short-term, medium-term, and long-term daily activities and lifestyle decisions. Van Acker et al. [30] provided theoretical justification that travel behavior was driven by at least three components: a spatial component, a socio-economic component, and a personality component.

There are several studies related to the intention of electric motorcycles that use travel behavior as a motivating factor for behavior intentions [23], [24], [31]. Aguilera-García et al. [23] examined the determinants of shared e-scooter adoption in Spain using socio-economic factors, travel attributes, and attitudes or preferences. By measuring the attributes of travel behavior, respondents' information was collected on using two-wheeled vehicles as the primary mode, the frequency of trips in the week, the use of public transportation, and the frequency of use of particular modes in one week. It was found that travel attribute factors strongly influenced the adoption of electric scooters. Mitra and Hess [24] also researched adopting e-scooter use in Toronto by considering travel behavior attributes, such as frequently used modes and travel time. However, these attributes proved to be insignificant in influencing intentions. Instead, travel attitudes about the environment, cost-effectiveness, and affordability encourage using electric scooters. Venkadavarahan and Marisamynathan [31] found that mileage factors using two-wheeled vehicles and motorcycle use significantly affect the intention to use electric motorcycles.

Research considering this factor usually uses attributes such as travel frequency and use of particular modes. In this study, we will separate weekdays from weekends because the purpose of traveling on weekdays and weekends can differ in travel behavior, affecting mode selection decisions. Therefore, this study will reveal whether there is an influence on the frequency and purpose of traveling on weekdays and weekends. Previous research has also revealed that travel behavior variables are correlated with the adoption of electric motorcycles [23], [24], [31]. Even though there are mixed results between these studies, it is hypothesized that travel behavior variables can impact. In this research, we consider three travel behavior factors. First, travel time refers to the time a person usually travels in one day. Second, the frequency of travel a person usually takes in one day. Third, a person's purpose in traveling to a destination in one day. We will separate the frequency and purpose of traveling on weekdays and weekends. Thus, the purchase intention based on WTP will be caused by five travel behavior variables shown in **Figure 1**.

2.2. The Role of Theory of Planned Behavior (TPB)

Based on the TPB, a person performs a behavior due to the individual's intention to perform the behavior. Ajzen [32] expanded the Theory of Reasoned Action (TRA) because the theory cannot accommodate behavior when a person does not have *volitional control*. Therefore, Ajzen added a third variable, perceived behavioral control, which aims to capture an individual's volitional level of use. When applied to technology acceptance, TPB is a reasonably general model [33]. The construction of the TPB is assumed to be content-free so that it can be applied to all kinds of behaviors. In the TPB, a person's intention to perform a behavior is caused by three variables: attitude toward behavior, subjective norm, and perceived behavioral control.

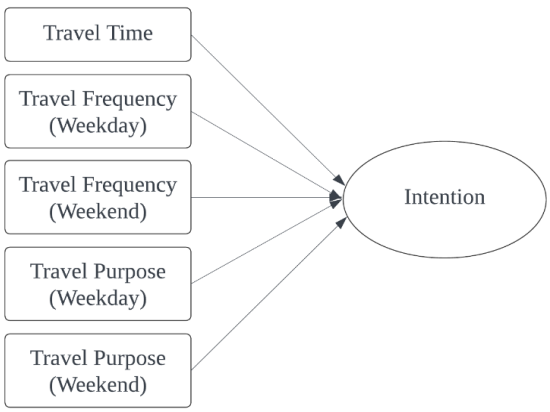

Figure 1. Theoretical framework of travel behavior

Attitude toward behavior is assumed to be a function of behavioral beliefs. Behavioral beliefs are the subjective opportunity a person has to perform a behavior that can produce a particular outcome or experience. This study investigates people's attitudes to determine if they believe using electric motorcycles is good. The second variable in the TPB is subjective norms. Normative beliefs can be divided into two aspects: *injunctive* and descriptive. *Injunctive* is a subjective expectation or opportunity a group of close associates gives to approve or disapprove behavior in specific considerations. Descriptive is the belief that the prominent person doing the behavior will significantly affect our decision to do that behavior, too. Both types of normative beliefs were used in this study to measure a person's subjective norms. Lastly, perceived behavioral control is based on measurable control beliefs. These beliefs refer to factors that can facilitate or even hinder the performance of a behavior. This study's control includes technical ability, time, and money. *Control beliefs* are defined as a person's subjective chance that a motivating or inhibiting factor can be present when performing a behavior.

Many researchers have used the TPB model to predict a person's intention to use an electric motorcycle [15], [25], [26], [34]. Eccarius and Lu [26] examined shared electric scooter usage intentions in Taiwan and found that all three TPB variables played a significant positive role in electric scooter usage intentions. Murtiningrum et al. [25] and Rahmawati et al. [15] examined the intention to use electric motorcycles in Indonesia. They found the same results, which showed that the three TPB variables significantly affected the adoption of electric motorcycles. Similar results were found in a study on adopting electric scooters in Colombia conducted by Rodríguez-Correa et al. [34]. In this study, TPB was used in the context of a person's intention to pay a higher cost to buy an electric motorcycle. TPB variables such as attitudes, subjective norms, and perceived behavioral control were used to construct purchase intentions, and other variables such as socio-demographics and travel behavior.

Figure 2 shows the theoretical framework from TPB. Purchase intention, which can provide behavioral outcomes, will be caused by three latent factors: attitude, subjective norms, and perceived behavioral control, consistent with TPB theory [32]. Therefore, it is hypothesized that attitude toward behavior (electric motorcycle), subjective norms, and perceived behavioral control have a direct positive relationship to purchase intention, as shown in **Figure 2**.

2.3. *Modeling Framework*

The hybrid choice model, or HCM, is a new discrete choice model (DCM) generation that combines these and latent variable models [35]. The most common model is proposed by calling it the generalized random theory. The theory is in the form of adding several extensions to the random utility model (RUM). These extensions are flexible disturbances, latent variables, and latent classes. **Figure 3** shows that HCM consists of two main components: the multiple indicators multiple causes (MIMIC) model and the DCM [36], [37]. The MIMIC model can explain the relationship between latent variables and their explanatory variables, such as socio-demographic characteristics and latent indicators [38].

The HCM method in this research is intended to integrate the adoption model as a latent variable with the observed variable of travel behavior. The research used three latent variables based on TPB: attitudes toward behavior, subjective norms, and perceived behavioral control. Each latent variable has its own indicator, which describes the relationship through a measurement model. Five travel behavior variables were also used in this research, such as travel time, travel frequency (weekday & weekend),

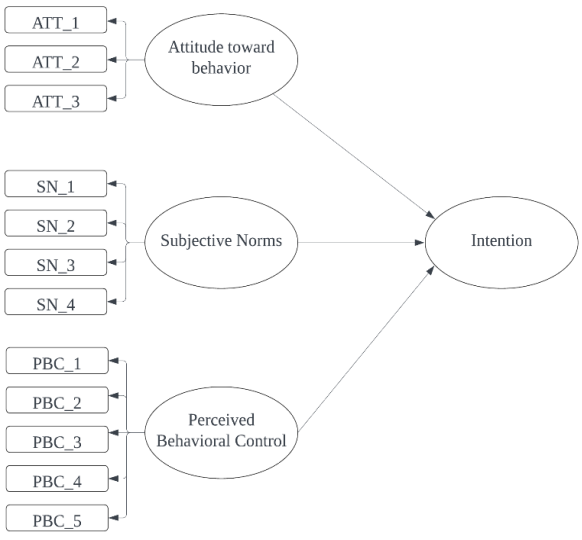

Figure 2. Theoretical framework of TPB

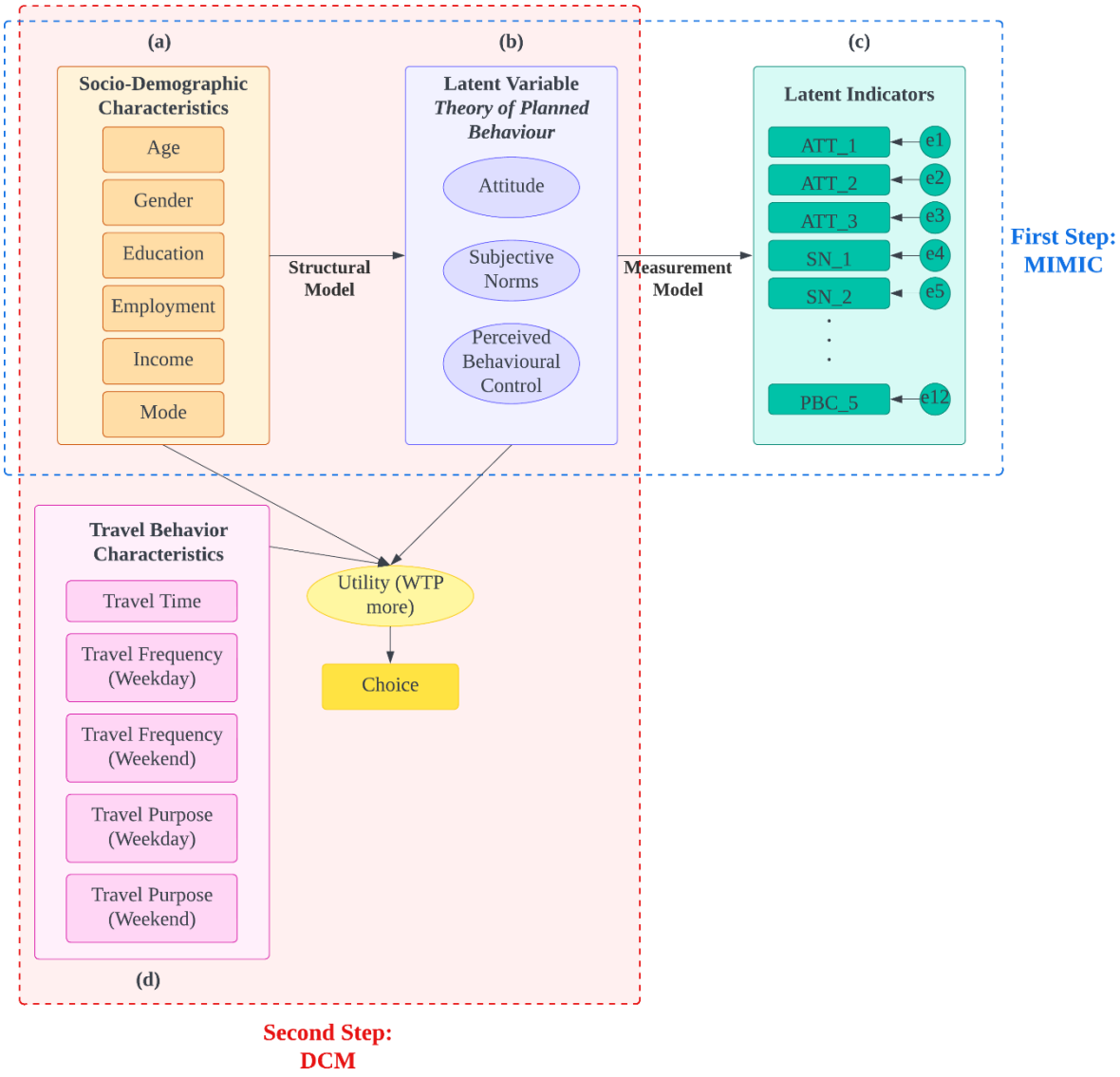

Figure 3. Hybrid choice model framework

and travel purpose (weekday & weekend). Meanwhile, the endogenous variable used in this research is the respondent's willingness to pay more to buy an electric motorbike. The HCM estimation process uses the Biogeme 3.11 package, which is written using Python 3.9 programming language. Biogeme is an open-source package designed for general maximum likelihood estimation of parametric models, emphasizing discrete choice models. In the process, the Pandas library is also used to set up the data used.

2.4. *MIMIC Model*

The MIMIC model used in this study considers three main variables: socio-demographic variables, TPB, and latent indicators. The box in **Figure 3a** shows the socio-demographic characteristics used in the study (i.e., age, gender, education, occupation, income, and mode of choice). This factor will be used as an explanatory factor for the latent variables of TPB, commonly referred to as the structural model. The structural model associates latent variables with variables of the socio-demographic characteristics of each individual. The following Eq. (1) shows this relationship.

$$LV_{ji} = \delta S_i + \eta_i + \gamma_i \quad (1)$$

Where δ is the vector parameter of the socio-demographic variable to be estimated, is γ_i an error assumed to be normally distributed $N(0, \sigma_\gamma)$. While η_i is an error component that is also normally distributed $N(0, \sigma_\eta)$, which is quite common as a component in the choice model [39].

The ellipse in **Figure 3b** shows three latent variables adopted based on the TPB theory. These

latent variables have several indicators, as shown in **Figure 3c** and **Table 3**. This measurement model relates the latent variable to its indicator through the equation of some indicators. Therefore, the following equation (2) describes the indicator. I_{fi}.

$$I_{fi} = d_f + \theta_f LV_{ji} + \mu_{fi} \quad (2)$$

Where θ_f is a coefficient that describes the character of a latent variable, d_f is an intercept, and μ_{fi} is an error assumed to be normally distributed $N(0, \sigma_\mu)$. To be run, the initial values of the indicator θ_f and d_f will be set as 1 and 0 [35].

The latent variable indicator is a discrete variable that uses a five-level Likert scale [39]. Therefore, it is necessary to define τ_i to describe the symmetry of these indicators by defining two positive parameters (δ_1 and δ_2). The following Eq. (3) to Eq. (6) shows this relationship.

$$\tau_1 = -\delta_1 - \delta_2 \quad (3)$$

$$\tau_2 = -\delta_1 \quad (4)$$

$$\tau_3 = \delta_1 \quad (5)$$

$$\tau_4 = \delta_1 + \delta_2 \quad (6)$$

Thus, the probability of a response can be expressed as an ordered probit model as follows (see Eq. (7)).

$$P_r(I_i = j_i) = P_r(\tau_{i-1} \leq z \leq \tau_i) \quad (7)$$

2.5. The Choice Model

Eq. (8) below shows how the utility function U_{yes} is associated with alternatives to answer "Yes" to the question of purchasing an electric motorcycle.

$$U_{yes} = \beta_s S_i + \beta_{tb} TB_i + \sum_{j=1}^{3} \beta_{LVj} LV_{ji} + \eta_i + \varepsilon_i \quad (8)$$

Where S_i is the socio-demographic characteristic vector of each individual, TB_i is the characteristic vector of each individual's travel behavior, LV_{ji} is the vector of latent variable construction based on the TPB and β_s, β_{tb}, β_{LVj} are the vectors of the parameters to be estimated. Errors ε_i is assumed to be extreme values that are identically and independently distributed. While noise η_i is a component of errors that are assumed to be normally distributed $N(0, \sigma_\eta)$.

The probability of an individual i choosing alternatives "Yes" or "No" is a multiplication between the conditional probability that a person has an alternative "Yes" and the conditional distribution function of the indicator. Therefore, the following Eq. (9) describes the probability.

Based on Eq. (9), δ is the set of all estimated parameters, X is the set of all explanatory variables (socio-demographic and travel behavior). The first part of the integral shows the part of the choice model. The second part is part of the measurement model. The last part is part of the structural model of latent variables.

2.6. Survey Design

This study explores the willingness to pay more for buying an electric motorcycle. Based on previous research, surveys are an appropriate tool to explain related issues because the adoption process is often caused by various factors, such as psychological factors that cannot be measured through revealed data. The survey in this study was conducted using an Indonesian language questionnaire consisting of three sections. The first section explains the research's purpose and benefits with a statement of ethical and data security issues. The second section contains socio-demographic variables, such as gender [40], age [40], education [40] employment [24], income [40], and primary modes of transportation [24]. This section also contains questions about respondents' travel behavior, including the frequency and purpose of traveling on weekdays and weekends and the time spent traveling [23]. The third section contains measurement models related to TPB and adapted from several previous studies [15], [41]–[44]. Each latent variable indicator was measured using a five-point Likert scale, with 1 for strongly disagree and 5 for strongly agree.

The pre-survey was conducted with 30 people to improve the clarity of the questionnaire. Based on the feedback from the pre-survey, several improvements were made to the statements on the questionnaire to increase the clarity of their meaning. This study used the convenience sampling method, where the questionnaire was designed using Google Forms

$$f(y_i, I|X; \delta) = \int_{LV} P(y|X, LV; \sum \varepsilon) f_i(I|LV; \lambda) \times f_{LV}(LV|S; \upsilon) dLV \quad (9)$$

and distributed through social media with several requirements, namely being at least 17 years old and domiciled in 20 cities in Indonesia with the highest number of motorcycles [45], [46]. This survey was conducted online from March to April 2023. The minimum sample size was calculated considering standard error at 95% significance, the proportion of the population, and acceptable error [47]. Referring to the research of Adnan et al. [48], using an effect size f^2 of 0.12, a minimum sample of 171 respondents was obtained. Based on the survey that has been conducted, 951 respondents were obtained. Fifteen respondents' data were detected as invalid and duplicated, resulting in 936 valid data. Data outliers can cause results to be inaccurate in analyses that use log-likelihood estimation methods [49]. We calculated the residual Pearson on each data with a limit control ± 2 [50]. Data outside the control limit was an outlier that could interfere with the analysis results. The outlier data were removed based on 936 valid data, leaving 906 samples for use in this analysis.

3. Result and Discussion

3.1. Sample Characteristics

This section describes the characteristics of the sample used. **Table 1** explains the socio-demographics of respondents. Respondents are pretty evenly distributed by gender, with men known to have slightly more, 52% versus 48%. Survey participants are dominated by people under the age of 43 years (84.1%) or, in other words, millennials and Gen-Z. Respondents have diverse education levels, with 51.7% Diploma/Bachelor, 43.4% High School, and 5% Master/Doctor. 41.4% of participants had full-time jobs, with many business people (21.1%) and part-time workers and students (15.8% and 15%). Meanwhile, in terms of income, it is known that the distribution of respondents is different, with the most significant number being those with incomes below IDR 10 million (88%). In addition, most respondents (85.1%) use motorcycles as the primary mode of transportation for their daily activities.

In addition, **Table 2** shows the characteristics of respondents' travel behavior. Only a few respondents had travel time below 15 minutes (7.5%), with 19.2% travel time above 60 minutes. This data indicates that transportation activities are essential for respondents because they are time-consuming in one day. On weekdays, most respondents travel more than five times (43.8%), with the most goals being work (56.8%), then business (21%), and school (15.2%). While on weekends, most respondents only travel less than three trips (85.2%), with most destinations being visiting relatives/friends (39.6%), shopping (26.5%), and holidays (24.1%).

Table 1. Respondent profile

Characteristic	Items	Frequency	Percentage
Gender	Man	471	52.0%
	Woman	435	48.0%
Age	17 - 28	327	36.1%
	29 - 42	435	48.0%
	43 - 58	137	15.1%
	>58	7	0.8%
Education	High School	393	43.4%
	Diploma/Bachelor	468	51.7%
	Master/Doctor	45	5.0%
Employment	Student	136	15.0%
	Businessmen	191	21.1%
	Full-Time	375	41.4%
	Part-Time	143	15.8%
	Do not work	61	6.7%
Income	IDR 0 – 5,000,000	500	55.2%
	IDR 5,000,001 – 10,000,000	297	32.8%
	IDR 10,000,001 – 20,000,000	87	9.6%
	> IDR 20,000,000	22	2.4%
Mode	Motorcycle	771	85.1%
	Private car	52	5.7%
	Transit bus/minibus	31	3.4%
	Transit train	7	0.8%
	Taxi/ride-hailing	31	3.4%
	Other	14	1.5%

Table 2. Characteristics of respondents' travel behavior

Characteristic	Items	Frequency	Percentage
Travel Time	<15 minutes	68	7.5%
	15-30 minutes	378	41.7%
	30-60 minutes	286	31.6%
	>60 minutes	174	19.2%
Frequency (weekdays)	<2	74	8.2%
	2-3	204	22.5%
	4-5	231	25.5%
	>5	397	43.8%
Frequency (weekend)	<2	404	44.6%
	2-3	377	41.6%
	4-5	77	8.5%
	>5	48	5.3%
Purpose (weekdays)	Other	63	7.0%
	Work	515	56.8%
	School	138	15.2%
	Business	190	21.0%
Purpose (weekend)	Other	15	1.7%
	Work	74	8.2%
	Holiday	218	24.1%
	Visiting relatives/friends	359	39.6%
	Shopping	240	26.5%

Table 3 summarises respondents' answers related to the indicators used in the measurement model. The attitude towards behavior variable has the highest average answer. **Table 3** indicates that the average respondent in the mix of "agrees" to "strongly agree" that electric motorcycles can provide good benefits. The average respondent answered "neutrally" to "agree" on the subjective norm variable that measures whether external parties influence the adoption of electric motorcycles. Respondents are also known to have good knowledge and technical ability of electric motorcycles, as seen from the average respondent answering in the mix of "agrees" to "strongly agree" on behavioral control variables. However, the average respondent only answered in the mix of "neutral" to "agree" on the financial ability to buy an electric motorcycle.

3.2. Hybrid Choice Model Result and Discussion

We estimate the coefficients in structural, measurement, and binary logit models by maximizing the log-likelihood of HCM. The first two models result from the MIMIC model, which analyzes the relationship between socio-demographic variables and indicators on the TPB latent variables. The binary logit model analyzes the selection of willingness to pay more for electric motorcycles based on three main variables: socio-demographic, TPB, and travel behavior. The dependent variable in this study was calculated by asking respondents, "Are you willing to pay more to buy an electric motorcycle?". Two alternative answers are provided, "Yes" and "No". The latent variable of attitude toward behavior has three indicators, subjective norm has four indicators, and perceived behavioral control has five indicators. All indicators have a positive relationship with latent variables. Indicators for attitude and perceived behavioral control variables had relatively similar impacts. In subjective norms, indicators regarding valued people's opinions influence the construction of these latent variables the most. **Table 4** shows the relationship between these indicators and explanatory variables in the structural model, which are significant at a 95% confidence level. The age variable (43 – 58 years) has a latent relationship with the latent variable attitude towards behavior. In the last education variable, only the Diploma/Bachelor level has a latent relationship with the three latent variables. Income below five million in one month has no latent relationship. In contrast, all types of employment are proven to have latent variable relationships. This MIMIC model can explain the TPB variance of 34.8% and is classified as almost substantial [51].

Table 3. Characteristics of respondents to TPB indicators

Observed Variable		Distribution (%)					Avg.	Std. Dev
		1	2	3	4	5		
ATT_1	I think using an electric motorcycle is a good idea	0.44	0.88	12.14	27.37	59.16	4.44	0.77
ATT_2	I think using an electric motorcycle is a wise idea	0.33	1.32	15.67	29.69	52.98	4.34	0.81
ATT_3	I think using an electric motorcycle is beneficial	0.44	1.21	14.90	29.69	53.75	4.35	0.81
SN_1	People who are important to me will think that I should use an electric motorcycle	1.21	5.08	29.80	27.81	36.09	3.92	0.98
SN_2	People who influence my behavior will think that I should use an electric motorcycle	2.10	6.07	32.67	26.60	32.56	3.81	1.03
SN_3	People whose opinions I value prefer me to use an electric motorcycle	2.87	5.63	31.02	27.59	32.89	3.82	1.04
SN_4	Riding an electric motorcycle will give others a good impression of me	2.10	4.64	31.13	29.25	32.89	3.86	1.00
PBC_1	I have the freedom to decide whether to buy an electric motorcycle or not	0.99	0.99	14.02	24.94	59.05	4.40	0.84
PBC_2	I have the financial ability to buy an electric motorcycle in the future	1.99	4.75	25.17	28.15	39.96	3.99	1.01
PBC_3	If I want it, I can buy and use an electric motorcycle for the next vehicle purchase	1.32	2.98	23.95	30.35	41.39	4.08	0.94
PBC_4	I know how to use an electric motorcycle	1.55	5.52	24.72	27.48	40.73	4.00	1.01
PBC_5	I will not worry when using an electric motorcycle	1.32	4.97	23.62	28.59	41.50	4.04	0.98

Table 4. MIMIC model estimation result

Variable	Coefficient	p-value	Variable	Coefficient	p-value
Attitude (ATT)			**Perceived Behavioral Control (PBC)**		
Indicators			**Indicators**		
ATT_2	0.283	0.000	PBC_2	0.539	0.000
ATT_3	0.243	0.000	PBC_3	0.473	0.000
Explanatory Variables			PBC_4	0.512	0.000
Age (43-58)	0.358	0.049	PBC_5	0.439	0.000
Education (Diploma/Bachelor)	0.412	0.000	**Explanatory Variables**		
Employment			Education (Diploma/Bachelor)	0.238	0.003
Businessman	0.948	0.000	Employment		
Full-Time	0.953	0.000	Businessman	0.949	0.000
Part-Time	1.170	0.000	Full-Time	1.020	0.000
Does not work	0.833	0.000	Part-Time	1.060	0.000
Income			Does not work	0.720	0.000
5,000,001 – 10,000,000	0.354	0.002	Income		
10,000,001 – 20,000,000	0.698	0.000	5,000,001 – 10,000,000	0.520	0.000
> 20,000,000	1.320	0.002	10,000,001 – 20,000,000	0.959	0.000
Subjective Norm (SN)			> 20,000,000	0.942	0.003
Indicators			Mode		
SN_2	0.638	0.000	Taxi/ride-hailing	-0.368	0.049
SN_3	0.733	0.000	Other	0.490	**0.083**
SN_4	0.421	0.000			
Explanatory Variables					
Education (Diploma/Bachelor)	0.184	0.023			
Employment					
Businessman	0.626	0.000			
Full Time	0.600	0.000			
Part-Time	0.754	0.000	**Init. Log Likelihood**	-20504.51	
Does not work	0.563	0.006	**Final Log Likelihood**	-13370.11	
Income			**Rho-Square**	0.348	
5,000,001 – 10,000,000	0.279	0.004	**AIC**	26914.22	
10,000,001 – 20,000,000	0.303	0.049	**BIC**	27335.44	
> 20,000,000	0.739	0.013	**Num Parameters**	87	

Note: **bold** $p < 0.1$, regular $p < 0.05$

Next, we estimate the binary logit model by considering the three TPB latent variables and travel behavior with the appropriate construction in the MIMIC model. In this analysis, a basic model is made by considering only socio-demographic variables, then adding travel behavior variables, and finally, adding latent variables. This gradual model creation aims to determine changes that might occur. This scheme is necessary because the relationship between variables can change when there are additional factors [24]. For example, those aged>58 years are more likely to make purchases when the TPB latent variable is added (see **Table 5**, Model 3). Changes also occurred in the gender variable. It became a significant influence when adding the TPB latent variable. Besides that, this gradual model creation aims to determine whether the addition of variables has significant added value. **Table 5** shows that adding variables to each model increases the capability of the binary logit model. The model proved to be better from each designation, judging from the increase in R^2 value and decrease in AIC value. An increase in R^2 indicates a better fit of the model [52]. Meanwhile, a decrease in the AIC value indicates a more efficient model because the model's predictive performance will be better [53].

The logit model estimation results are shown in **Table 5**. It found that each age group significantly influenced consumers' intentions to buy electric motorcycles. Baby boomers over the age of 58 have the highest chance of adopting. These results differ from previous studies suggesting that younger generations are more likely to adopt [23], [24]. Male consumers are also shown to have a higher chance of purchasing an electric motorcycle in the study area. This results aligns with research conducted in Indonesia by Zudhy Irawan et al. [54] regarding the intention of using electric motorcycles. The higher the level of education a person pursues, the more likely a person is to buy an electric motorcycle. This result aligns with previous research [18], [55]. Someone with high enough knowledge has a faster tendency to adopt new technology. Based on other socio-demographic variables, business people have the best chance of adopting electric motorcycles. Other jobs, including students, full-time workers, part-time workers, and unemployment, have negative effects. These results are consistent with some previous research that also states the same for freelancers [56], workers [23], and unemployment [24]. In terms of income, someone with a total income above IDR 10 million in one month has up to twice the chance of buying an electric motorcycle. Despite government purchase price subsidies, consumers with incomes below IDR 10 million still do not consider electric motorcycles as their top choice. Christoforou et al. [57] state that electric motorcycle users are those who do not put cost as a top priority. Based on the category of transportation mode used, the "other" category has the highest chance of buying an electric motorcycle. The category contains consumers who travel by using electric motorcycles or bicycles. The results confirm research by Reck and Axhausen [58], where someone with electric motorcycle ownership or an annual public transport ticket is more likely to use a scooter or electric bike. Consumers with more environmentally friendly modes of daily transportation have a better tendency. This result can be seen from the estimation results that users of conventional motorcycles and private cars are the categories least likely to buy electric motorcycles.

When reviewing travel behavior variables, the duration and purpose of traveling on holidays do not have a significant effect. Results regarding insignificant duration are in line with Caroll [59] and Mitra & Hess [24] but differ from Hermawan & Lee [18]. Hermawan & Le [18] present evidence that short trips (<30 minutes) have a positive impact on the intention of using shared e-scooters. Meanwhile, the results on the variable purpose of traveling contradict the research by Christoforou et al. [57], stating that electric scooters in Paris are often used for strolling or visiting relatives/friends. Furthermore, it differs from Aguilera-García et al. [23] who found that the frequency of traveling has an unclear influence. Our research shows that consumers who have an average of 2 – 3 trips on weekdays are more likely to purchase an electric motorcycle. While on weekends, someone who takes < 3 trips is reluctant to buy an electric motorcycle. When viewed from the purpose of traveling, consumers who want to travel to work on weekdays have the highest opportunity compared to other destinations, such as attending school. This result supports the research of Aguilera-García et al. [23] about shared e-scooters.

Table 5. Binary logit model estimation result

	Variable	Will you pay a higher price for an electric motorcycle? (Yes/No)								
		Model 1			Model 2			Model 3		
		Value	Std. Error	p-value	Value	Std. Error	p-value	Value	Std. Error	p-value
Socio-demographic characteristics	**Age (Base: 43-58)**									
	17 – 28	1.410	0.252	**0.000**	1.590	0.265	**0.000**	2.520	0.347	**0.000**
	29 – 42	0.704	0.211	**0.001**	0.849	0.224	**0.000**	1.640	0.299	**0.000**
	>58	0.363	0.990	0.714	0.672	0.948	0.478	5.220	1.260	**0.000**
	Gender (Base: Female)									
	Man	0.029	0.156	0.855	0.079	0.164	0.631	0.774	0.208	**0.000**
	Education (Base: High School)									
	Diploma/Bachelor	-0.350	0.150	**0.020**	-0.248	0.154	0.109	1.610	0.393	**0.000**
	Master/Doctor	0.290	0.346	0.403	0.381	0.367	0.300	2.110	0.494	**0.000**
	Employment (Base: Businessmen)									
	Student	-0.846	0.275	**0.002**	-6.650	1.120	**0.000**	-14.000	1.760	**0.000**
	Full Time	-0.330	0.186	***0.076***	-15.000	1.800	**0.000**	-15.800	1.810	**0.000**
	Part-Time	-0.480	0.240	**0.045**	-15.100	1.790	**0.000**	-15.800	1.800	**0.000**
	Does not work	-1.580	0.368	**0.000**	-10.100	1.600	**0.000**	-12.700	1.650	**0.000**
	Income (Base: < 5 Million Rupiah)									
	5 – 10 Million	0.661	0.165	**0.000**	0.66	0.17	**0.00**	4.720	0.820	**0.000**
	10 – 20 Million	1.250	0.277	**0.000**	1.19	0.28	**0.00**	8.350	1.450	**0.000**
	>20 Million	1.180	0.470	**0.013**	1.16	0.48	**0.02**	8.310	1.490	**0.000**
	Mode (Base: Taxi/Ride Hailing)									
	Motorcycle	-1.020	0.251	**0.000**	-0.318	0.307	0.301	4.260	1.030	**0.000**
	Private car	-0.897	0.390	**0.022**	-0.120	0.444	0.787	5.070	1.170	**0.000**
	Transit bus/minibus	-0.366	0.497	0.461	0.341	0.502	0.497	5.570	1.220	**0.000**
	Transit train	-1.270	0.788	0.108	-0.568	0.917	0.535	7.820	1.940	**0.000**
	Other	0.069	0.638	0.914	0.910	0.675	0.178	9.380	1.870	**0.000**
Travel Behavior	**Time (Base: 15-30 Minutes)**									
	<15 minutes				-0.087	0.307	0.776	0.026	0.314	0.933
	30 – 60 minutes				0.061	0.178	0.730	0.177	0.181	0.329
	>60 minutes				-0.119	0.218	0.585	0.021	0.231	0.927
	Frequency weekdays (Base: >5 Times)									
	<2				-0.055	0.308	0.857	0.175	0.324	0.589
	2 – 3				0.129	0.202	0.523	0.362	0.207	***0.080***
	4 – 5				0.145	0.184	0.429	0.273	0.190	0.150
	Frequency weekend (Base: 4 – 5)									
	<2				-1.280	0.259	**0.000**	-0.681	0.270	**0.012**
	2 – 3				-1.120	0.265	**0.000**	-0.512	0.268	***0.056***
	>5				-0.902	0.384	**0.019**	-0.281	0.392	0.474
	Purpose weekdays (Base: Business)									
	Other				8.770	1.650	**0.000**	9.890	1.680	**0.000**
	Work				14.900	1.800	**0.000**	16.600	1.780	**0.000**
	School				5.990	1.090	**0.000**	6.870	1.110	**0.000**
	Purpose weekend (Base: Holiday)									
	Other				0.482	0.580	0.406	0.807	0.619	0.192
	Work				-0.169	0.311	0.587	0.102	0.321	0.750
	Visit relatives/friends				-0.166	0.188	0.375	0.065	0.202	0.749
	Shopping				0.033	0.202	0.872	0.242	0.211	0.253
Theory of Planned Behavior	LV1: Attitudes Toward Behavior							-0.006	0.036	0.873
	LV2: Subjective Norms							-0.039	0.070	0.580
	LV3: Perceived Behavioral Control							-7.300	1.430	**0.000**

Variable	Will you pay a higher price for an electric motorcycle? (Yes/No)								
	Model 1			Model 2			Model 3		
	Value	Std. Error	p-value	Value	Std. Error	p-value	Value	Std. Error	p-value
Initial LogLikelihood	-627.9913			-627.991			-626.271		
Final LogLikelihood	-564.6282			-546.268			-530.926		
R^2	0.101			0.130			0.152		
AIC	1165.256			1160.537			1141.852		
BIC	1251.819			1324.044			1334.214		

Note: ***bold italics*** $p < 0.1$, **bold** $p < 0.05$

The results of the analysis of TPB latent variables in this study are very different from previous studies [9], [15], [25], [26], [34]. In this study, attitude toward behavior and subjective norms do not influence the intention to purchase electric motorcycles. Meanwhile, perceived behavioral control variables proved significantly influential but had a negative direction. This result means that the higher the behavioral control consumers possess, the more reluctant these consumers are to buy electric motorcycles. These results indicate that the adoption process of electric motorcycles is still weak in the study area. Most consumers already feel they have reasonable control over using electric motorcycles (see **Table 3**). However, this is still not a motivating factor for buying an electric motorcycle. This result may also be because information about the advantages of using electric vehicles, such as reducing gasoline use and being more environmentally friendly, still does not directly affect the intention of adopting electric motorcycles [60]. In addition, it should be noted that this study investigates the willingness to pay more for electric motorcycles, in contrast to most other studies that analyzed the variable willingness to buy.

To our understanding, we are the first to integrate the latent variable TPB with travel behavior for the electric motorcycle object. Aguilera-García et al. [23] used travel behavior attributes like vehicle ownership and trip frequency. We expand the travel behavior by adding duration and purpose of travel and separating weekends and weekdays. Mitra and Hess [24] also use travel behavior, especially time for travel. Both researchers used other factors, such as Aguilera-García et al. [25], who use attitude, and Mitra and Hess [15], who use subjective norms. However, this is not a latent variable based on the TPB framework. Attitude is an observable variable, such as individual concerns about new technologies. Meanwhile, subjective norms are used to measure social perceptions. Apart from that, other researchers using TPB as model construction do not use observable variables (i.e., travel behavior), and they only use the SEM method [15], [25], [26], [34]. Second, this research offers new insights because it uses willingness to pay more to measure consumer purchasing intentions. Some studies use willingness to buy, which might explain why perceived behavioral control has a negative influence while usually positive.

3.3. Policy Implication

Through this paper, researchers believe that intention is the initial stage or an essential factor for changing the behavior of shifting from conventional motorcycles to electric motorcycles. However, positive intentions do not always result in regular use, but they will be a potential market [24]. Therefore, this study presents suggestions for future regulations so that the process of adopting electric motorcycles in the study area can be carried out. The Indonesian state is shifting from conventional motorcycles to electric ones. It can be seen from all the rules and incentives provided by the government related to this vehicle. In addition, there is also a target to stop selling conventional motorcycles entirely by 2045. It should be remembered as a context that Indonesia is a densely populated country where most people (~85%) use motorcycles as their primary mode of transportation.

Based on the results of this study, someone's interest in paying more to buy an electric motorcycle still needs to be higher, only 42.5% of respondents. Where the baby boomer community (>58 years), has a higher education level (starting with Diploma/Bachelor's), income above IDR 10 million per month, and uses public transportation or environmentally friendly modes are the most likely to have the intention of purchasing an electric motorcycle. Manufacturers can use this

information to segment consumers with high prospects because they will accept electric vehicle products easily. This segmentation should no longer require high-cost incentives to market electric motorcycles. Thus, marketing costs can be diverted to other consumer segmentations to make them more efficient and effective.

This situation is not ideal. Most Indonesians are gen-Z and gen-Y and pursue formal bachelor/high school education. In addition, Indonesia's average income is still far from the IDR 10 million per month based on BPS data (as of August 2023). This result shows that the process of adopting electric motorcycles still needs to be revised in Indonesia, so it is necessary to improve the strategy. The penetration process of electric motorcycles needs to be aimed at Generation Z and Millennials who are pursuing higher education or have worked. This generation is the younger generation who should be faster to accept technological innovation, have purchasing power, and have a large number (around 53.8% of the total Indonesian people). This study's findings reinforce that someone who moves to work has a higher chance of buying an electric motorcycle. This situation is relatively good because the number of stayer workers in the same region for life and work is relatively large, reaching 121 million people.

Furthermore, the intention to purchase electric motorcycles is more common among people with more environmentally friendly modes of public transportation. The context of electric motorcycles is intended to substitute conventional motorcycles or private vehicles. Plus, the study found that behavioral control variables had a negative influence. These results indicate that technical and financial capabilities are not barriers to purchasing electric motorcycles. Therefore, the government's purchase price subsidy policy can be considered reasonable and must be continued. However, people still do not consider the impact of purchasing an item a determining factor, as seen in the insignificance of variable attitudes towards electric motorcycles. This phenomenon indicates that it is necessary to socialize the positive impact of electric motorcycles and the responsibilities generated by purchasing them. Prospective users must consider information about these advantages when buying a vehicle. According to Turoń et al. [61], this can be done by increasing education on the topic since high school and the responsibilities that need to be held. In addition, subjective norms have often been shown to influence purchasing intentions in other countries significantly. However, this was not the case in this study. These results indicate the need to emphasize the socialization of electric motorcycles carried out by figures who are respected by the public.

Finally, this study revealed that someone with a low mobility frequency on weekdays is more likely to make purchases. These findings indicate that people do not trust electric motorcycles for high mobility use. Findings about someone mobile on holidays having a negative tendency can strengthen these indications. This finding may be due to the lack of a reliable image of electric motorcycles for use in high frequencies. For this reason, it is necessary to improve the technical capabilities of electric motorcycles, such as mileage, speed, and battery [62], along with supporting infrastructure. In addition, the duration of travel should not be an obstacle for someone buying an electric motorcycle. This mode is intended to be used as a substitute for conventional motorcycles because it is more environmentally friendly. This electric motorcycle should have capabilities that are at least equivalent to conventional motorcycles. This finding has begun to take shape in other countries (France), where someone who does mobility for a long duration will use an electric scooter for a long duration, too [57].

4. Conclusion

As efforts increase in using electric motorcycles as a substitute to reduce carbon emissions, the hybrid choice model analysis of the intention to purchase electric motorcycles can identify the factors driving the process. Several factors were found to influence purchase intentions using the behavioral theory of TPB with socio-demographic variables and travel behavior. We use 906 data on people in Indonesia who are over 17 years old and live in the 20 biggest cities.

Socio-demographic variables are proven to have a significant role in one's electric motorcycle purchase intentions. Unlike most other research, the baby boomer generation (>58 years) with higher education above a Diploma/Bachelor's has the highest opportunity to purchase an electric

motorcycle. Other variables, such as income, also positively influence, with income above IDR 10 million having twice the chance of making a purchase. This result is considered an inefficient situation for complete substitution from conventional to electric because the group is not the majority group of society. Someone with a private mode of transportation tends to be reluctant to buy an electric motorcycle. Findings on travel behavior variables also reinforce this. A person's perception of the reliability of electric motorcycles has yet to be formed. It can be seen that someone who travels more than three times in one day is more reluctant to buy. In addition, no relationship was found between the weekend travel purpose and willingness to pay more. This result shows that people still hesitate to use electric motorcycles when not working. This phenomenon indicates that manufacturers must increase their product capabilities to be equivalent to a conventional motorcycle. So that someone feels safe when switching from a conventional to an electric motorcycle. This situation is again strengthened based on the findings of the TPB latent variables. Out of the three variable constructions, only the perceived behavioral control variable was shown to have a significant effect, with a negative sign. This phenomenon is a symptom that the adoption process of electric motorcycles in Indonesia still needs to improve. People felt they had the ability – both technical and financial – to make a purchase, but that did not happen.

Based on these results, the process of adopting electric motorcycles is still not on target. Where the emphasis should be focused on millennials or Z who are working, in addition to this generation being the majority generation, the intention of purchasing more environmentally friendly innovations should be easy to do. In addition, this generation can be a generation that can transmit this innovation to other generations. On the other hand, subsidizing the purchase price of electric motorcycles works effectively. However, improvements still need to be made. This finding can be improved by emphasizing the positive impact of this adoption process on both health and the environment from a high school level.

This research certainly has limitations that should be addressed in future research. First, this research only uses data from 20 cities in Indonesia. Further research can increase the sample size by adding the number of cities so that the results are more comprehensive and can be used to make generalizations. In addition, this study only uses one kind of behavioral theory framework. A deeper analysis is needed, considering other behavioral theories or extending the TPB framework, which can increase the complexity of the model. This study uses only stated preference (SP) surveys, so it cannot calculate market share. Revealed preference (RP) research is needed to know this information. The RP survey will show people's actual behaviors and choices when confronted with real options and constraints, while SP only describes them in a hypothetical context. This research only uses ordinary binary logit without considering the heterogeneity of the distribution of exogenous variables. Thus, future research can conduct analysis using mixed logit, which can consider heterogeneity in individual preferences to produce a more thorough analysis. In addition, nested logit models can also be carried out in future research to understand better consumer selection of various types of two-wheeled electric vehicles. Furthermore, this study was conducted using respondents from urban areas in Indonesia. Further research can occur in rural areas that still need supporting infrastructure to add a more holistic understanding. Finally, an analysis of market segmentation related to electric motorcycles needs to be conducted to provide research on people's behavior.

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Author's Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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