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What factors influence the intention to use electric motorcycles in motorcycle-dominated countries? An empirical study in Vietnam

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ABSTRACT

Transitioning to electric motorcycles (EMs) can reduce dependence on carbon-based fuels, mitigate air pollution, and lower greenhouse gas emissions in countries where motorcycles dominate the transportation landscape. However, the factors influencing fleet electrification in these countries remain largely unknown. Given that this challenge pertains to the prior adoption of new technology, technology acceptance theories can provide valuable insights into the adoption of EMs. Additionally, misinformation about EM risks and self-assessment of knowledge could interact as determinants of adoption. This study integrates the Technology Acceptance Model (TAM), the Theory of Planned Behavior (TPB), and perceived risk to elucidate the impact of psychosocial factors on consumers' intentions to use EMs. Furthermore, it examines the direct and moderating effect of subjective knowledge about EM technology on the formation of this behavioral intention. Structural Equation Modeling (SEM) analysis was applied to investigate data collected from 762 respondents through personal interviews using a questionnaire. The results confirm that all original TAM and TPB constructs significantly influence behavioral intention, aligning with theoretical expectations. As hypothesized, perceived risk was found to exert a negative influence on the intention to adopt EMs. Additionally, subjective knowledge was observed to moderate the relationship between perceived usefulness and subjective norms concerning the intention to use EMs. These findings offer a roadmap for developing strategies aimed at encouraging adoption intentions toward EMs, particularly in countries like Vietnam.

1. Introduction

In many Low- and Middle-Income Countries (LMICs), traffic is predominantly composed of two-wheel motorcycles. For instance, in Vietnam, motorcycles account for over 90% of all traffic. Gasoline-powered motorcycles have become the primary mode of transportation in both urban and rural areas in Vietnam due to their affordability, convenience, and flexibility. Consequently, air pollution levels have risen significantly over the past decade, particularly in urban areas. A 2021 survey reported that air pollution is the top concern among Vietnamese citizens (Statista, 2021). Official data reveals that approximately 60,000 Vietnamese people lose their lives annually due to the impacts of air pollution (WHO, 2021).

To combat the escalating pollution levels, the government has introduced policies and initiatives aimed at reducing carbon emissions. In 2021, Vietnam also officially committed to achieving net-zero emissions by 2050 at the United Nations Climate Change Conference (COP26) (PWC, 2022). To address the challenges in the transport sector, Vietnam must increase the use of public transport and active travel. However, until these infrastructure projects are completed, one complementary option is to introduce zero-emission vehicles powered by electricity or hydrogen fuel cells. Unfortunately, current green policies

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promoting the usage of electric motorcycles (EMs) have seen limited success, with fewer than 10% of the two-wheeler (i.e., scooters and mopeds) fleet being electric (Tran et al., 2022). Consequently, there is a pressing need to identify the factors influencing the acceptance and adoption of EMs. These findings will play a crucial role in supporting evidence-based policies and interventions to encourage the adoption of this innovative mode of transportation.

This research aims to investigate the factors influencing the intention to use EMs in a motorcycle-dependent country like Vietnam. We have chosen to focus on behavioral intentions, as they are a strong predictor of behavior according to psychosocial theories (Ajzen, 1985). The literature suggests that consumers' beliefs about electric vehicles significantly affect their adoption. Furthermore, EMs are still considered a new technological innovation in many regions compared to conventional motorcycles. Therefore, this research integrates the Theory of Planned Behavior (TPB) developed by Ajzen (1985) and the Technology Acceptance Model (TAM) introduced by Davis (1989a) into a unified theoretical model.

An innovative aspect of this research is the extension of the TPB and TAM hybrid model to include perceptions of risk and knowledge related to electric technologies. The media has increasingly highlighted potential safety issues with electric vehicles, such as explosions, which could impact the adoption of this technology. Additionally, in LMICs, EMs are relatively new technologies, and many individuals may lack adequate knowledge about their capabilities and associated risks. When users lack knowledge about a product or its potential outcomes, they may either overestimate or underestimate the value or risks associated with it. Previous studies have found that consumer knowledge directly and positively influences the intention to use electric vehicles (Wang et al., 2018; Jaiswal et al., 2021a). However, there has been limited exploration of the moderating role of subjective knowledge, particularly concerning the technology of EMs, on usage intention formation. To address this gap, this study will examine how usage intention varies among users with different levels of knowledge.

In summary, the primary objective of the present investigation is to construct a novel theoretical model for analyzing the determinants of the intention to use electric motorcycles (EMs). This model will encompass elements from the Technology Acceptance Model (TAM), the Theory of Planned Behavior (TPB), perceived risk, and subjective knowledge. Furthermore, we will explore the influence of socio-demographic factors on the intention to use EMs, as their impact on intention is theoretically anticipated (Nguyen-Phuoc et al., 2022a, 2022c). It is worth noting that research on electric vehicles, particularly in LMICs, has been notably scarce. Therefore, this research holds significance not only from a theoretical standpoint but also in terms of practical implications for the adoption of EMs.

This paper is organized as follows: the subsequent sections provide the theoretical foundation for the study and outline the formulation of research hypotheses. It then elucidates the research methodology employed to support the proposed model and test the hypotheses. Following that, the paper presents the research results, systematically analyzing the data using Partial Least Squares – Structural Equation Modeling (PLS-SEM). Afterward, it delves into the theoretical implications, acknowledging any limitations, and suggesting directions for future research. Finally, the last section encapsulates the study's conclusion and its practical implications.

2. Background

2.1. The technology acceptance model

The Technology Acceptance Model (TAM), introduced by Davis (1989b), is a concise psychological theory that encompasses key factors for understanding and predicting an individual's acceptance of technology. TAM posits that attitude towards behavior (ATT) plays a crucial role in determining behavioral intention. According to Ajzen (1991), ATT is closely associated with the assessed outcomes of behavior, such as intention to use (ITU), and individuals with a more positive ATT are more likely to adopt the behavior.

To account for the potential impact of technology characteristics on behavioral intention, TAM introduces two variables: perceived usefulness (PUN) and perceived ease of use (PEU). PUN is defined as the extent to which an individual believes that a specific technology can enhance their performance (Davis, 1989b). It is based on the expected benefits individuals can gain from using the technology and directly influences both ATT and ITU (Venkatesh and Davis, 2000). PEU, on the other hand, measures the extent to which an individual believes that using a specific technology will be effortless (Davis, 1989b). Unlike PUN, the relationship between PEU and ITU is not always direct. Instead, it is often assumed to indirectly influence ITU by enhancing ATT and PUN (Jaiswal et al., 2021c; Venkatesh and Davis, 2000; Wang et al., 2020).

Numerous empirical studies demonstrate the critical role of ATT in shaping intention to use (ITU). For instance, more favorable ATT is associated with a greater intention to adopt commercial electric vehicles in several European countries (Austria, Denmark, Germany), hybrid electric vehicles in China, and shared parking in Taipei (Kaplan et al., 2016; Liang et al., 2019; Wang et al., 2016). In Austria, 1398 respondents cited PUN as a critical reason for choosing e-bikes (Wolf and Seebauer, 2014). Similar results are reported for other services like ride-hailing, bike-sharing, and automated vehicles (Chen and Lu, 2016; Jing et al., 2021; Xu et al., 2018). Additionally, the benefits of electric vehicles, such as enjoyment and cost savings on fossil fuels, contribute to ATT, subsequently influencing usage intention. Previous analyses of environmentally friendly modes of transportation (Plazier et al., 2017; Simsekoglu and Klöckner, 2019; Tu and Yang, 2019) have confirmed the positive role of PEU in shaping ATT and PUN.

Although some studies provide conflicting results regarding the relationships between ATT, PUN, PEU, and ITU (e.g., insignificant effects of PUN on the intention to use electronic toll collection service in China, Chen et al., 2007), in light of the prevailing findings discussed above, five hypotheses are formulated as follows:

H_1. PEU positively influences PUN;

H_2. *PEU positively influences ATT;*

H_3. *PEU positively influences ATT;*

H_4. *PUN positively influences ITU;*

H_5. *ATT positively influences ITU.*

2.2. Theory of planned behaviour

While acknowledging the undeniable importance of the Technology Acceptance Model (TAM) in assessing the intention to adopt new technology, it is worth noting that the TAM may have limitations, particularly in its failure to account for social influences and the perception of access restrictions to these services (King and He, 2006; Malhotra and Galletta, 1999). Hence, the use of both TAM and the Theory of Planned Behavior (TPB) as an integrated theoretical framework represents a comprehensive approach, a choice embraced by numerous scholars in the field (Chen et al., 2007; Choe et al., 2021; Jing et al., 2021; Liang et al., 2019; Taylor and Todd, 1995; Tu and Yang, 2019).

The TPB, recognized as the most important conceptual framework for explaining behavioral intentions (Conner and Armitage, 1998), posits that making a behavioral decision is a result of a reasoned and rational process in which attitude (ATT), subjective norms (SJN), and perceived behavioral control (PBC) influence behavioral intention, which in turn determines actual behavior. The use of TPB in examining the choice of electric motorcycles (EMs) is essential because mode choice is typically made in a reasoned manner under the influence of social factors (Fu, 2021; Scheiner and Holz-Rau, 2007). Theoretically, SJN is associated with the perceived social pressure to engage in a

specific behavior. Individuals tend to consider and follow the opinions of significant others (e.g., relatives, friends, and colleagues) to some extent when forming their behavioral intentions (Conner and Armitage, 1998). On the other hand, PBC refers to a person's perceived confidence or ability to undertake a behavior, which is determined by their perceived opportunities and available resources to perform that action (Ajzen, 1991, 2002). A higher level of control over performing a behavior tends to motivate the intention to carry it out.

The TPB is one of the most commonly used frameworks for investigating the intention to choose new and/or electric modes (Bamberg et al., 2003; Fu, 2021; Hoffmann et al., 2017; Pojani et al., 2017). Existing literature has consistently demonstrated a positive link between Subjective Norms (SJN) and Intention to Use (ITU). For instance, a study conducted in Korea found that the intention to use drone food delivery services is higher among those who declare a higher level of SJN (Choe et al., 2021). However, another study in the Netherlands and the UK highlighted that the social stigma associated with cycling presents an obstacle to the use of e-bikes (Jones et al., 2016).

Greater Perceived Behavioral Control (PBC) has been found to encourage the intention to use ride-hailing services in China, utilize ride-sourcing services in Vietnam, and avoid polluted roads in 16 countries (Jing et al., 2021; Nguyen-Phuoc et al., 2022b; Oviedo-Trespalacios et al., 2021). Based on the arguments presented above, two hypotheses are developed as follows:

H_6. SJN positively influences ITU;

H_7. PBC positively influences ITU.

2.3. Perceived risk (PRI)

Perceived risk (PRI), defined as the perception of uncertain and unexpected consequences associated with purchasing a product or using a service (Cunningham, 1967), is often integrated into studies examining pro-environmental behaviors that combine the Technology Acceptance Model (TAM) and the Theory of Planned Behavior (TPB) (Jing et al., 2021; Ning et al., 2021). Higher levels of PRI are typically associated with lower intentions to accept new technological innovations (Lee, 2009; Lu et al., 2005; Wang et al., 2020).

Common concerns among consumers regarding electric vehicles include extended charging times, a shortage of charging infrastructure, and various battery-related issues, such as the risk of explosion during charging and the high cost of battery replacement (Carley et al., 2013; Coffman et al., 2017; Kim et al., 2018; Krishna, 2021). In Vietnam, the adoption of electric vehicles is still in its early stages, resulting in limited support services (e.g., maintenance and customer services) due to a lack of capacity and experience (Schröder et al., 2021). Consequently, users may face potential inconveniences and effort losses when seeking and using maintenance services. Furthermore, riding electric two-wheeled vehicles (e.g., e-bikes and EMs) in mixed traffic poses a unique risk due to the silent operation of their engines, which may cause other riders to fail to notice their presence or recognize them late, thereby increasing the risk of collisions. These combined risks discussed above may discourage the adoption of e-motorcycles. Therefore, this study introduces an additional hypothesis below:

H_8. *PRI negatively influences ITU.*

2.4. Subjective knowledge (SKN)

Subjective knowledge (SKN) regarding a product's technology pertains to how customers perceive their level of understanding of a technology-based product. It can be quantified by assessing the extent to which individuals believe they comprehend the product (Huang et al., 2021; Park and Ohm, 2014). This concept aligns with the argument that subjective knowledge plays a pivotal role in aiding customers in their decision-making processes (Kaplan, 1991).

In the context of sustainable technologies, numerous studies have demonstrated that an individual's knowledge about a green product significantly influences their attitude and intentions to purchase such products (Burgess et al., 2013; Ha and Janda, 2012; Qian and Yin, 2017). Studies conducted in Vietnam concluded that the limited knowledge of the urban middle class presents a barrier to sustainable consumption (Chi et al., 2021; De Koning et al., 2015). Huang et al. (2021) discovered that SKN positively affects Perceived Ease of Use (PEU), Perceived Usefulness (PUN), perceived fun to use, and behavioral intention concerning electric vehicles in China. These findings are consistent with other studies conducted in Germany and China (Degirmenci and Breitner, 2017; Wang et al., 2018). This suggests that when individuals possess a comprehensive understanding of electric vehicle technology, including aspects like driving range, battery capacity, charging duration, and noise levels, they are less likely to encounter difficulties while driving and are more likely to appreciate the advantages of these vehicles. Consequently, they tend to hold a more positive attitude and exhibit a higher intention to purchase (Pagiaslis and Krontalis, 2014; Wang et al., 2018). Furthermore, since risk perceptions can stem from a lack of knowledge, acquiring more relevant information can help alleviate perceived risk (PRI) (Grasmück and Scholz, 2005; Park and Ohm, 2014).

Consumers often have limited knowledge about vehicle technology characteristics, such as charging time, travel range, and driving comfort, as they primarily focus on financial aspects such as taxes, insurance, and fuel costs (Lane and Potter, 2007). Huang et al. (2021) emphasized that customers also tend to prioritize environmental knowledge of electric vehicles over technological knowledge. A study involving 21 U.S. cities highlighted that approximately two-thirds of the 2,302 participants provided incorrect answers to basic questions about plug-in electric vehicles, with nearly 75% underestimating the advantages of these vehicles (Krause et al., 2013). These misconceptions can introduce biases that influence the relationships between the intention to choose electric vehicles and its predictors, including individual perceptions of usefulness (PUN), ease of use (PEU), risk perceptions (PRI), as well as social norms (SJN) and perceived behavioral control (PBC) over electric vehicle usage (Coffman et al., 2017). Given this context, this study hypothesizes that subjective knowledge about EM technology moderates the effects of PUN, ATT, SJN, PBC, and PRI on intention to use (ITU):

H_9. *SKN positively influences ITU;*

H_{10}. *SKN moderates the link between PUN and ITU;*

H_{11}. *SKN moderates the link between ATT and ITU;*

H_{12}. *SKN moderates the link between SJN and ITU;*

H_{13}. *SKN moderates the link between PBC and ITU;*

H_{14}. *SKN moderates the link between PRI and ITU.*

2.5. Control variables

The decision to use an electric vehicle varies across socio-demographics (Chee et al., 2020; Coffman et al., 2017; Nguyen and Pojani, 2022). As presented by Tran et al. (2013), an industry survey in the EU and the US emphasize that early adopters of battery electric vehicles are more inclined to be male, 18–34 years old, and well-educated with high income. Similar findings of gender, income and educational levels are made among early adopters of electric bikes in Sacramento (Popovich et al., 2014). Nevertheless, the evidence from Austria demonstrates that most early adopters of e-bikes are older persons with a lower education level and household income compared to the general population (Wolf and Seebauer, 2014). In the present research, four demographic characteristics, including gender, age, level of education, and income, are looked at as control variables of ITU.

Fig. 1 shows the theoretical research framework of this study.

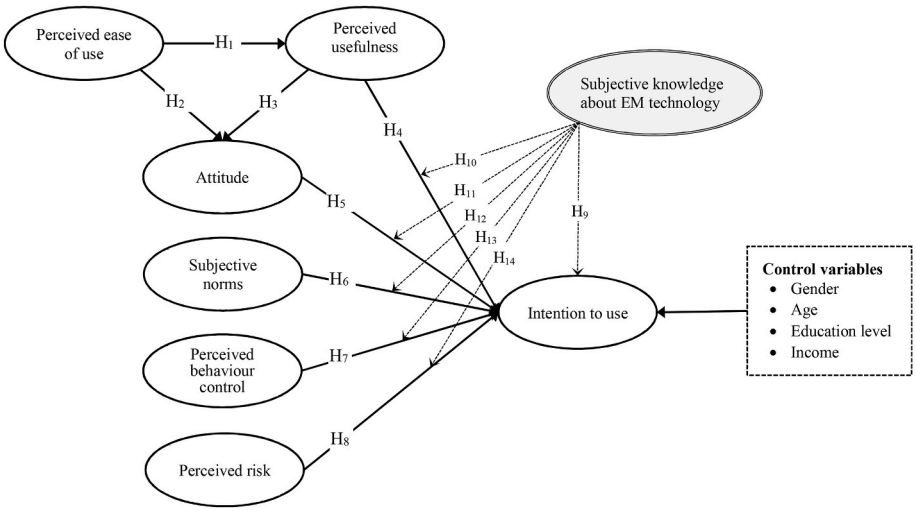


Fig. 1. Proposed conceptual model.

3. Measurement, sampling and data collection

The questionnaire is composed of three main parts. The first part presents the research aim, research objectives and the rights of survey respondents. In the second part, a set of questions measuring the latent constructs are shown (see Table A1). These measurement items are derived from various sources: PEU (Xu et al., 2018; Wang et al., 2020); PUN (Xu et al., 2018); PBC (Nguyen-Phuoc et al., 2022b); SJN and ATT, ITU (Nguyen-Phuoc et al., 2022a); and SKN (Huang et al., 2021a). In this study, the PRI construct is measured by four items developed by the authors. The risk of using electric vehicles is mentioned in previous studies, such as the lack of charging points, battery explosion, and maintenance cost (Capuder et al., 2020). It is noted that all latent constructs are measured by multiple-item scales which are scored on a 7-point Likert scale with values ranging from 'Strongly disagree' to 'Strongly agree'. The last part includes questions pertaining to respondents' socio-demographic data (e.g., gender, age, income).

In order to validate the developed theoretical model and research hypotheses, face-to-face surveys are conducted to collect data. Before publishing the formal survey questionnaire, it has to go through two pretests. Firstly, the initial questionnaire is sent to a panel of five transport experts to get their comments. In the second round, the revised questionnaire is tested with students from the University of Danang (30 students) who are selected to participate in the pilot survey. The feedback is used to edit and refine the questionnaire (e.g., correcting typos, revising some scales, and changing the questionnaire format). The average required time to answer the questionnaire is identified to be around 15 min. The final version is used to collect data in Danang City (DN) and Ho Chi Minh City (HCM) - the two large cities in Vietnam, between April 2022 and May 2022. According to Song et al. (2012), in the case the survey population was substantial, the convenience sampling method is particularly effective in collecting data. As such, this method is used for this study. Two groups of research assistants in two cities go to public areas (e.g., supermarkets, bus stations, coffee shops) and invite people to take part in the survey. A screening question, 'Have you ever owned an electric motorcycle?', is asked to recruit respondents. Only respondents who answered 'No' were invited to participart in the survey (take around 20–25 min) and the research purpose and objectives were briefly elucidated. A small amount of money (around $1) is paid to respondents if they complete the survey questionnaire. In total, more than 800 people take part in the survey; however, 769 respondents return their answers with a response rate of around 96 percent. Nevertheless, after data screening, 762 valid responses are kept for further analysis.

Regarding data analysis, PLS-SEM (Partial Least Squares Structural Equation Modeling) is employed to identify latent variables that yield the most favorable outcomes for adoption intention. In comparison to covariance-based structural equation modeling (CB-SEM), PLS-SEM offers several advantages, particularly when dealing with data characterised by a smaller sample size and non-normal distribution. Moreover, the model in this study was constructed by integrating two theories, TAM and TPB. Therefore, PLS-SEM is chosen to test the developmental theories, as recommended by Fornell and Bookstein (1982).

4. Results

4.1. Participant characteristics

Fig. 2 illustrates the detailed demographic characteristics of participants (i.e., gender, age, marriage, education level, current job position and monthly income). Specifically, the proportion of respondents by gender is nearly equal with 52.1% female and 47.9% male. The mean age of respondents is 34.93 years old with a standard deviation SD = 14.21. The group 25–39 accounts for the highest proportion, followed by the group 16–24. Regarding education level in the sample, almost half (49.1%) of the participants have a university degree, whereas those with college, high school, secondary school, above university, and below secondary school degree made up 19.1%, 13.2%, 8.7%, 7.2%, and 2.9%, respectively. In terms of respondents' occupation, the majority of research participants are full-time workers (49.1%), followed by students with 20.3%. Other groups account for smaller proportions, including part-time employees, housewives, retired people, and others, accounting for 9.8%, 9.7%, 5.6% and 4.7%, respectively. Regarding income, more than one-third of the respondents have an income from 5 to 10 million VND (37.3%) and 20.5% of them enjoy an income from 10 to 15 million VND per month. A smaller percentage of the survey's respondents (17.0%) earn <5 million VND, 14.7% has no income and the remaining (10.5%) earn >15 million VND per month.

4.2. Overall model

The fit of the developed model should be examined before conducting the evaluation of measurement models and structural models. Several structural model goodness-of-fit indicators were used to assess the structural model's fitness, including the Root Mean Square Residual (SRMR) and the Normed Fit Index (NFI). The results indicate that all of the indicators are acceptable, with SRMR = 0.057 (<0.08 threshold) and NFI = 0.829 (>0.8 threshold), confirming the fitness of the structural model (Henseler et al., 2016).

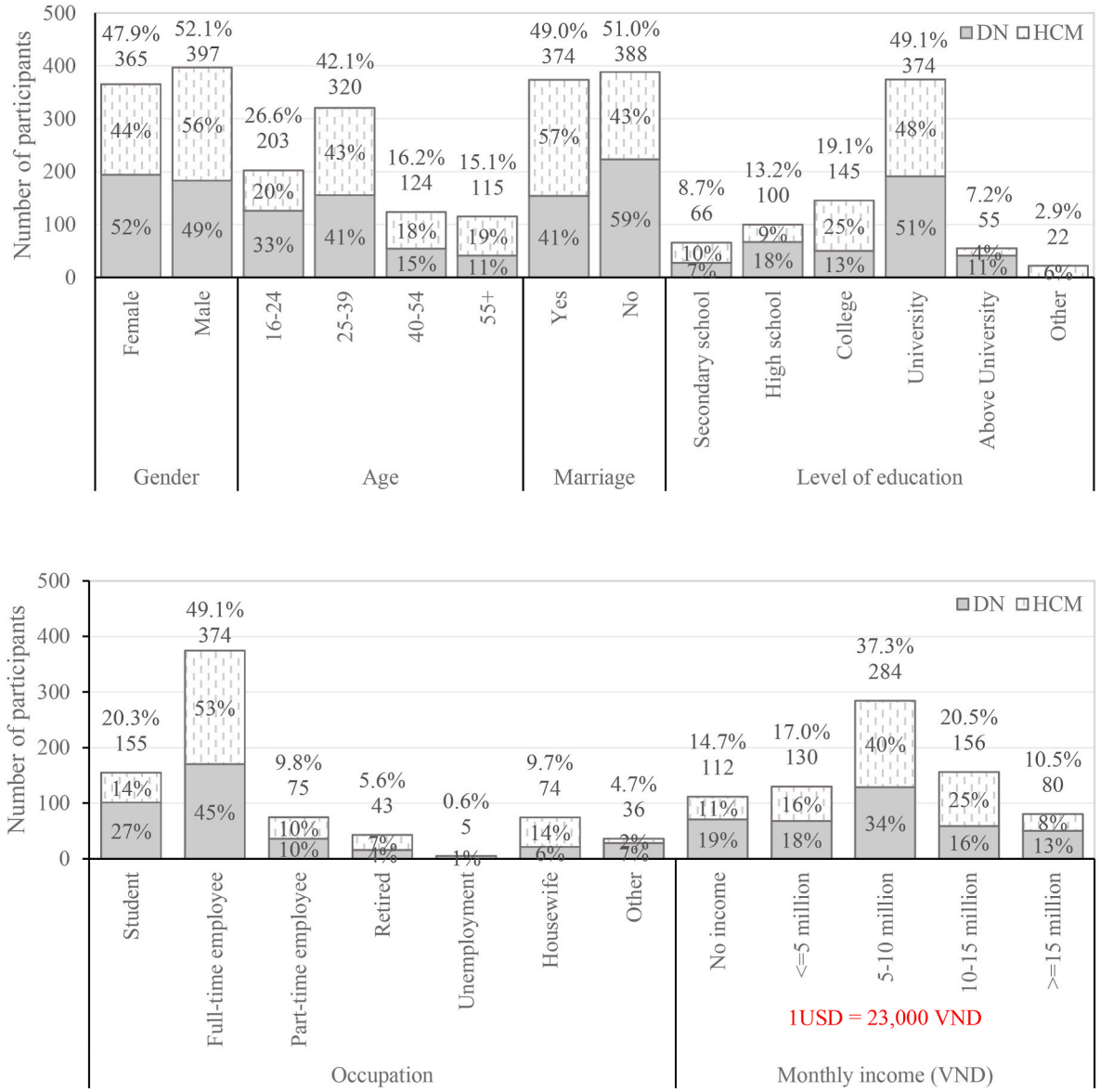


Fig. 2. Participant characteristics.

4.3. Measurement model (outer model)

To evaluate the outer model, a number of criteria are assessed, including indicator loadings, internal consistency reliability, convergent validity, and discriminant validity (Hair et al., 2019) (see Table 1). The results indicated that the outer loadings of most measurement items exceed 0.708 (the threshold). The item PRI1 with factor loadings of 0.673 is maintained in the measurement model since the value is slightly below 0.708, and the related constructs' values do not alter significantly when this item is removed. Next, the Cronbach's alpha (CA) and Composite Reliability (rho_a & rho_c) values of all seven latent variables are higher than the 0.7 benchmarks, revealing that the internal consistency reliability of all latent variables is acceptable. In addition, the convergent validity of each latent variable is also confirmed by using the Average Variance Extracted (AVE) value with the minimum required value of 0.5.

Finally, both Fornell-Larcker criterion and Heterotrait-Monotrait (HTMT) ratio are examined to assess the discriminant validity. While Table 2 indicates that the square root of each construct's AVE is the highest comparing the correlation values of each pair of constructs, the figures shown in Table 3 also meet the HTMT ratio requirement of a value smaller than 0.85 (Hair et al., 2019), establishing the discriminant validity among the latent variables in the outer model. In conclusion, the results reveal that the outer model used in this study complies with all reliability and validity standards.

4.4. Structural model (inner model)

4.4.1. Direct effects

The PLS-SEM analysis in this study uses a Bias-corrected and Accelerated Bootstrapping confidence intervals with 762 cases and 5,000 samples to estimate the significance of path coefficients (β) that measured both direct and indirect path relationships (β) among the proposed variables. Table 4 and Fig. 3 demonstrates that all the proposed hypotheses from H_1 to H_7 are positively supported at the significance level of 1%, except H8 (supported at the significance level of 5%). Regarding the association between intention to use and its determinants, ATT has the strongest influence on ITU ($ß_{ATT→ITU} = 0.278$, $p < 0.01$), followed by SJN ($ß_{SJN→ITU} = 0.272$, $p < 0.01$) and PBC ($ß_{PBC→ITU} = 0.178$, $p < 0.01$) and PUN ($ß_{PUN→ITU} = 0.112$, $p < 0.01$). PRI is found to have a negative impact on ITU ($ß_{PRI→ITU} = -0.168$, $p < 0.05$). Additionally, PUN is a better predictor of ATT ($ß_{PUN→ATT} = 0.424$, $p < 0.01$)

Table 1
The evaluation of the first-order model.

Latent variables	Items	Loadings	CA	CR (rho_a)	CR (rho_c)	AVE
Perceived ease of use	**PEU**		0.841	0.878	0.902	0.754
	PEU1	0.875				
	PEU2	0.885				
	PEU3	0.804				
	PEU4	0.878				
Perceived usefulness	**PUN**		0.884	0.886	0.920	0.741
	PUN1	0.830				
	PUN2	0.860				
	PUN3	0.862				
	PUN4	0.850				
Subjective norms	**SJN**		0.854	0.859	0.911	0.774
	SJN1	0.946				
	SJN2	0.951				
	SJN3	0.929				
Perceived behavioural control	**PBC**		0.785	0.820	0.857	0.603
	PBC1	0.848				
	PBC2	0.878				
	PBC3	0.878				
Attitude	**ATT**		0.873	0.879	0.913	0.723
	ATT1	0.858				
	ATT2	0.895				
	ATT3	0.885				
Perceived risk	**PRI**		0.837	0.839	0.902	0.754
	PRI1	0.673				
	PRI2	0.710				
	PRI3	0.855				
	PRI4	0.852				
Intentions to use	**ITU**		0.953	0.954	0.970	0.914
	ITU1	0.953				
	ITU2	0.958				
	ITU3	0.958				

than PEU ($ß_{PEU→ATT} = 0.175$, $p < 0.01$). In terms of control variables, only age is found to have an impact on ITU; however, the magnitude of these impacts is relatively low. Age negatively influences the ITU ($ß_{Age→ITU} = -0.072$, $p < 0.01$) (see Fig. 4).

4.4.2. Indirect effects

A bootstrapping test is used as suggested by Zhao et al. (2010) to explore the mediating role of PUN and ATT in the relationships between the researched latent variables. Table 5 shows the results of three indirect paths related to four constructs, including PEU, PUN, ATT, and ITU, with the values of path coefficient, SD, t-values, and t-values. As observed in Table 5, all the indirect path associations are empirically supported at a significance level of 1%. The results indicate that ATT works as a mediator in the relationship between both PEU and ITU ($ß_{PEU→ATT→ITU} = 0.049$, $t = 3.218$, $p < 0.01$) as well as between PUN and ITU ($ß_{PUN→ATT→ITU} = 0.118$, $t = 5.821$, $p < 0.01$). Besides, the mediating role of PUN on the link between PEU and ITU is also confirmed ($ß_{PEU→PUN→ITU} = 0.062$, $t = 2.856$, $p < 0.01$). Additionally, the findings in Tables 4 and 5 demonstrate that the indirect and direct effects are in the same direction. This can be inferred that the mediation's effects are complementary (Zhao et al., 2010).

Table 3
Heterotrait-Monotrait ratio results.

Latent variables	ITU	ATT	PBC	PEU	PRI	PUN	SJN
ITU							
ATT	0.641						
PBC	0.521	0.652					
PEU	0.334	0.468	0.43				
PRI	0.127	0.091	0.106	0.178			
PUN	0.476	0.596	0.419	0.623	0.180		
SJN	0.585	0.659	0.465	0.255	0.076	0.600	

Table 4
Testing the hypotheses in the structure model.

Direct effects		Intention to use (ITU)	Attitude (ATT)	Perceived usefulness (PUN)
Latent variables	Perceived ease of use (PEU)		H_2: 0.175***	H_1: 0.555***
	Perceived usefulness (PUN)	H_4: 0.112***	H_3: 0.424***	
	Attitude (ATT)	H_5: 0.278***		
	Subjective Norms (SJN)	H_6: 0.272***		
	Perceived Behavioural Control (PBC)	H_7: 0.178***		
	Perceived risk (PRI)	H_8: 0.168**		
Control variables	Gender	-0.035^{ns}		
	Age	−0.072***		
	Education level	0.040^{ns}		
	Income	0.036^{ns}		
Predictive capability	R^2	0.473 (moderate)	0.293 (weak)	0.309 (weak)
	Q^2	0.369 (large)	0.164 (medium)	0.306 (medium)

Notes: ^{ns} non-significant, ***$p < 0.01$, **$p < 0.05$.

4.4.3. Total effects

Table 6 demonstrates the total effects of various latent variables on ITU in the developed model. ATT has the greatest influence on ITU ($ß_{ATT→ITU} = 0.278$, $t = 6.661$, $p < 0.01$), and followed by SJN ($ß_{SJN→ITU} = 0.272$, $t = 6.565$, $p < 0.01$). On the other hand, PRI is the lowest determinant of ITU ($ß_{PRI→ITU} = -0.168$, $t = 5.311$, $p < 0.01$).

4.5. Predictive capability evaluation

The study evaluates the coefficient of determination R^2 value and Stone-Gaisser's Q^2 value to assess the predictive accuracy and predictive relevance of the proposed model's predictive capability, respectively. According to Hair et al. (2019), the R^2 value ranging from 0 to 1 reflects the percentage of each dependent variable's variance that is explained by its antecedents in the model. The higher R^2 value showed that the model's prediction is more accurate. Table 4 demonstrates that 47.3% of the variance in intention to use is explained by proposed variables (PUN, ATT, SJN, PBC and PRI), describing a moderate level of predictive

Table 2
Fornell-Larcker Criterion results.

Latent variables	ITU	ATT	PBC	PEU	PRI	PUN	SJN	SKN
ITU	0.956							
ATT	0.583	0.879						
PBC	0.483	0.553	0.868					
PEU	0.313	0.411	0.362	0.861				
PRI	−0.115	0.053	0.038	0.104	0.777			
PUN	0.440	0.522	0.355	0.555	0.145	0.850		
SJN	0.553	0.591	0.417	0.238	0.032	0.545	0.942	
SKN	0.467	0.437	0.351	0.309	0.149	0.447	0.499	0.869

Table 5
Indirect effects.

Indirect path	ß	*SD*	*t*-value	*p*-value
PEU → PUN → ITU	0.062***	0.022	2.856	<0.01
PUN → ATT → ITU	0.118***	0.020	5.821	<0.01
PEU → PUN → ATT → ITU	0.066***	0.012	5.581	<0.01
PEU → ATT → ITU	0.049***	0.015	3.218	<0.01

Table 6
Total effects.

Total effects	ß	*SD*	*t*-value	*p*-value
ATT → ITU	0.278***	0.042	6.661	<0.01
SJN → ITU	0.272***	0.041	6.565	<0.01
PUN → ITU	0.230***	0.039	5.837	<0.01
PBC → ITU	0.178***	0.039	4.611	<0.01
PEU → ITU	0.176***	0.026	6.804	<0.01
PRI → ITU	−0.168***	0.032	5.311	<0.01

Table 7
Results of direct and moderating effects of subjective knowledge.

Path	Coefficient (ß)	SD	*t*-value	*p*-value	f^2
H_9: SKN → ITU	0.184***	0.041	4.488	0.000	
H_{10}: (PUN*SKN) → ITU	−0.060**	0.034	2.054	0.040	0.007
H_{11}: (ATT*SKN) → ITU	0.042^{ns}	0.042	1.001	0.317	0.002
H_{12}: (SJN*SKN) → ITU	0.131***	0.040	3.275	0.001	0.019
H_{13}: (PBC*SKN) → ITU	-0.047^{ns}	0.036	1.310	0.190	0.003
H_{14}: (PRI*SKN) → ITU	0.055^{ns}	0.035	1.545	0.122	0.008

Notes: *SD* = standard deviation, ^{ns} non-significant, $^{**}p < 0.05$, $^{***}p < 0.01$.

accuracy. Next, the Q^2 value is obtained based on the Blindfolding test in SmartPLS 3.0. The Q^2 value is above 0, demonstrating the model's capacity for predictive relevance (Hair et al., 2019). The result shows that the Q^2 value for ITU is 0.369, greater than 0.35, confirming the large predictive relevance for this endogenous latent variable. In conclusion, the values of R^2 and Q^2 indicate that the suggested model has enough predictive capability.

4.6. Moderation effect

This study tests the moderating role of subjective knowledge (SKN) about EM technology on the relationships between PEU, PUN, ATT, SJN, PBC, PRI and ITU. The results reveal a negative and significant moderating effect of SKN on the association between PUN and ITU (ß = −0.060, t = 2.054, $p < 0.05$), supporting hypothesis H_9 (Table 7). This shows that the positive relationship between PUN and ITU is weakened with an increase in the level of SKN. Also, the plotted interaction of Fig. 3a shows that the positive relationship between PUN and ITU is stronger when there is a lower (simple slope = 0.064) rather than a higher level of SKN (simple slope = 0.004). Table 7 also reveals a positive and significant moderating effect of SKN on the link between SJN and ITU (ß = 0.131, t = 3.275, $p < 0.05$), supporting hypothesis H_{11}. This means that the positive relationship between SJN and ITU is strengthened with an increase in the level of SKN. The plotted interaction of Fig. 3b shows that the positive relationship between SJN and ITU is stronger when there is a higher (simple slope = 0.357) rather than a lower level of SKN (simple slope = 0.226) (see Table 8).

Moreover, without the inclusion of the moderating effect the R^2 value for ITU is 47.3%, while the R^2 value rises to 51.1% with the inclusion of this effect. In addition, the f^2 impact magnitude of the moderating effect also should be considered (Hair et al., 2021). In the context of moderation, Kenny (2018) suggests that the realistic standards for small, medium, and large impact sizes of moderation are, respectively, 0.005, 0.01, and 0.025. Accordingly, the f^2 effect size value of 0.007 and 0.019 confirms that there is a small and a medium moderation effect of SKN between PUN and ITU and SJN and ITU, respectively.

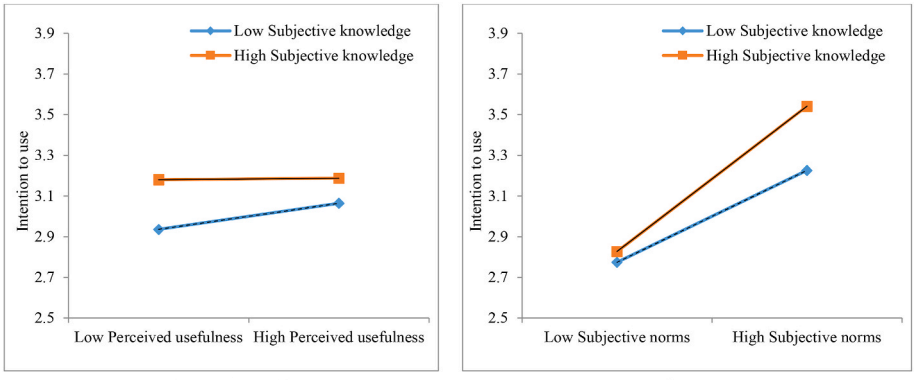
4.7. Multi-group analysis (MGA)

MGA is used to examine whether there are significant differences in the proposed model between the groups of people living in two different cities (in DN and HCM). Hence, both the Henseler's MGA and Permutation test are employed. In Henseler's MGA technique, significant differences between the specific path coefficients of two groups are identified if the *p*-value is higher than 0.95 or lower than 0.05 at a significance level of 0.05. While according to the recommendation of Matthews (2017), if a permutation p-value is lower than or equal to 0.05, there is a significant difference in path coefficients between the two groups. The results of MGA show that there are significant differences in the link between PRI → ITU and Income → ITU between the people in the two cities. PRI is found to significantly negatively impact the intention to use among users in HCM city. People with high income in HCM city are more likely to use EMs compared to lower-income people (ß = 0.130, $p < 0.05$) (see Table 8).

Fig. 4 presents the direct effects among constructs in the proposed model.

5. Discussion

Researchers and practitioners have shown increasing interest in understanding customers' intentions to use electric vehicles due to sustainability pressures. However, research exploring the adoption of electric motorcycles, the primary mode of transportation in the global south, remains limited. Most studies focus on environmental-related factors (Pramajaya and Haryanto, 2021; Utami et al., 2020; Zhu et al.,



a) PUN to ITU b) SJN to ITU

Fig. 3. Moderating effect of subjective knowledge.

Table 8
Multi-group analysis results (DN city vs. HCM city).

Direct path	Coefficients DN	Coefficients HCM	Coefficient Difference	Henseler's MGA *p*-values	Permutation *p*-values
PRI → ITU	0.009	−0.310***	0.319*	<0.001	<0.001
Income → ITU	−0.044	0.104***	0.148*	0.003	0.004

Note: For coefficient: ** significant at 95%, *** significant at 99%.
For coefficient difference: * significant at 95%.

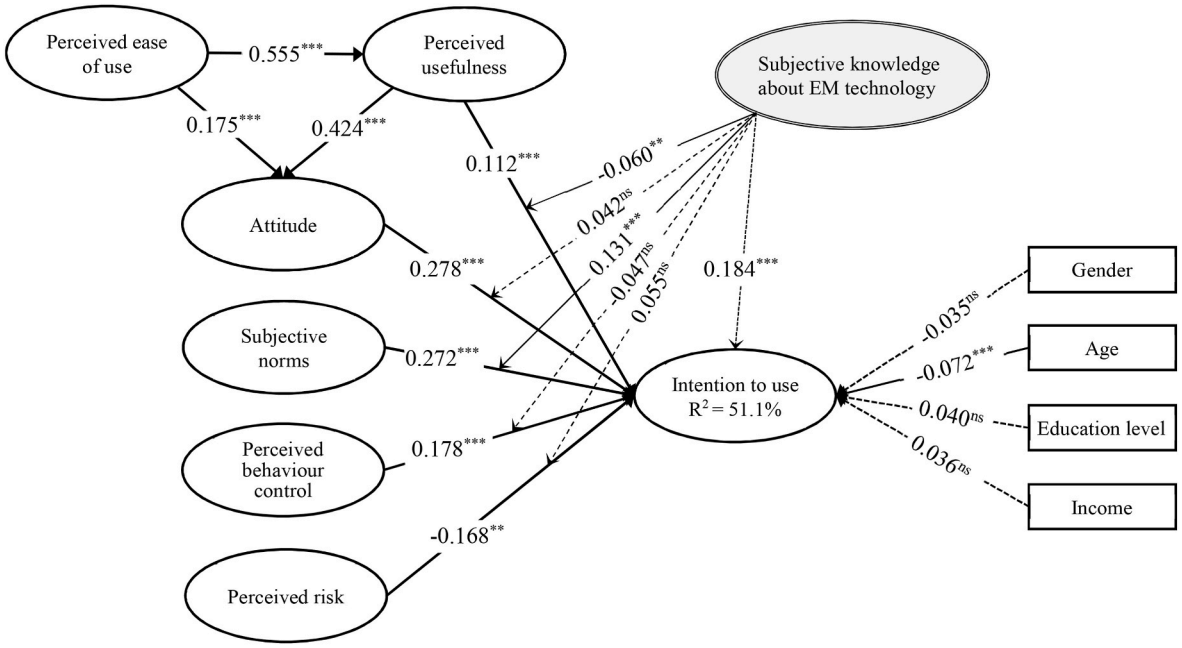


Fig. 4. Results of proposed model.

2019; Guerra, 2019), driving performance factors (Utami et al., 2020; Zhu et al., 2019; Guerra, 2019; Nguyen et al., 2021), power consumption issues (Huang et al., 2018), or price-related factors (Chang et al., 2022; Utami et al., 2020; Zhu et al., 2019; Guerra, 2019) and their impact on the intention to use electric two-wheelers. A few researchers have also applied technology acceptance theories such as TAM (Chen et al., 2017; Wu et al., 2015; Su et al., 2023), TRA (Pramajaya and Haryanto, 2021; Alzahrani et al., 2019), or TPB (Van Tuan et al., 2022; Wahab and Jiang, 2019) to understand the influence of individual and social factors on the adoption of EMs. This study contributes to the literature by integrating variables from both TAM and TPB, along with an additional variable, perceived risk, to create a new research model for examining the effects of psychological factors on consumers' intentions to use EMs. The research context chosen is a motorcycle-dominated, low-middle-income country.

The findings reveal that five variables, namely PUN, ATT, SJN, PBC, and PRI, serve as antecedents for consumers to use EMs. Among these variables, consumers' ATT is identified as the most critical factor influencing their intention to use this mode of transport. This result suggests that customers are more likely to adopt EMs when they hold a positive attitude toward these vehicles. Our results also highlight the mediating role of ATT, acting as a mediator for the indirect effects of PUN and PEU on consumers' intention to use EMs. This finding aligns with the original TPB, TAM, and other studies in the autonomous and electric vehicle field (Van Tuan et al., 2022; Shakeel, 2022; Shalender and Sharma, 2021; Khurana et al., 2020; Alzahrani et al., 2019; Huang and Ge, 2019; Wang et al., 2016, 2018; Moons and De Pelsmacker, 2012; Asadi et al., 2021). It underscores the significance of ATT as the strongest predictor of the intention to use EMs, making it a primary target for interventions aimed at increasing technology adoption.

The results demonstrate the positive relationship between SJN, the second most important determinant, and the intention to use EMs. This suggests that the opinions and recommendations of individuals significant to consumers, such as family members or friends, can influence their decision-making process regarding EM usage. Our results align with prior studies that emphasize the importance of external influences on consumers' decisions to use EMs, indicating that SJN significantly explains customers' intentions to use e-vehicles (Van Tuan et al., 2022; Li et al., 2022; Shakeel, 2022; Shalender and Sharma, 2021; Alzahrani et al., 2019; Adnan et al., 2018; Zhang et al., 2018; Mohamed et al., 2018; Simsekoglu and Nayum, 2019; Asadi et al., 2021). Additionally, this result sheds light on the inconsistent findings in the literature regarding the significance of SJN in the intention to use electric vehicles, where SJN has been cited as a non-significant predictor (Huang and Ge, 2019). This discrepancy could be attributed to cultural differences between Western and Asian countries, where the culture tends to be more collectivistic (Nguyen-Phuoc et al., 2022b).

Perceived behavioral control (PBC) is a key factor in the present study, which aligns with previous research (Shakeel, 2022; Shalender and Sharma, 2021; Mohamed et al., 2018; Wang et al., 2016; Simsekoglu and Nayum, 2019). Customers who have greater control over their perceived behavior, possess sufficient economic capability, and have confidence, are more likely to use an electric motorcycle (EM) in the future. This result contradicts findings in the literature that suggest there is no statistically significant relationship between PBC and the intention to use electric vehicles (Asadi et al., 2021). In summary, this study empirically validates the Theory of Planned Behavior (TPB) framework by identifying and confirming the relevance of the three original constructs: attitude (ATT), subjective norm (SJN), and perceived behavioral control (PBC), all of which have a significant positive impact on the intention to use EMs.

The present investigation also provides empirical support for the Technology Acceptance Model (TAM) in the context of electric motorcycles (EMs). As anticipated, the results demonstrate that perceived usefulness (PUN) is positively related to attitudes toward EMs and the intention to adopt these vehicles, confirming the findings of previous studies by Wang et al. (2018), Adu-Gyamfi et al. (2022), and Jaiswal et al. (2021b). In other words, when consumers perceive EMs as more beneficial, they tend to have a positive attitude toward these vehicles and are more inclined to use them. Furthermore, the results confirm a positive correlation between perceived ease of use (PEU) and PUN, as well as attitudes (ATT). Additionally, the mediating role of PUN between PEU and ATT is confirmed. Similarly, the mediating effect of ATT between PEU and customers' desire to use EMs is supported, highlighting the significance of ATT as a mediator. These findings suggest that customers are more likely to embrace EMs if they find them easy and convenient to operate, leading to a perception of the vehicle's benefit and a positive attitude. These insights contribute to the existing literature on EM usage intention and align with the findings of Jaiswal et al. (2021a) and Yankun (2020). Notably, this study reports such findings in the context of a LMIC for the first time.

The study reveals that perceived risk indicators (PRI), particularly concerns related to range anxiety, explosion, and fire, act as significant barriers influencing the intention to use electric motorcycles (EMs). As PRI levels increase, consumers' intentions to use EMs decrease. These findings align with prior research conducted by Choi and Ji (2015), Wang et al. (2018), Kim et al. (2018), Yankun (2020), and Jaiswal et al. (2021b), providing further clarification regarding the inconsistent result found by Chen et al. (2017), which suggested that PRI had no impact on consumers' intention to use hydrogen-electric motorcycles. A key implication of these findings is that they underscore the importance of collaboratively shaping policies for EMs deployment through community consultation. This approach seeks to strike a balance, ensuring an acceptable level of risk while promoting progress within a sustainable transportation system. In the context of EMs, this approach entails jointly developing strategies and regulations that address specific safety concerns related to electric motorcycles. Such an approach takes into account the preferences and risk tolerance of the community, which can influence the approval or rejection of certain models that meet the minimum safety threshold. Crucially, the management of the risk of explosion should be a shared responsibility among all stakeholders. Transparent and ethical communication is vital to ensure that riders are well-informed about potential risks associated with EMs.

While the Unified Theory of Acceptance and Use of Technology (UTAUT) and the extended Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) recommend age as a moderating variable, this study considers age as a control variable. Although our results contrast with those of Wang et al. (2017), who found that age has no effect on EM adoption intention, this finding contributes new and intriguing insights to the literature on electric vehicle usage intentions. Our results indicate that younger users are more likely to have a higher intention to use EMs than older ones, possibly because young people tend to be more curious and receptive to new technology. This aligns with findings from previous studies in the context of electric vehicles (Hidrue et al., 2011; Huang and Ge, 2019). Furthermore, the results of the multi-group analysis reveal that female customers in DN city are more likely to use EMs than males. This information is valuable for market segmentation, allowing marketers to efficiently identify and target specific market segments. Consequently, marketers can formulate effective strategies to boost EM sales and enhance brand equity.

The present study found that consumers' subjective knowledge about EM technology moderates the relationship between PUN and the intention to use EMs, as well as between SJN and this intention. Consumers who report having a limited understanding of EMs appear to exhibit a more pronounced increase in their intention to use EMs when the perception of usefulness is on the rise (Oh and Abraham, 2016). This trend is not observed among customers who possess a good knowledge of EMs. Consequently, the moderating role of subjective knowledge could potentially explain the inconsistent findings between PUN and INT in previous studies. Additionally, the impact of SJN on INT is found to be more significant among users who are knowledgeable about EM technology compared to users with a lower level of knowledge. Overall, the study underscores the importance of educating customers about EMs.

The present investigation has some limitations. First, while this study employs convenience sampling, future studies could benefit from systematic sampling across a more diverse population. Second, this study was conducted in Vietnam, where EM technology is still in its early stages but advancing rapidly. This unique context may lead to varying levels of EM usage compared to other countries or regions. Therefore, further research is necessary, either in Vietnam at a later stage when EMs have become more popular or in the context of other countries, to evaluate and validate our findings. Moreover, an extension of this investigation could involve comparing variations among different countries, especially those with a substantial number of motorcycle users, such as Vietnam, Indonesia, Malaysia, or Thailand. This comparative approach would offer deeper insights for policy assessments. Third, this study primarily employed TPB and TAM to examine the intention to use EMs in the context of adoption. Future research could explore the effects of other variables using models or theories such as the Norm Activation Model (NAM), Diffusion of Innovation theory (DoI), UTAUT, and UTAUT2. Finally, while behavioral intention has been proven to be a reliable indicator of actual behavior in several studies and can be used to anticipate real behavior, it may not always accurately predict actual behavior. Therefore, further investigation is required to analyze the actual use of EMs.

6. Conclusion and implications

This study investigates the determinants that influence the intention to use electric motorcycles (EMs) in a motorcycle-dominated country. The findings offer valuable insights for governments and electric vehicle manufacturers seeking to develop strategies to encourage EM usage. First, governments and manufacturers should focus on fostering positive consumer attitudes towards this new mode of transportation, as attitude emerges as the most significant predictor of EM usage intention. The results reveal that perceived usefulness and ease of use have a positive relationship with attitudes toward EMs. Therefore, it is advisable for policymakers and administrators to place greater emphasis on enhancing consumer awareness regarding the utility and user-friendliness of EMs. This approach can potentially improve people's attitudes towards this mode of transport and elicit more favorable responses regarding their intention to purchase one. Second, the current study highlights the significance of subjective norm as a critical predictor of EM usage intention. When individuals are hesitant to adopt EMs, it may be due to uncertainties about their benefits or a lack of understanding. Consequently, interventions at both community and individual levels are needed to leverage norms in facilitating the adoption of more sustainable technology. Third, considering the negative impact of perceived risk (PRI) and the positive effect on consumers' subjective knowledge, measures should be implemented to enhance consumers' knowledge, alleviate their concerns, and reduce their perceptions of risk associated with EMs. Increasing awareness about EMs and their practicality can effectively boost consumers' intention to use them. For instance, manufacturers and relevant stakeholders can disseminate specific and comprehensive information through various public media channels, such as television, newspapers, magazines, radio, television programs, social media, and online networks. This approach can help consumers gain a deeper understanding of EMs. Moreover, EM manufacturers and retailers should consider optimizing their sales and services. This could include offering insurance, emphasizing the safety performance of EMs, enhancing after-sales services, providing responsive customer support, promoting the functional

features of EMs, and expanding the network of service centers and charging infrastructure.

Authorship statement

Duy Quy Nguyen-Phuoc: Conceptualization, Methodology, Software, Validation, Investigation, Data Curation, Writing-Original Draft Preparation, Writing-Review and Editing, Visualization. *Thi Minh Truong*: Data Curation, Writing-Original Draft Preparation, Visualization. *Minh Hieu Nguyen*: Writing – Original Draft Preparation, Methodology. *Huong-Giang Pham*: Writing – Original Draft Preparation. *Zhi-Chun Li*: Conceptualization, Writing – Original Draft Preparation, Writing-Review and Editing. *Oscar Oviedo-Trespalacios*: Conceptualization, Writing-Original Draft Preparation, Writing-Review and Editing.

Data availability

Data will be made available on request.

Appendix

Table A1
Measurement scales

Code	Scales	Sources
PEU	**Perceived ease of use**	
PEU1	I think it is easy to learn how to drive EMs	Xu et al. (2018)
PEU2	It would be simple to control EMs	Wang et al. (2020)
PEU3	I would have no problems if I use EMs	Wang et al. (2020)
PEU4	Overall, I think EMs is easy to use	Xu et al. (2018)
PUN	**Perceived usefulness**	
PUN1	I think using EMs can make my driving easier	Xu et al. (2018)
PUN2	I think using EMs can improve my driving safety performance	Xu et al. (2018)
PUN3	I think using EMs can provide me a better driving experience	Authors developed
PUN4	I think using EMs can offer me a comfortable, relaxing driving experience	Authors developed
SJN	**Subjective norms**	
SJN1	Most people who are important to me support that I should use EMs	Nguyen-Phuoc et al. (2022b)
SJN2	Most people who are important to me agree that I should use EMs	Nguyen-Phuoc et al. (2022b)
SJN3	Most people who are important to me recommend that I should use EMs	Nguyen-Phuoc et al. (2022b)
PBC	**Perceived behavioural control**	
PBC1	I am capable of using EMs	Nguyen-Phuoc et al. (2022a)
PBC2	If I want, I can easily use EMs	Nguyen-Phuoc et al. (2022a)
PBC3	I have enough money to buy EMs	Nguyen-Phuoc et al. (2022a)
ATT	**Attitude**	
ATT1	I think that using EMs is valuable	Nguyen-Phuoc et al. (2022b)
ATT2	I think that using EMs is right	Nguyen-Phuoc et al. (2022b)
ATT3	I think that using EMs is necessary	Nguyen-Phuoc et al. (2022b)
ITU	**Intentions to use**	
ITU1	I will use EMs in the future	Nguyen-Phuoc et al. (2022b)
ITU2	I have an intention to use EMs in the future	Nguyen-Phuoc et al. (2022b)
ITU3	I am likely to use EMs in the future	Nguyen-Phuoc et al. (2022b)
PRI	**Perceived risk**	
PRI1	Electric vehicles may not have sufficient power to reach the final destination	Authors developed
PRI2	Electric vehicles may run out of power and not be able to find a charging station on time to replenish the battery	Authors developed
PRI3	The batteries of electric vehicles may combust when damaged, overcharged or subjected to high temperatures	Authors developed
PRI4	Explosions may occur while charging electric vehicle batteries	Authors developed
SKN	**Subjective knowledge**	
SKN1	I know the integration of EMs and information and communications technology to manage the vehicles	(Huang et al., 2021b)
SKN2	I know the collaborative discharge capability of EM batteries and its application scenarios	(Huang et al., 2021b)
SKN3	I know the technological performance (such as charging time, acceleration, driving comfort and driving range) of EMs	(Huang et al., 2021b)
SKN4	I know the technological advantages of EMs over gasoline vehicles	(Huang et al., 2021b)

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