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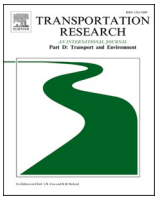

Electrifying Vietnam's streets: Identifying the determinants of electric two-wheelers uptake

Nguyen Thanh Trung, Tania Urmee *

School of Engineering and Energy and Centre for Water, Energy and Waste, Murdoch University, 90 South Street, WA 6150, Australia

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ABSTRACT

This study analysed the key determinants driving Vietnam's electric two-wheeler (E2W) market and proposes strategies to foster its growth. Using a multifaceted research approach, combining expert interviews and comprehensive consumer surveys involving 385 respondents. The study adopts the relative importance index for data analysis, highlighting the paramount significance of reliable charging infrastructure, upfront purchase costs, and reduced emissions. Additionally, E2Ws are favoured by sustainable design, modern aesthetics, simplified licensing, and purchase incentives that facilitate its adoption. Other primary considerations include technological aspects, such as safety, range, battery lifespan, and charging duration. Analysis of 15 expert interviews using NVivo software reveals the suitability of E2Ws for Vietnam's dense urban roads, economic advantages, and environmental priorities. While there's excitement about E2Ws, obstacles like climate impact, financial barriers, and infrastructure gaps remain. The research concludes with recommendations for promoting E2W adoption, emphasizing awareness drives, policy clarity, safety protocols, and technological advancements.

1. Introduction

With rising global concern over the rapid changes in climate and increasing greenhouse gas emissions, many countries have committed to the Paris Agreement, initiating relevant national strategies in response (WMO, 2018). The transportation sector accounts for a significant role in global carbon dioxide (CO_2) emissions, contributing approximately 23 % of global emissions (AL-GHUSSAIN, 2019, Sioshansi and Webb, 2019). In 2022, worldwide CO_2 emissions from transportation increased by over 250 Mt CO_2, reaching close to 8 Gt CO_2, a 3 % rise compared to 2021 (IEA, 2023). Emissions of increasing greenhouse gases in the transportation sector mainly arise from the combustion of fossil fuels used in vehicles such as motorcycles, cars, trucks, ships, trains, and aircraft (IPCC, 2023). As renewable technologies advances, the electric vehicle (EV) market is poised for significant expansion (Olabi et al., 2021, Alami et al., 2022). As a result, EVs are becoming a key component of sustainable city planning, helping countries to meet their emission reduction goals (Al-Swaiedi et al., 2021, Al-Swaiedi et al., 2022, Alkhalidi et al., 2018). In some countries, there is a growing momentum for electric two-wheelers (E2Ws) including electric bikes, electric motorcycles, electric scooters, and electric mopeds. An illustrative case of this trend can be observed in China (Cherry et al., 2016, Lin et al., 2017). The increased interest in electric vehicles (EVs) is evident through the increased emphasis on research and development (Subramaniam et al., 2019, Abo-Khalil et al., 2022).

The novel contribution of this paper to the existing literature lies in its comprehensive assessment of the electric two-wheeler (E2W)

* Corresponding author.
E-mail address: T.Urmee@murdoch.edu.au (T. Urmee).

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market in the context of Vietnam's urban traffic. While prior research on E2Ws has often focused on other regions or aspects (Gielen et al., 2019, Shehata et al., 2022, Olabi et al., 2022), this study provides a unique and in-depth analysis of the current state and evolution of the E2W market specifically within Vietnam. Additionally, it examines into the previously underexplored determinants behind the adoption of E2Ws in the Vietnamese context, shedding light on key factors influencing consumer choices. By scrutinizing the policies aimed at promoting E2W adoption and their actual effects, this paper offers valuable insights into the effectiveness of governmental interventions in shaping sustainable urban mobility solutions. The study also adds a significant contribution to the literature by offering a holistic perspective on E2Ws in Vietnam, filling gaps in our understanding of this crucial aspect of sustainable urban transportation.

In the Association of Southeast Asian Nations (ASEAN) region in 2019, transportation produced 24 % of energy-related emissions and about 5 % of global transportation-related CO_2 emissions (ITF, 2022). ASEAN nations view the transportation sector as a focal point for emission reduction by exploring strategies related to public transportation, transport demand regulation, pedestrian pathways, electrified and hybrid vehicles, regular vehicle upkeep, fuel efficiency, biofuel utilisation, and sustainable cargo transport (GIZ, 2016). Thailand has set a goal to transition all its vehicle sales to EV by 2035 (THANTHONG-KNIGHT, 2021), followed by Singapore in 2040 (Teo, 2020), with Vietnam and Indonesia targeting 2050 (Vietnamese Government, 2022, Reuters, 2021).

In 2022, Vietnam was ranked the 30th most polluted country based on the annual average PM2.5 concentration (IQAir, 2022). Vehicle-induced air pollution, particularly from petrol-fuelled motorcycles, scooters and mopeds, is a pressing concern that has led to government action in Vietnam's major urban centres (Nguyen et al., 2020). Between 2014 and 2018, car ownership increased by 13.7 % per annum, and motorcycles and mopeds by 9 % in Vietnam (Le et al., 2021). Approximately 300,000 new cars and over 3 million new motorcycles are added to the roads each year. In Hanoi and Ho Chi Minh, the country's most populous cities, only 10 % of commuting demands are met by public transport, while the remaining rely on two-wheelers for transportation (Hiep et al., 2020). For instance, in 2019, Hanoi had a total vehicle population of 6.6 million, of which 5.7 million are motorcycles (Nguyen et al., 2020). These figures emphasize Vietnam's substantial reliance on 2Ws which are also significant contributors to emission (Jones et al., 2013).

Vietnam is proactively working towards mitigating increasing greenhouse gas emissions and addressing air pollution concerns. During COP26, the nation pledged to reach net-zero emissions by 2050 (DEZAN SHIRA, 2021) and updated its Nationally Determined Contributions in 2022. To meet these targets, transformative measures in the transportation arena are imperative. The government has established an ambitious target: producing and importing fossil-fuel vehicles for local consumption will cease by 2040 (QUANG, 2022).

1.1. Two-wheeler vehicle market in Vietnam

The transition to clean energy is evident in the escalating preference for EVs, especially E2Ws such as electric bikes and motorcycles. According to the Ministry of Industry and Trade, electric motorcycle sales have increased significantly in recent years (Vietnam news, 2023). This trend positions Vietnam as the leading electric two wheeler (E2W) market in the ASEAN region and the second-largest worldwide, trailing only China (Vietnam news, 2023). As such, the shift from gasoline-powered two wheelers to E2Ws holds significant potential.

Fig. 1 displays the yearly sales of two wheelers from 2016 to 2022, as detailed by the National Traffic Safety Committee (Huong Le, 2022) and Motor Cycles Data (Team, 2023). Between 2016 and 2017, two-wheeler sales steadily climbed, peaking at around 3.6 million units in 2018. However, a downward trend was evident in 2019, and the repercussions of the COVID-19 pandemic further suppressed sales in 2020 and 2021. In 2022, the two wheeler market in Vietnam made a remarkable recovery, with sales of 3.38 million units, rebounding from a two-year decline caused by the COVID-19 pandemic (Team, 2023). Compared to Vietnam's total two-wheeler count, E2Ws constitute a small fraction. In perspective, in 2020, E2Ws accounted for a mere 7 %, with conventional two wheelers making up the remaining 93 % (Huong Le, 2022). From 2022 to 2030, the proportion of E2Ws in Vietnam is projected to increase from

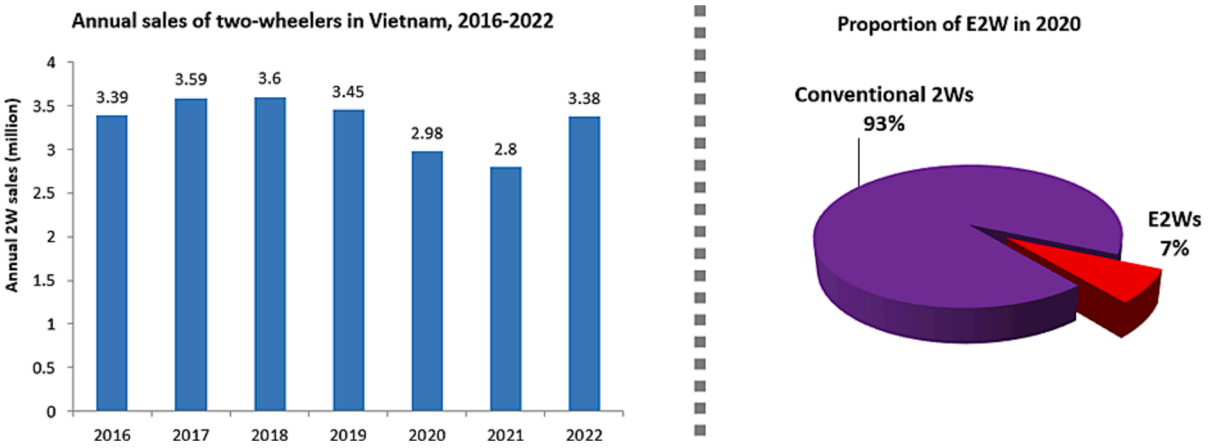

Fig. 1. Two-wheeler growth and proportion of E2Ws in Vietnam.

10 % to 16 %. While petrol-driven motorcycles remain the prevalent transportation choice, their growth rate, hovering between 2 % and 4 %, lags considerably behind the projected expansion rate for E2Ws (Hiep et al., 2023).

While there are optimistic projections for the E2W market, it is crucial to acknowledge the existence of substantial barriers. Therefore, gaining insights into the current state of E2W markets in Vietnam and to identify existing challenges becomes essential.

Moreover, no clear strategy exists for developing, planning, and investing in E2W infrastructure (Hiep et al., 2023). While some studies have explored the impact of incentives and technology on electric motorcycle adoption as far back as 2013 (Jones et al., 2013), a comprehensive research focus on the factors influencing E2W adoption in Vietnam's cities remains absent. In addition, more in-depth studies are needed on the pros and cons of E2Ws in Vietnam and the popularity of E2Ws in the short term and long term (Huu and Ngoc, 2021). Moreover, there is still a lack of preferential policies of the government, indications on the research, investment, infrastructure, and citizen's awareness on E2Ws in Vietnam. For instance, on the consumer front, there is a conspicuous absence of policies to encourage E2W ownership, utilization, and the E2W industry (Liu et al., 2022).

This paper aims to answer the following questions:

- What is the current state of the E2W market in Vietnam's urban traffic, and how has it evolved?
- What are the key determinants of adopting E2Ws in Vietnam?
- What policies have been implemented and its effects to promote the adoption of E2W?

Section 2 describes the methodology of the research followed by the survey results and discussion in section 3. Meantime, section 4 presents the conclusion and policy implications.

2. Methodology

The methodology is illustrated in Fig. 2 and detailed in the following sections.

2.1. Step 1: Desktop study

Secondary data sources such as market reports, industry journals, and articles related to E2W adoption were analysed to track the growth and evolution of the E2W market in Vietnam. Policy documents such as laws, regulations, and directives were examined to grasp these policies' objectives, targets, and strategies. This analysis provides insights into the current state of the E2W market within Vietnam's urban transportation landscape and the effectiveness of policies promoting E2W adoption in Vietnam. A comprehensive set of attributes influencing E2W usage relevant to Vietnam was identified during this step and used to develop the survey and interview questionnaire.

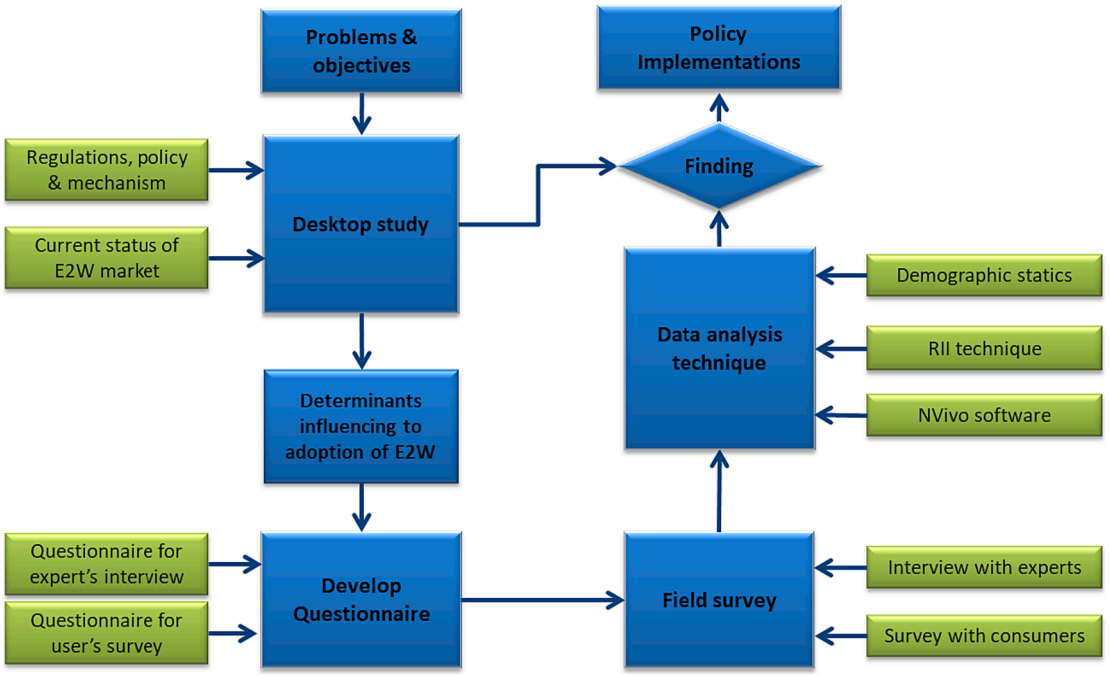

Fig. 2. Methodological framework of the study.

2.2. Step 2: Field survey

2.2.1. Survey with consumers

The face-to-face survey was conducted among two-wheeler consumers in Hanoi (Vietnam's capital). As of September 2022, Hanoi had about 6.5 million motorbikes, mainly for personal transportation (Luan, 2023). Using the Raosoft sample size determination formula, with a 95 % confidence level and a 5 % margin of error, 385 respondents were chosen for the survey. This face-to-face survey occurred in public areas between 15 July and 10 August 2023, with all 385 distributed surveys returned (100 % response rate).

The questionnaires were deployed to identify how E2W users voted for important determinants. This questionnaire had two main sections, with the first section gathering demographic information, such as name, age, gender, educational level, and information on their 2Ws. The second section comprised questions on a 5-point Likert scale (1 = 'Not important' to 5 = 'Very important'). A pilot study was conducted with 20 students who currently own motorcycles to ensure the questionnaire was clear and easy to understand. Their feedback was crucial in refining the questions for broader distribution. Table 1 presents an example from the questionnaire's second section for reference.

2.3. Interview with experts

The expert opinions on urban traffic compatibility, influencing factors, barriers, solutions and future trends of the E2W market in Vietnam were collected through approximately 20-minute interviews to consolidate the proposed attributes. Fifteen experts with at least five years of experience in the transport sector were invited for interviews to elicit their valuable opinions on the importance of E2W attributes in Vietnam. Among these experts, six held management positions, four represented industry associations, and five were purely came from academics as illustrated in Fig. 3.

2.4. Step 3: Data analysis using the relative importance index technique and NVivo software

2.4.1. Analyse consumer's survey data

The relative importance index technique was used to analyse the survey results, as the survey utilized a 5-point Likert scale. This method efficiently ranks determinants based on their perceived importance (Murugan and Marisamynathan, 2022, Kassem et al., 2020, Gebrehiwet and Luo, 2017) by converting Likert scale responses into a common scale ranging from 0 to 1. This transformed scale allows for easy comparisons among various determinants and offers a clear perspective on the relative weight of each factor.

The relative importance index computation was implemented using Microsoft Excel, enabling the index assessment across different sets, as presented in the following equation.

$$RelativeImportanceIndex(RII) = \frac{\sum(Weight \times Frequency)}{Total\ number\ of\ responses \times Maximum\ weight} = \frac{1 \times n_1 + 2 \times n_2 + 3 \times n_3 + 4 \times n_4 + 5 \times n_5}{N \times 5}$$

Where Weight is the value a respondent gives to each determinant, ranging from 1 to 5, n_1 to n_5 indicates the number of respondents who rated a factor from Not Important to Very Important, respectively, Maximum weight is capped at 5, and N is the total number of respondents. The relative importance index has a potential value between 0 and 1.

Analyse expert's interview data

NVivo software was used to analyse the interview results of stakeholders. NVivo is a globally recognised tool for qualitative data analysis capable of extracting insights from the collected data. The primary goal was to identify key insights related to the interview questionnaires, enhancing the depth and richness of the study's findings (Denscombe, 2010).

Fig. 4 illustrates the analysis process using NVivo, which comprises three main stages: data preparation, data analysis, and exporting outcomes.

2.5. Step 4: Final selection of key determinants and policy formulation

In this step of methodology, the derived results from step 3 are discussed. A final list of determinants and other factors influencing the adoption of E2Ws in Vietnam is formulated. A framework of strategies to increase the share of E2W in Vietnam is also proposed

Table 1
Sample survey questionnaire.

Determinants	Not important	Less important	Neutral	Important	Very important
Infrastructure					
Maintenance services	☐	☐	☐	☐	☐
Road condition	☐	☐	☐	☐	☐
Road gradient	☐	☐	☐	☐	☐
Parking infrastructure	☐	☐	☐	☐	☐
Charging infrastructure	☐	☐	☐	☐	☐

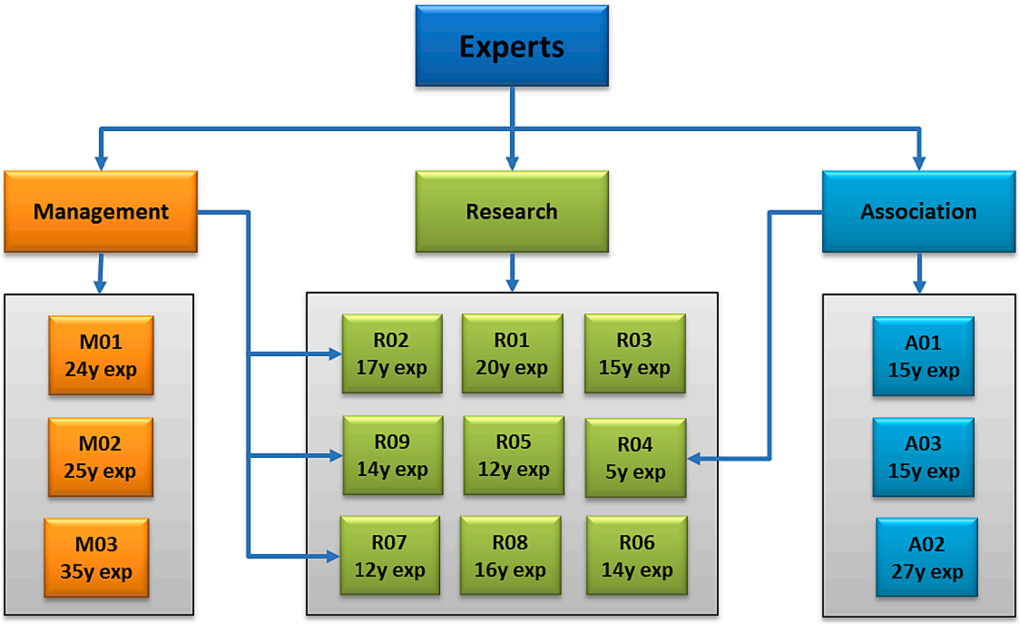

Fig. 3. Mapping of expert allocation for the interviews.

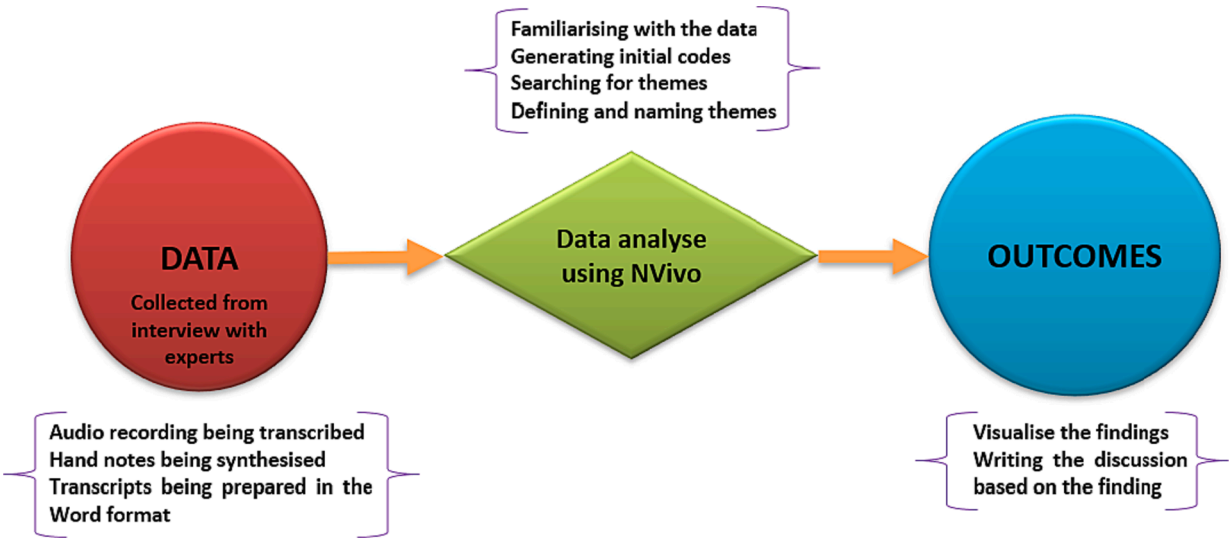

Fig. 4. Analysis process using NVivo.

along with policy recommendations.

3. Results and discussion

3.1. Survey results and discussion

3.1.1. Demographics of survey participants

Fig. 5 displays survey data where 49 % of respondents are aged 25–49, followed by 18–24-year-olds at 39 %, and those 50 + at 12 %. Gender-wise, males account for 56 %, slightly more than the 44 % female representation. This suggests a wide age range appeal for two-wheelers in Vietnam.

Refer to Fig. 6, the educational background of two-wheeler users was surveyed, highlighting that two wheelers are the preferred mode of transport for people from diverse educational levels.

Fig. 7 illustrates the occupation of survey respondents, showing that while two wheelers are favored by individuals from a wide

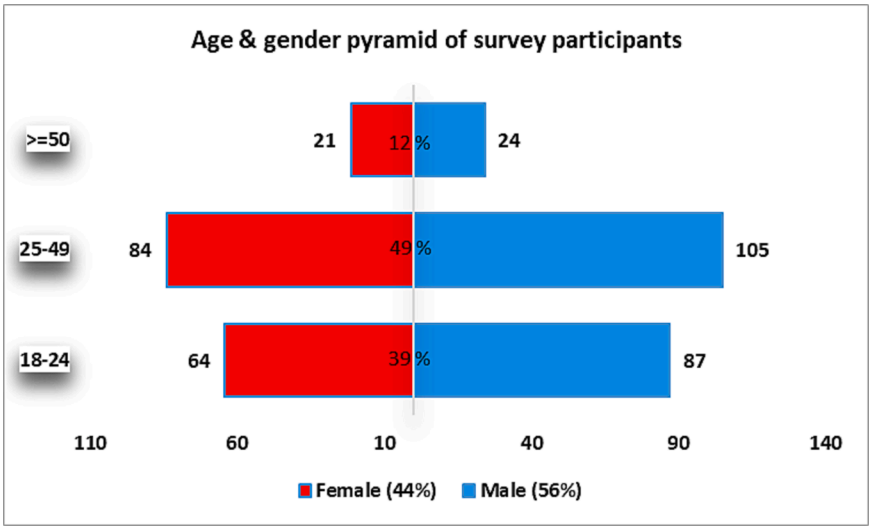

Fig. 5. Age and gender pyramid of survey participants.

range of professional backgrounds, they seem to be more preferred by students.

Refer to Table 2, most of the respondents (30.9 %) had average monthly incomes in the middle-income bracket ($426 to < $639.99), followed by individuals with monthly incomes ranging from $213 to $425.99. This pattern indicates that the bulk of two wheeler users are clustered in the middle-income bracket, as the average monthly income per capita in urban areas is about $256 USD (General Statistic Office, 2022). The average USD to VND exchange rate used in this study, as of April 2023, was $1 = 23,471[d].

3.1.2. Two-wheeler usage

A significant portion, about 35 % of participants as shown in Fig. 8, have been driving for over a decade. The results paint a picture of a diverse two-wheeler community, with the majority of participants having extensive experience riding 2Ws.

Refer to Fig. 9, a substantial portion of two-wheeler users (43.9 %) were frequent riders using their vehicle daily. The data underscores the prominence of two wheelers as a primary mode of transportation for many. Most respondents (49.1 %) typically drive for 1–2 h daily, suggesting that most 2 W users typically have shorter commutes or prefer to moderate their daily driving durations.

In Vietnam, four primary types of two-wheelers are prevalent: bicycles, mopeds, scooters, and motorcycles. Bicycles are pedal-powered, mopeds have engines up to 50 cubic centimetres (cc) scooters are over 50 cc with automatic transmission, and motorcycles are over 50 cc with manual transmission. A striking 99.7 % of survey participants own at least one two-wheeler, indicating high ownership rates in Vietnam. Motorcycles are the most common, chosen by 48 % of respondents, followed by scooters at 33.1 %, as per Fig. 10. This reflects the diverse preferences in two-wheeler models. Additionally, 80 % of those surveyed are well aware of E2Ws,

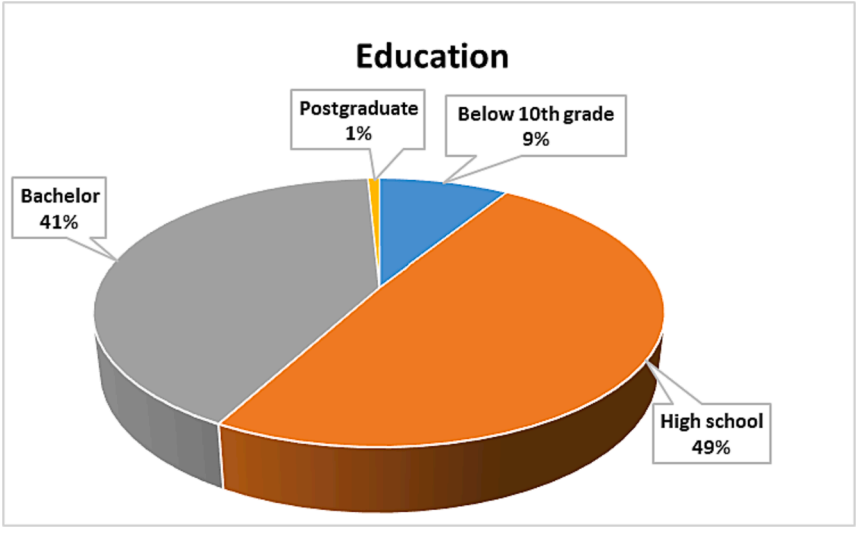

Fig. 6. Education level of participants.

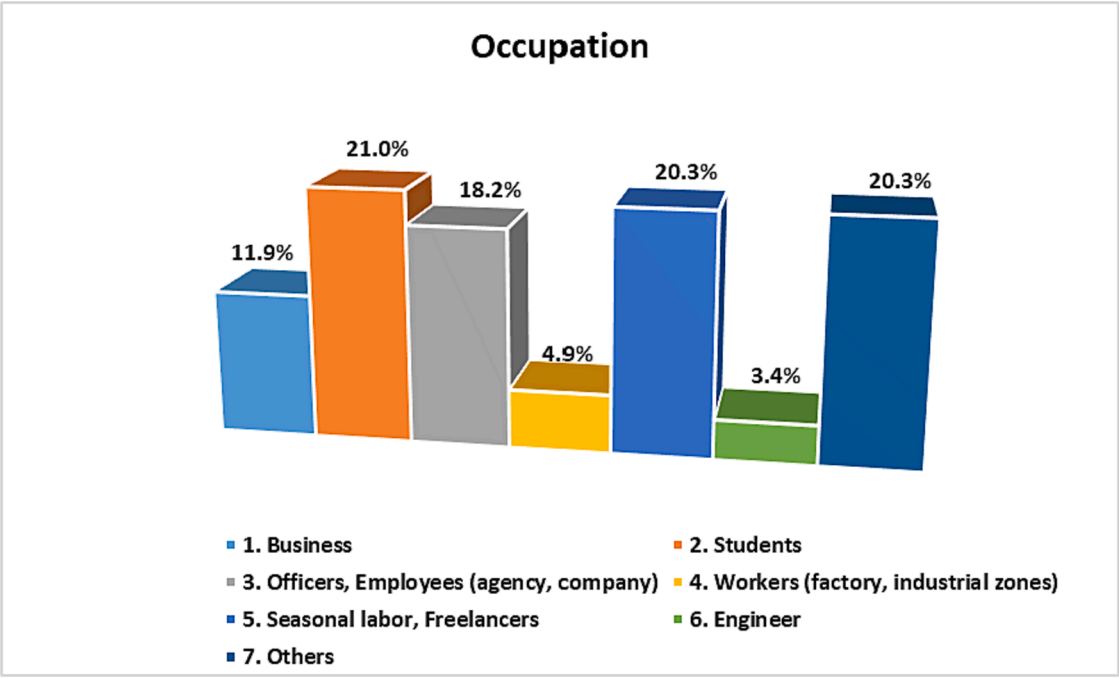

Fig. 7. Occupation group of participants.

Table 2
Average monthly income of participants (US$).

No	Average monthly income (US$)	Responses	Percentage (%)
1	< 213	99	25.7
2	213 to 425.99	107	27.8
3	426 to 639.99	119	30.9
4	640 to 851.99	31	8.1
5	852 to 1,065.99	17	4.4
6	≥ 1,066	12	3.1

while 20 % are not, suggesting a potential market for E2Ws in the country.

3.1.3. Operating cost for two-wheelers

Fig. 11 presents the monthly operating and maintenance costs of 2Ws. A significant 63.1 % of respondents spend less than $43 per month, followed by 28.3 % in the $43–85.99 range. According to the statistical yearbook of Vietnam, the average monthly income per capita in urban areas was about $256 USD in 2022 (General Statistic Office, 2022). The operating and maintenance costs for gasoline-powered two wheelers do not seem economical when they could account for about 16.8–33.6 % of the total average income.

3.1.4. Determinants of purchasing electric two wheelers

The survey results were analysed using the relative importance index method. Table 3 offers clear insights into the primary determinants of potential consumers considering the transition to E2W.

Infrastructure determinants

With the rapid adoption of EVs, infrastructure has become a pivotal factor. The availability and quality of infrastructure directly impact user convenience and confidence, influencing purchasing decisions.

Referring to Fig. 12 and Table 3, it is evident that for potential E2W adopters in Vietnam, the availability of charging stations is a crucial factor influencing their decision. This concern is understandable; even the most advanced E2Ws would have limited utility if convenient charging options are scarce. According to (Zhang et al., 2013) the expansion and improvement of charging infrastructure, including coverage, fast charging, and reliability, are expected to boost E2W adoption rates. As the charging infrastructure matures, with widespread coverage, fast charging capabilities, and reliability, the E2W adoption rate will likely increase (Shao et al., 2012).

Road conditions are crucial in the adoption of E2Ws as they directly impact vehicle performance and reliability. For potential adopters, especially in areas with challenging terrains, the quality of roads can significantly influence their decisions, with poorly maintained or steep roads posing challenges to the vehicle's battery life and functionality. While not a primary concern for all,

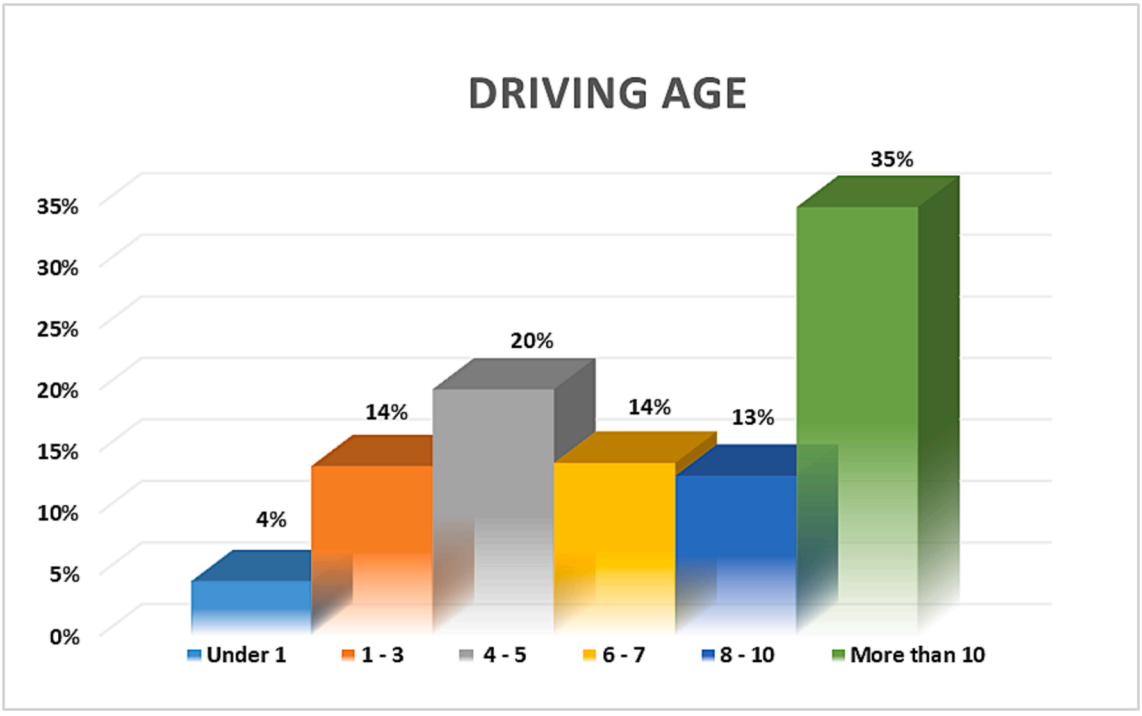

Fig. 8. Driving age in years of survey participants.

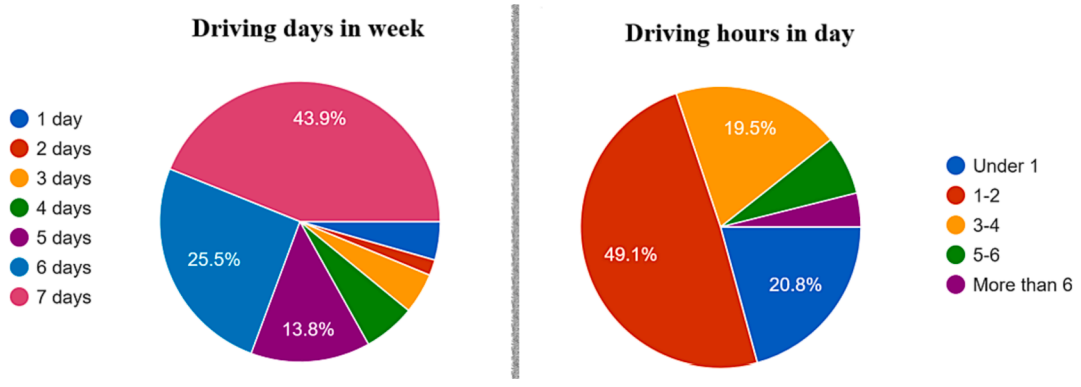

Fig. 9. Driving frequency of participants.

particularly urban commuters, the availability of well-maintained roads is essential for fostering the adoption of E2Ws.

Notably, parking infrastructure seemed surprisingly low on the priority list, given urban congestion, likely due to the compact design of 2Ws, allowing them to fit into tight spaces. Many urban areas already cater to large two-wheeler populations, implying that electric models are easily accommodated.

Economic determinants

Despite the importance of the direct costs of E2Ws associated with purchasing, operating, and maintaining, indirect or long-term economic factors, such as resale value and cumulative monetary savings, do not command the same immediate attention.

Refer to Table 3 and Fig. 13, the purchase cost is the most significant factor for potential E2W adopters. Being a substantial upfront financial commitment, it is understandable that consumers prioritise this aspect, as reported elsewhere (Wang et al., 2016, Kara et al., 2017). The initial cost becomes the first gatekeeper in the decision-making process, dictating whether E2Ws are financially accessible to a wide demographic or remain a niche luxury. Furthermore, in a developing economy like Vietnam, where the average income is typically lower than developed nations, the purchase cost can make or break the decision for many potential buyers.

Standing as the second most important factor in terms of economy, the operating cost plays a pivotal role in the long-term financial viability of owning an E2W. Consumers are not just concerned with the upfront cost but are also focused on the long-run expenses. E2Ws, by design, promise lower operating costs due to fewer moving parts and reliance on cheaper electricity as opposed to

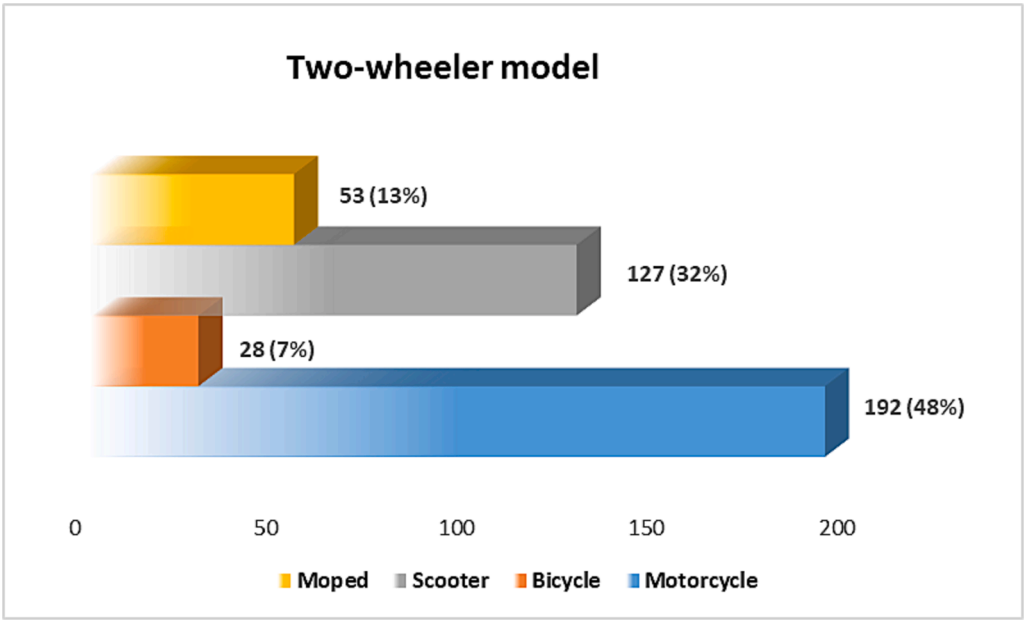

Fig. 10. Two-wheeler model of survey participants.

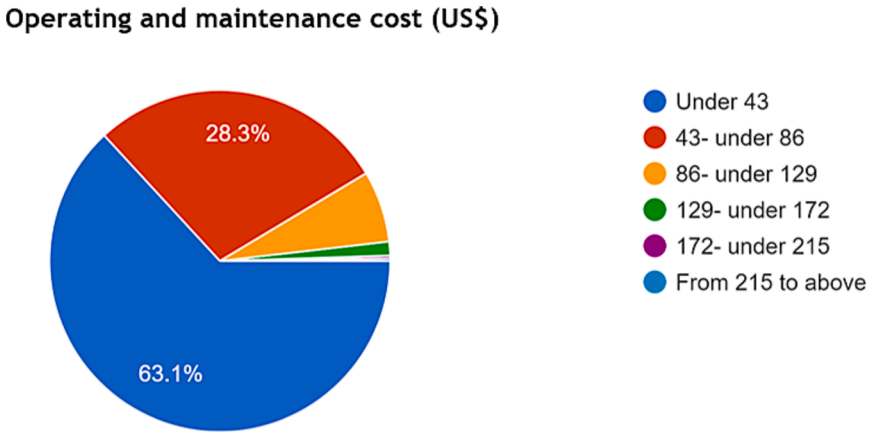

Fig. 11. Operating and maintenance cost for two wheelers of survey participants (US$).

conventional fuels. Commuters who travel longer distances are likely to switch to electric vehicles to save on fuel costs, according to a past research (Hidrue et al., 2011). It is clear that consumers are keen on ensuring that these promised reductions in operating costs are substantial and consistent.

Maintenance cost is another significant economic determinant. This alligns with the study of Yang et al., which found that E2Ws offer economic advantages by reducing fuel and maintenance costs compared to gasoline-powered two wheelers (Yang et al., 2020).

Resale value has gained the lowest attention from E2W adaptors regarding economic attributes. Though it might seem surprising initially, the reduced priority on resale value can be seen in the context of the evolving EV market. With rapid advancements in battery technology and electric vehicle design, older models might become obsolete more quickly, reducing their resale value. Additionally, the nascent stage of the E2W market in Vietnam might make potential buyers uncertain about the future resale market.

Environmental determinants

As shown in Table 3 and Fig. 14, jointly equal ranking with emissions reduction, the importance of reducing noise pollution showcases the increasing awareness and desire for quieter urban environments. Traditional combustion engines are a significant contributor to the cacophony of city sounds. E2Ws promise not just cleaner, but also quieter commutes. This ranking demonstrates that residents in Vietnam's urban areas are yearning for a reprieve from the constant noise, making this a significant factor in their vehicle choice.

This suggests that if consumers adopt E2Ws, they would prioritise on environmental concerns. Such findings align with prior

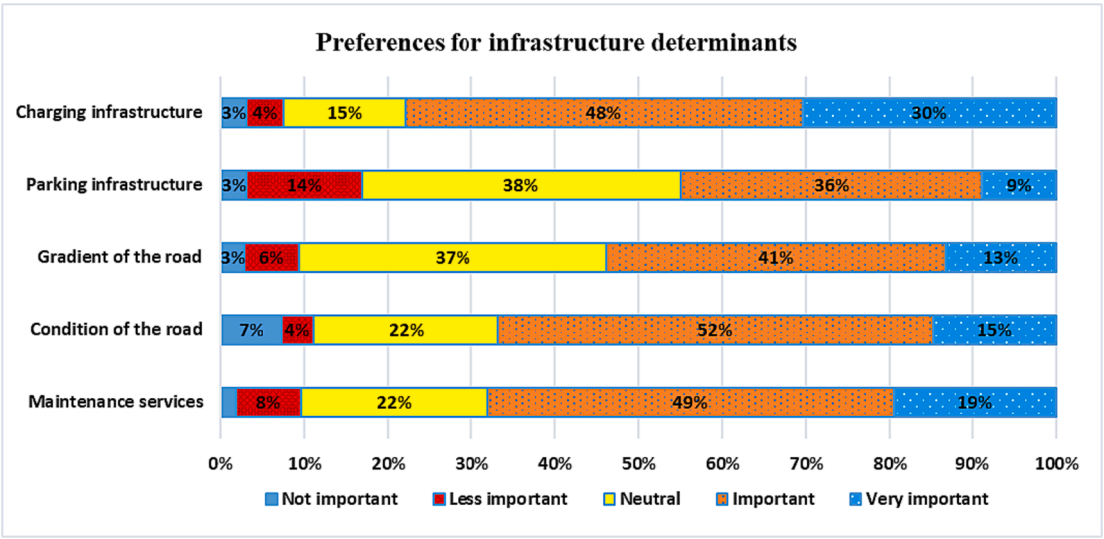

Fig. 12. Preferences for infrastructure determinants.

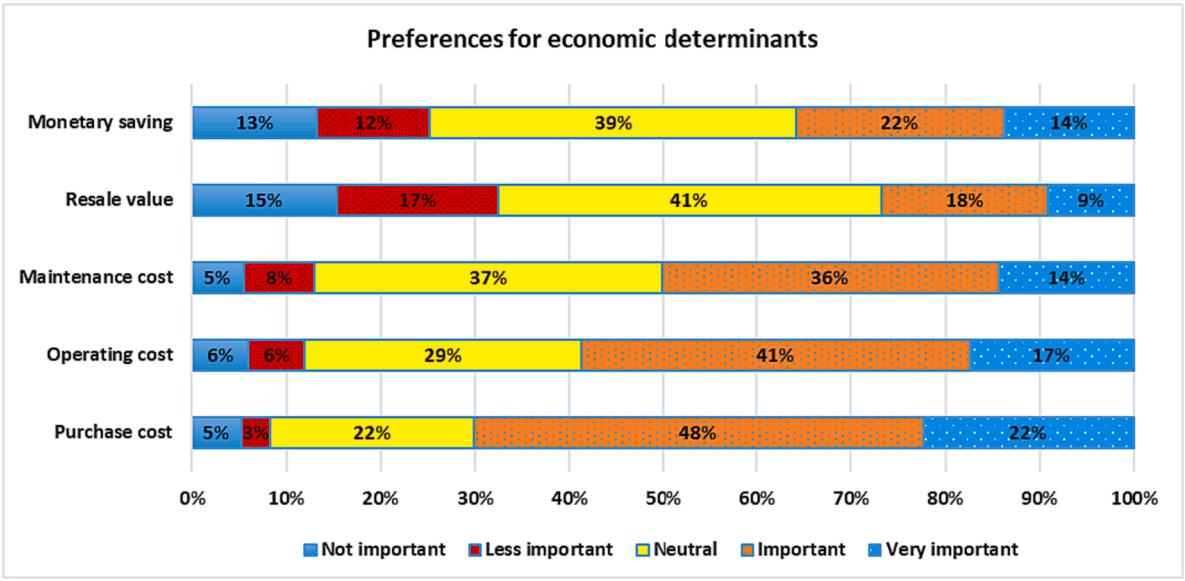

Fig. 13. Preferences for economic determinants.

research regarding electric scooters (Al MamunZainol and Hayat, 2020) and EVs (Wang et al., 2016).

Social determinants

The decision to adopt an E2W is not solely based on personal convenience or economics; the social dimension also plays an influential role, with the three top attributes being contribution to society, appearance and style, and trend in using as referred to Table 3 and Fig. 15.

Urban dwellers in Vietnam seem to value the positive environmental and societal impact of EVs. This awareness and desire to contribute towards a cleaner, more sustainable environment indicates a commendable societal shift when E2Ws can serve as an eco-friendly alternative, diminishing harmful emissions and noise and potentially addressing land use challenges in crowded urban areas (Eccarius and Lu, 2020). The aesthetic appeal of E2Ws also matters to consumers. A stylish, modern appearance might boost the owner's self-perception and showcase their vehicle as a symbol of progressive thinking and aligning with the zeitgeist of contemporary urban life.

Being seen as 'in vogue' or 'keeping up with the times' also has a fair amount of weight. As EVs become mainstream, there is a growing trend to be part of this transformative wave. Adopters seem to be influenced by what is trendy, indicating a blend of personal choice and societal influence, as reported by Tu and Yang (Tu and Yang, 2019).

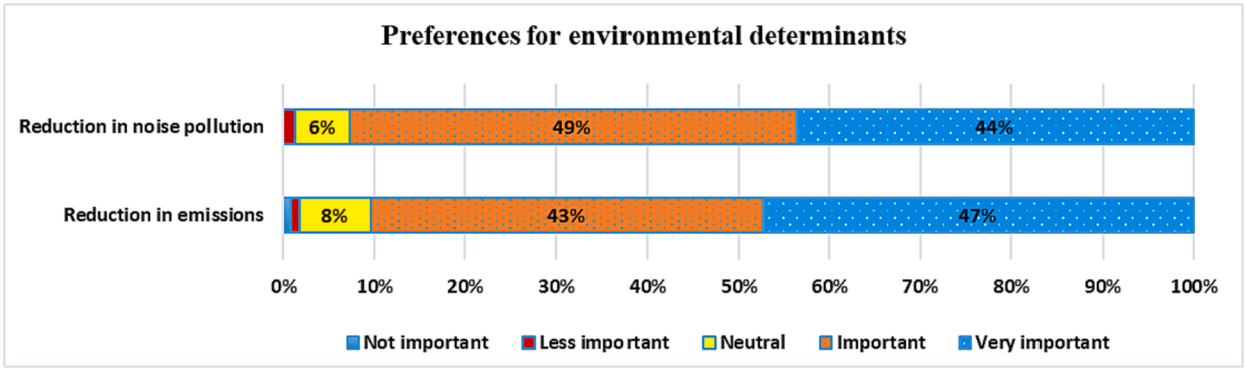

Fig. 14. Preferences for environmental determinants.

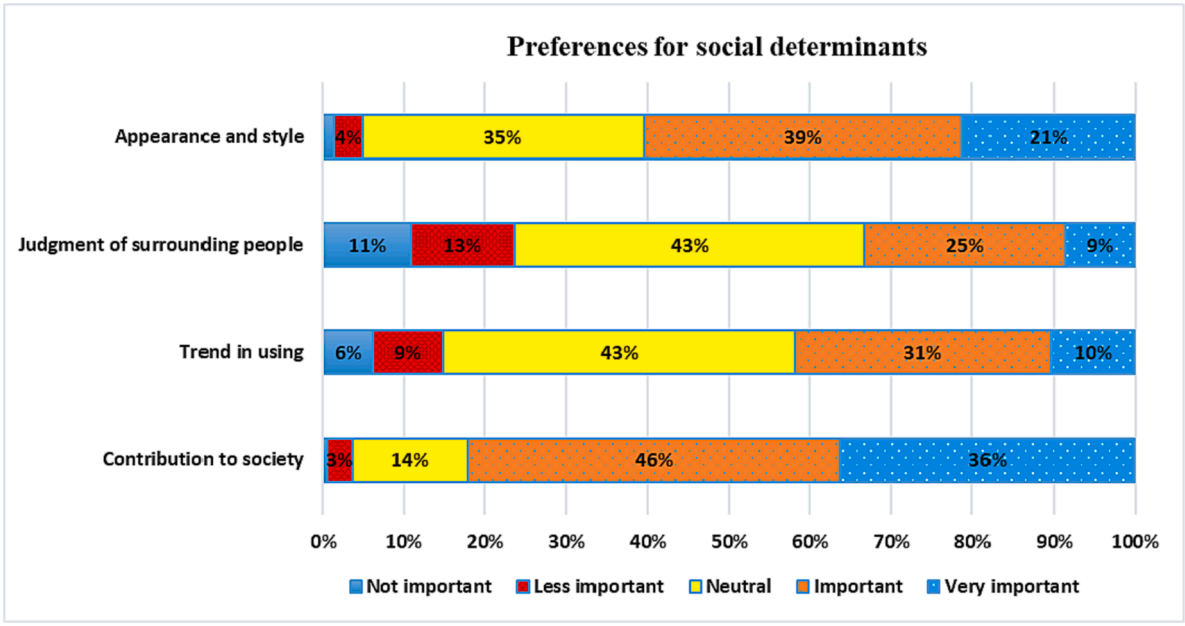

Fig. 15. Preferences for social determinants.

While society's judgement can influence many aspects of people's lives, when it comes to adopting E2Ws in Vietnam, people might be less concerned about the immediate judgement of their peers. One study also indicated that the views of consumers' relatives, friends, co-workers, or superiors had minimal influence on their attitudes or actions concerning EV acquisitions (Tu and Yang, 2019).

Policy determinants

Policy plays a pivotal role in shaping consumer behaviour, especially in nascent markets like EVs. The combination of direct monetary benefits and long-term savings can dramatically impact consumer decisions.

Refer to Fig. 16 and Table 3, the ease of obtaining licences for E2Ws has emerged as the top policy-based determinant. This highlights the significance consumers place on hassle-free registration and operation. An accessible licensing system means potential amdopters face fewer bureaucratic hurdles, thus speeding up their adoption journey.

Purchase subsidies appear as the second most crucial determinant, aligned with other studies (Wahab and Jiang, 2019). This suggests that the initial cost barrier for potential adopters can be considerably reduced with financial incentives. Direct subsidies on purchase could make E2Ws more affordable for a larger segment of the population, thereby boosting their adoption.

Besides, reduced rates for electricity, especially during off-peak hours, can significantly impact the long-term costs of operating an E2W. According to one study, fuel types and operating costs are considered some of the most important attributes for E2W adoption (Choi et al., 2022).

While tax discounts are generally seen as an attractive incentive, their impact might be perceived as spread out over a more extended period and might cause less impact on buyers who do not have a bank loan. This makes annual tax discounts to be less immediately enticing than upfront purchase subsidies or direct cost reductions.

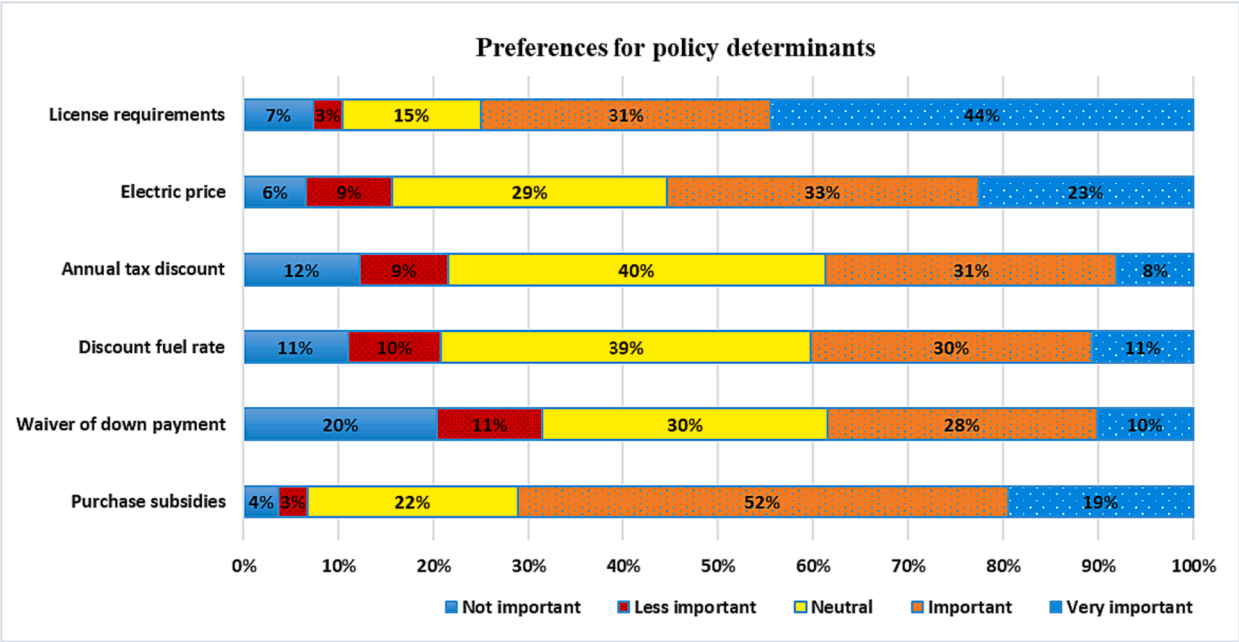

Fig. 16. Preferences for policy determinants.

The least prioritised determinant is the waiver of down payments. This could hint at a general acceptance among consumers to make initial investments without waiting for the waiver of down payments if they perceive long-term benefits, such as reduced operating costs.

Technology determinants

Technological advancements serve as the backbone of the EV industry, enhancing both the utility and appeal of these vehicles. When it comes to E2Ws, consumers prioritise aspects that ensure both efficient commuting and safety.

Refer to Fig. 17 and Table 3, topping the list, the emphasis on safety features underlines a universal consumer sentiment—safety is paramount. As E2Ws navigate the bustling streets of Vietnam's cities and their extreme climates, including flooding, advanced safety mechanisms can instil confidence in riders, reassuring them that their choice is both eco-friendly and secure. A recent study in Macau

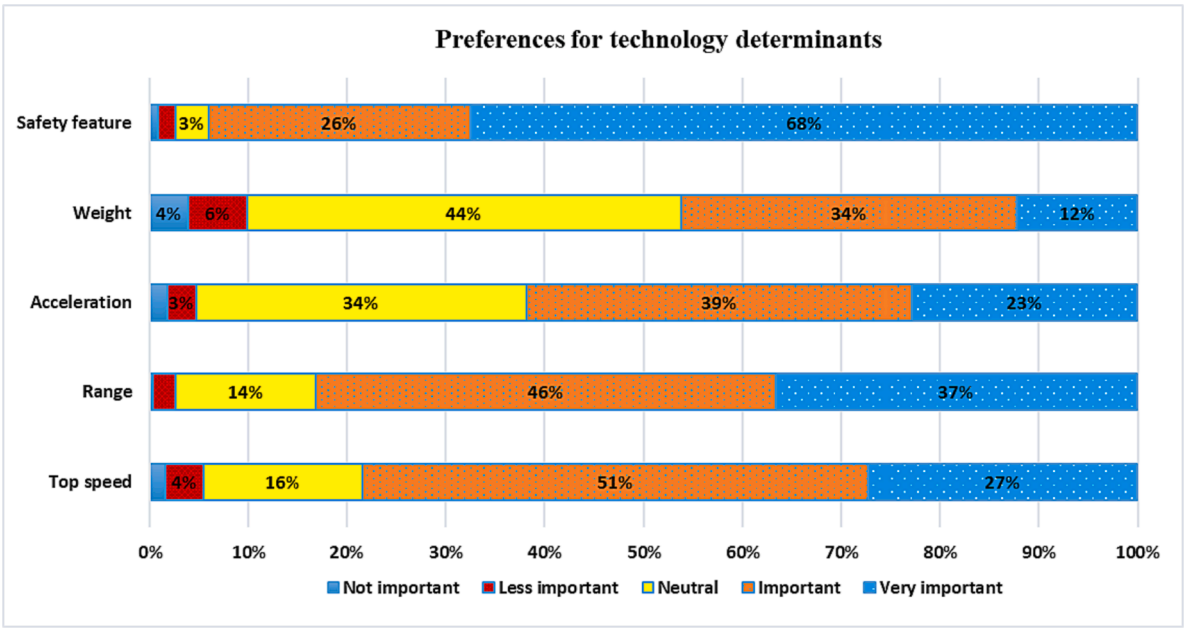

Fig. 17. Preferences for technology determinants.

reported that safety is a significant factor for individuals when buying an electric motorcycle (Zhu et al., 2019). Additionally, fire-based risk could be a big concern for E2W consumers.

The range of an E2W determines how far it can travel on a single charge. Given the urban context of big cities, consumers are likely looking for vehicles that can comfortably cover daily commutes without frequent recharges (CHERRY, 2007). A longer range ensures convenience and reduces any potential range anxiety, leading consumers to pay more (Bouguerra and Layeb, 2019).

In the fast-paced environment of major cities, having an E2W that can keep up with the traffic flow is essential. A competitive top speed ensures riders can reach their destinations promptly. One study found that the E2W's top speed significantly contributes to positive user experiences (Popovich et al., 2014).

The weight of an E2W impacts its manoeuvrability, especially in congested urban areas. However, the lower prioritisation might indicate that potential adopters believe modern E2Ws are already lightweight or other factors like safety and range overshadow the weight consideration. In another study, half of the consumers identified the added weight of E2Ws as an issue, expressing concerns that it might heighten the risk of flat tyres (Dill and Rose, 2012).

Battery:

The battery is the heart of any EV, dictating its efficiency, utility and longevity. For urban commuters, particularly in bustling cities like Vietnam, certain battery-related factors might be critical in their decision-making process.

Refer to Table 3 and Fig. 18, ranking first, the longevity of a battery speaks volumes about the overall durability and value-for-money of an E2W. Consumers appear to prioritise a longer battery lifespan, ensuring they will not frequently invest in costly replacements, offering better long-term savings (Zhu et al., 2019).

Time is another valuable asset, especially in fast-paced urban environments. The amount of time a battery takes to charge directly affects how quickly riders can get back on the road. A previous study also concluded that shorter charging times could significantly boost consumer adoption of electric motorcycles (Guerra, 2019). Moreover, the frequency with which a battery needs recharging affects its convenience. Less frequent recharging saves time and suggests better energy storage capacity, making daily commuting hassle-free.

Charging technology, which had the lowest priority ranking, is fast-growing; however, consumers may feel that advances in this area have reached saturation. Advanced charging technologies have been widely developed and applied, so these factors are not their primary concern.

3.2. Interview results and discussion

3.2.1. Urban traffic compatibility for E2Ws in Vietnam

Vietnam's urban landscape presents a unique blend of challenges and opportunities when considering E2W development. Fig. 19 presents an overview of Vietnam's urban transportation characteristics for E2W from the perspective of 15 experts.

As shown in Fig. 19, 93 % of experts underscore how Vietnam's urban transportation characteristics appear favorable for the adoption of E2Ws. This is attributed to multiple reasons:

Dense urban characteristics: 93 % of the experts expressed that Vietnam's urban roads, predominantly narrow and congested, align with the compactness and agility of E2Ws. This inherent compatibility ensures that E2Ws can manoeuvre through traffic more efficiently than larger vehicles, making them an ideal fit for Vietnam's cityscapes, consistent with other findings (Trinh and Pham, 2019).

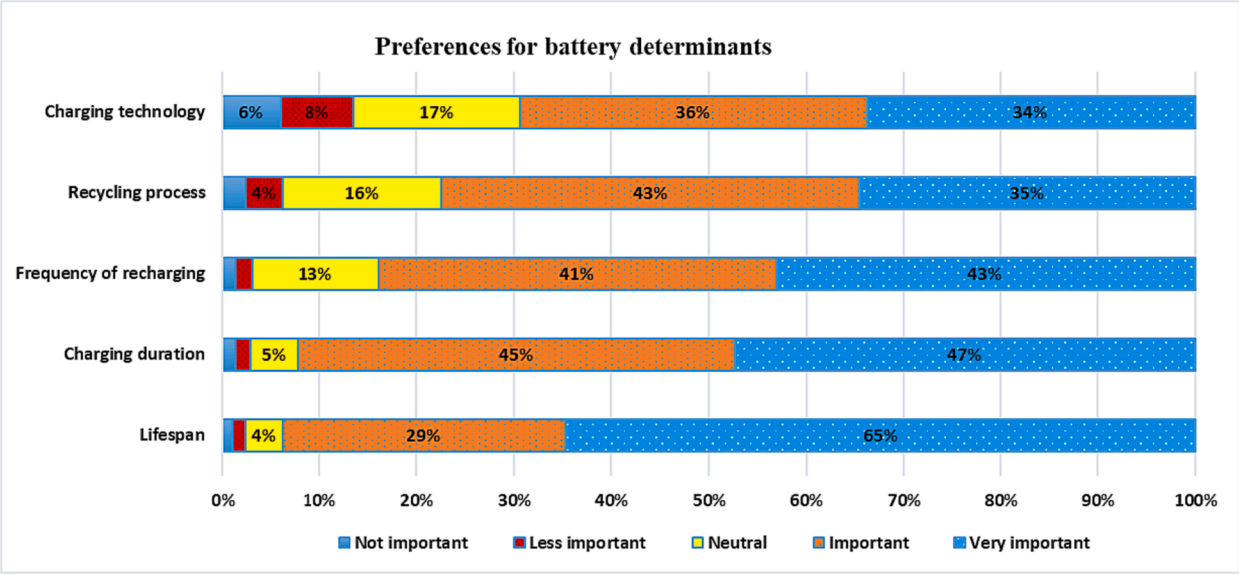

Fig. 18. Preferences for battery determinants.

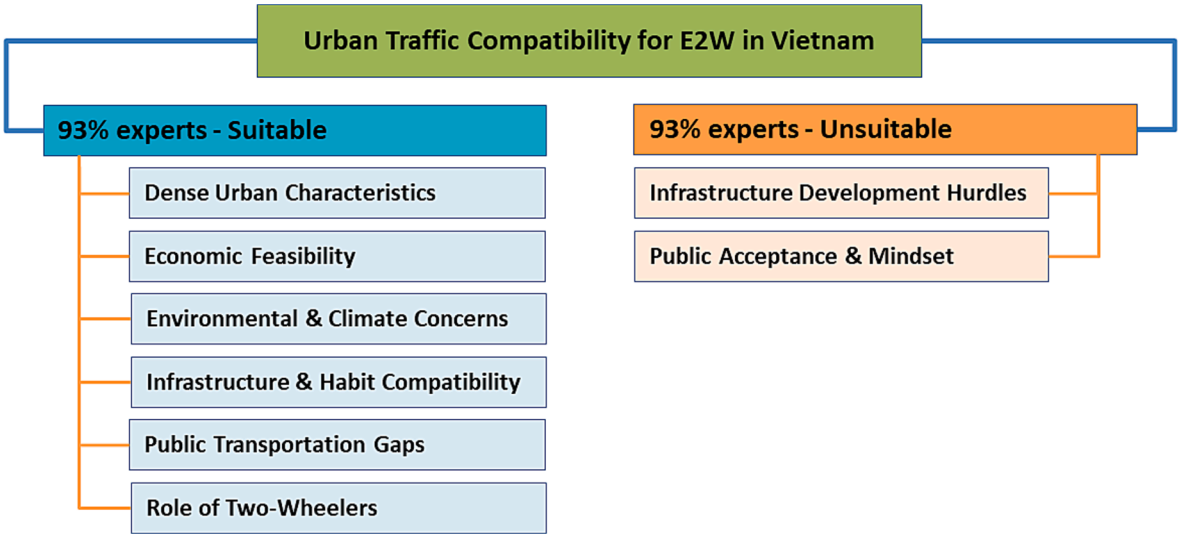

Fig. 19. Urban traffic compatibility for E2Ws in Vietnam.

Economic feasibility: Given Vietnam's economic landscape, where average incomes may not support car ownership of cars for the majority of the population, two wheelers offer an affordable and efficient alternative. One study found that electric cars and hybrids are often too expensive for middle-income residents in developing countries (Gorzelany, 2019).

Environmental needs: The current pollution challenges faced by Vietnamese urban areas can be alleviated, to a degree, by promoting E2Ws that help to reduce increasing greenhouse gas emissions. E2Ws also help to address noise pollution concerns, providing dual environmental benefits.

Infrastructure Compatibility: The cities of Vietnam, defined by their dense living spaces and narrow lanes, are well-suited for the use and storage of 2Ws. Given the compact nature of Vietnamese urban spaces, the limited range of E2Ws is less concerning. This is consistent with a study indicating that the availability of infrastructure is key to reduce range anxiety (Mendoza et al., 2016).

Public transportation gaps: In the absence of an extensive and efficient public transport system in many parts of urban areas in Vietnam as one study mentioned (Huu and Ngoc, 2021), E2Ws can fill the mobility gap by offering a fast, flexible, and efficient mode of transport. Some studies have indicated that E2Ws' popularity might prompt users of public transportation and private cars to change their usual mode of travel (Kroesen, 2017, FAIRLEY, 2010).

Vital role of Two-Wheelers: The cultural and economic significance of two wheelers in Vietnam extends beyond personal transportation. They serve as tools for goods transportation and a source of livelihood for many, emphasising their potential popularity in electric form.

On the other hand, 7 % of experts presented concerns about the not yet unsuitable urban transportation characteristics for E2Ws in Vietnam. This is due to infrastructure development hurdles and public acceptance. While E2Ws present a sustainable solution, challenges arise in the development of charging infrastructure. Its establishment and maintenance could be daunting in certain areas, especially city centre areas where lands are limited. Nevertheless, a study highlighted that E2Ws have the advantage of a removable battery, which can be charged using a standard wall socket at home or the office, eliminating the need for specialized infrastructure (Weiss et al., 2015a). Furthermore, this expert expressed that the success of E2Ws depends significantly on their acceptance by the general public. A segment of the Vietnamese population remains unfamiliar and skeptical about electric vehicles, which can pose challenges to market growth.

3.2.2. *Factors influencing the decision to adopt E2Ws in Vietnam*

Numerous factors influence E2W adoption in Vietnam from expert's perspectives. Fig. 20 visually represents the relative emphasis or frequency of discussion for each factor among the experts, with larger rectangles indicating greater significance.

The following key factors emerged from the study as influential in driving E2W adoption.

Consumer perceptions play a vital role in driving the adoption of E2Ws. Many consumers associate brand image and personal characteristics with their choices. There are concerns regarding the usability of E2Ws for long distances and their perceived prolonged charging times. For some, E2W raises apprehensions about their functionality during rainy seasons and their frequency of charging, as one expert mentioned. Habits established by prolonged use of gasoline vehicles pose challenges for transitioning, one expert noted, underscoring the importance of changing these deeply ingrained habits, another expert added.

From an economic standpoint, the initial purchase cost is often a pivotal factor for consumers, as an expert highlighted in alignment with other studies (Zhu et al., 2019, Jayasingh et al., 2021). E2Ws present competitive pricing and, over the long term, are viewed as being more cost-effective in terms of both purchase and operation, several experts commented. Especially with E2Ws imported from countries like China, there's a noticeable cost advantage, as one expert pointed out. When operational costs are considered, the appeal

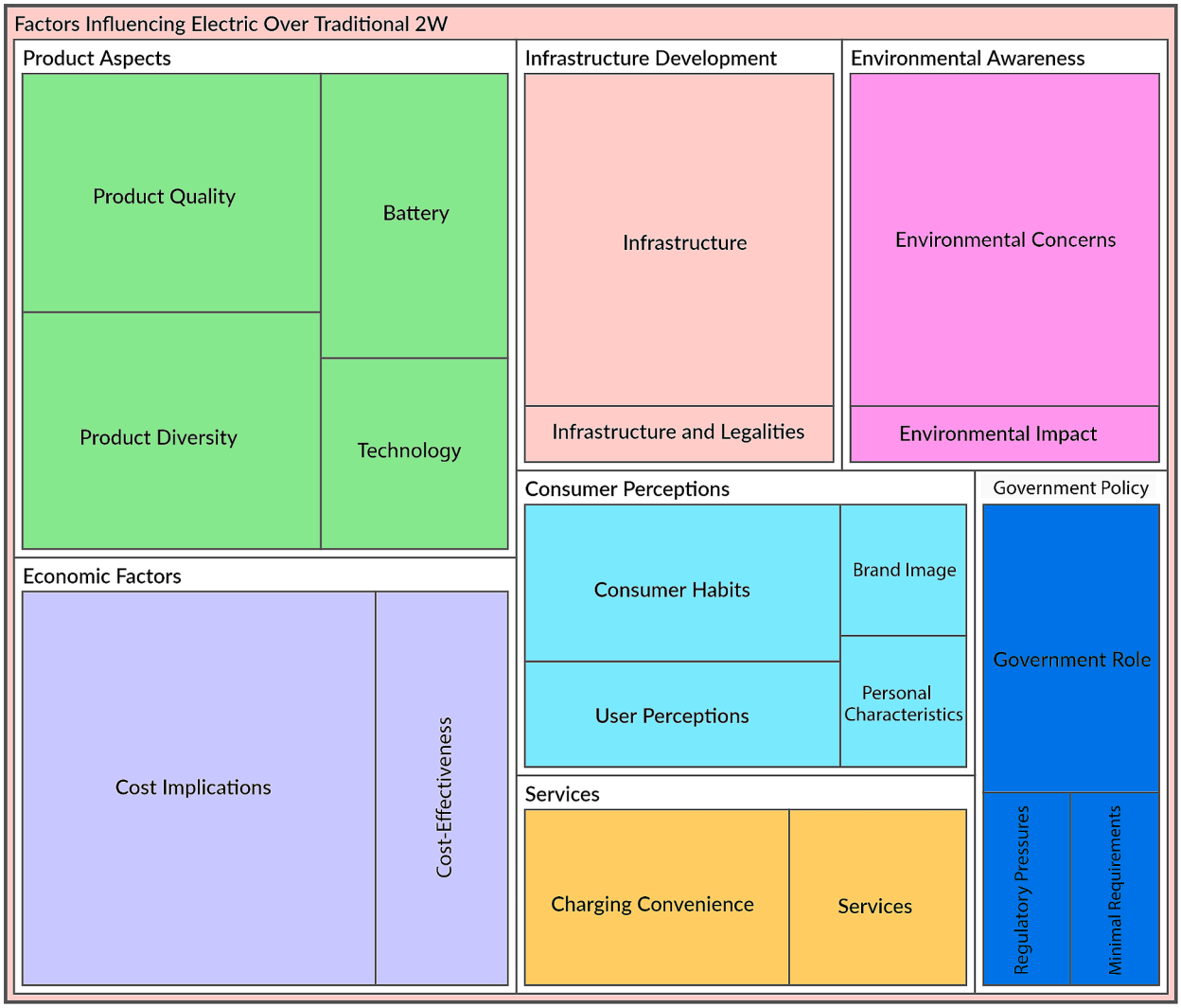

Fig. 20. Factors influencing electric over gasoline two wheelers in Vietnam.

of E2Ws becomes more pronounced due to their lower costs compared to gasoline vehicles, as mentioned by a few experts. This is matched with findings from other studies (Tuayharn et al., 2015, Kerdlap and Gheewala, 2016), and in one typical example in Vietnam, the running cost of E2Ws is eightfold lower than that of larger gasoline motorcycles (Jones et al., 2013).

Growing environmental concerns drive consumer interest in E2Ws due to their potential to reduce emissions. The younger demographic, in particular, appears more environmentally conscious and influenced by the sustainable benefits offered by E2Ws. As the implications of pollution from conventional vehicles become more evident, this factor is anticipated to gain further prominence in decision-making, as mentioned by one expert. This is consolidated by another study, which found that environmental awareness may have a greater impact than conventional tangible factors like speed, cost, and time savings (Bretones and Marquet, 2022).

Government policies can have a profound impact on the adoption rate of E2Ws. Supportive policies, such as incentives, can make E2Ws more appealing and accessible, as a couple of experts opined. Furthermore, policies targeting the reduction of fossil fuel consumption, such as high fuel taxes, can tilt the balance in favour of EVs, according to a few expert views. Another study highlighted that for stable clean vehicle demand, policymakers should prioritize stricter fossil-fuel vehicle regulations (Yang, 2010).

The availability of necessary infrastructure, notably charging stations, is crucial for the widespread adoption of E2Ws, as one expert mentioned, which is aligned with other research findings (Mayer, 2020, Patil and Majumdar, 2022). Though home charging is convenient, the development of public charging infrastructure needs to be expedited to match the growth in E2W users, as suggested by some experts. A more comprehensive infrastructure would mitigate concerns related to charging duration and accessibility, as highlighted by experts.

Quality, durability, and design of the E2Ws and their batteries are vital for user satisfaction. Features such as smartphone integration for monitoring offer added user value, one expert pointed out. The distance an E2W can travel before needing a recharge is a concern for many potential users, as another expert noted, which was also emphasized by other studies (Will et al., 2021).

Contemporary designs and advanced features make E2Ws attractive to a broader audience, according to several experts.

Support services, such as maintenance and battery replacement, provide additional assurance for E2W users, one expert highlighted. The charging process's convenience and affordability are also pivotal in influencing the decision to adopt E2Ws, as a few experts pointed out.

The decision to adopt E2Ws over traditional gasoline-powered vehicles in Vietnam is influenced by a blend of consumer perceptions, economic considerations, environmental awareness, governmental policies, infrastructure development, product attributes, and associated services. These observations align with recent studies conducted in Vietnam (Trinh and Pham, 2019, Hiep et al., 2023, Jones et al., 2013).

The findings from both the consumer survey and expert interviews present complementary perspectives on various determinants influencing E2W adoption. Both sources align on pivotal factors, highlighting a cohesive understanding despite minor differences in perspectives. Infrastructure emerges as a crucial aspect, with emphasis on the need for an expansive charging network in both sets of data. Similarly, economic viability, encompassing purchase cost and long-term operational expenses, stands out prominently, echoed by experts and corroborated by the survey. Environmental concerns, government incentives, battery-related concerns, and consumer perceptions also exhibit consistent alignment across the two datasets. This harmony in insights confirms how many different factors influence E2W adoption, showing how they are all connected and impact consumers' choices. It gives a solid understanding of what drives E2W adoption in Vietnam.

3.2.3. *Barriers to deploying E2Ws in Vietnam*

The interview results indicate that deploying E2Ws in Vietnam faces multifaceted barriers as shown in Fig. 21.

Climate-Related Barriers: Vietnam's geographical characteristics present a genuine challenge for the deployment of E2Ws. One expert highlighted that the nation frequently experiences heavy rains and flooding. Such conditions pose significant threats to E2Ws, making them susceptible to damage and raising safety concerns.

Financial Challenges: The transition to electric mobility is financially intensive. Several experts emphasize the high initial costs, especially for top-quality E2Ws. High factory investment costs further compound this barrier. The overarching sentiment suggests that the relatively high price of reliable E2Ws compared to their gasoline counterparts remains a significant deterrent, as echoed by multiple experts.

Infrastructure Gaps: Infrastructure emerges as a paramount concern. As one expert mentioned, the EV ecosystem's infrastructure, especially charging systems, is still in its infancy. Multiple experts pointed towards the lack of public charging stations. There's a consensus about the inadequacy of the current power infrastructure, with predictions that it will require extensive upgrades to accommodate an increased number of E2Ws. Richardson found out that unrestricted charging of battery EVs can impact the efficiency, capacity, and performance of the electric grid (RICHARDSON, 2013).

Policy and Regulatory Hurdles: Policy barriers feature prominently in the feedback. One expert noted the absence of a clear roadmap from the government, slows the transition from gasoline to E2Ws. Experts also raise concerns about the lack of comprehensive policies and supportive mechanisms like other markets, such as the exemption of registration tax for E2Ws, tax reduction and financial incentives as subsidies (Sierzchula et al., 2014, Zhang et al., 2011). Inconsistencies in battery types and systems are also mentioned as regulatory hurdles. Potential movement restrictions in future city regulations can also be attributed to one of the policy hurdles.

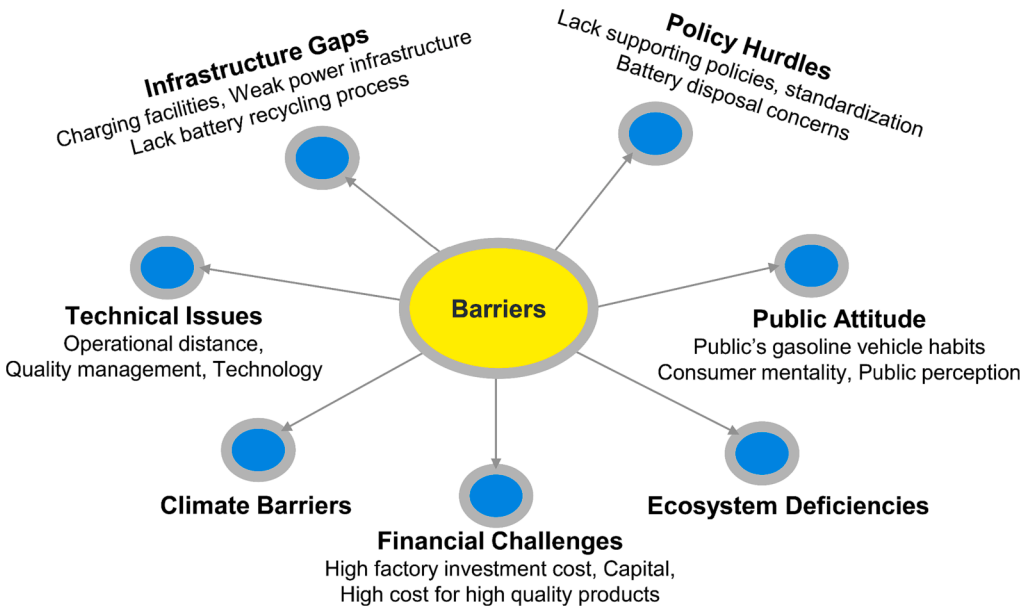

Fig. 21. Barriers to E2W implementation in Vietnam.

Public Attitude and Behaviour: The public's entrenched habits and perceptions serve as significant barriers. The deep-rooted preference for gasoline-powered vehicles complicates the transition to electric alternatives. Misconceptions about E2W performance, range, and battery durability further hamper their acceptance.

Support Ecosystem Deficiencies: A robust support ecosystem is crucial for the growth and maintenance of any new technology. However, Vietnam currently lacks a comprehensive support system for E2Ws. Essential services like repair, maintenance, and customer care are notably missing, as emphasized by one expert.

Technical Issues: The technical aspects of E2Ws, including battery quality and charging duration, also present challenges. One expert pointed out that current models might not be equipped for long-distance travel, while another expert highlighted the influx of inferior quality E2Ws in the market, posing potential safety risks.

3.2.4. Solutions for boosting E2W development under Vietnam's unique conditions

The experts' insights have highlighted several key solutions for encouraging the development of E2Ws in Vietnam as illustrated in Fig. 22, considering the country's unique conditions as a developing nation.

There was a consensus among experts that Vietnam needs to integrate E2W-based technology and knowledge into educational curriculums. Increased public awareness and education on the environmental advantages of E2Ws are paramount. A study underscored the importance of increasing public awareness campaigns to promote the use of electric motorcycles (Murtiningrum et al., 2022).

The price and affordability of E2Ws in Vietnam are pivotal factors. One expert suggested direct incentives to bridge the price gap, aligning with another study indicating the need for subsidies to narrow the price difference between E2Ws and conventional two wheelers (Murtiningrum et al., 2022). Another expert recommended government-backed financial incentive, while a third emphasised the importance of offering financial incentives for those transitioning from traditional bikes.

Most experts stressed the significance of developing charging infrastructure. One expert mentioned the importance of consistent electricity supply, as one study anticipated a significant rise in power demand, increasing battery EV usage (Lopes et al., 2010). Other factors included the need to establish dedicated E2W lanes and increase road quality when broad adoption of E2Ws in developing nations necessitates enhanced traffic safety measures and urban infrastructure adjustments (Weiss et al., 2015a).

Localisation and targeting the right users were emphasised as market solutions, alongside supporting businesses in infrastructure and ecosystem development, understanding and catering to potential E2W users, the need for domestic research and development, cooperation between various sectors, and developing example models like E2W taxis.

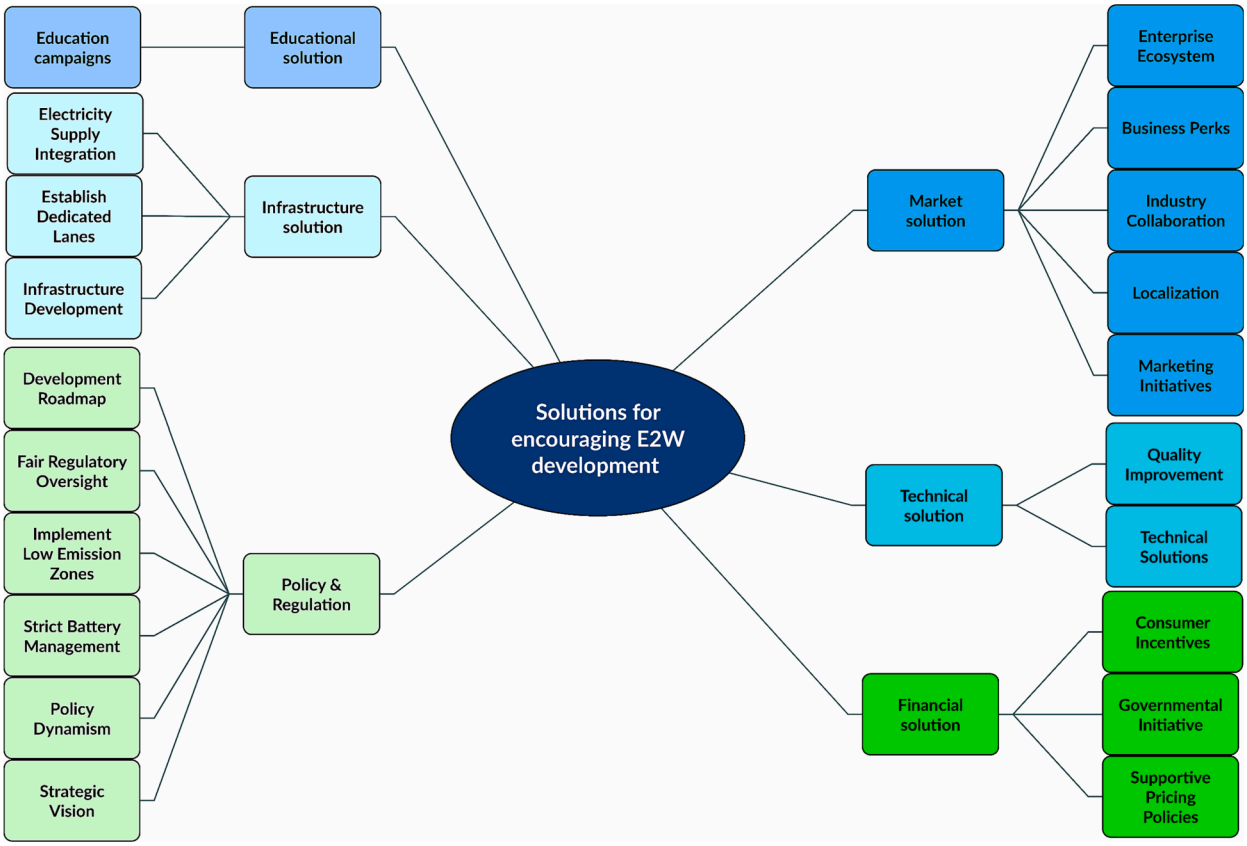

Fig. 22. Solutions for encouraging E2W development to Vietnam's unique conditions.

Many experts felt that the government plays a critical role, highlighting the need for a clear vision, growth objectives, and learning from other countries, such as establishing low-emission zones within cities. These suggestions align with those in other studies, including one conducted in Hamburg (Flämig et al., 2020).

Enhancing E2W features was a recurring theme, including designing models that shift public perceptions, adapting E2Ws to Vietnam's conditions (e.g., regular flooding), establishing technical and safety standards, innovating technical aspects to reduce charging times, enhancing battery life, and reducing pressure on the grid network. For instance, some scientists have believed smart charging can balance the load, negating extra installation capacity needs (Zheng and Jian, 2016, Van Der Kam and van Sark, 2015).

3.2.5. *Government policies and their impacts on E2W adoption*

Under fifteen expert's perspectives, it seems that the responses trend towards the perspective that government policy has had limited influence on the adoption of E2Ws in Vietnam.

In relation to ineffectual policies, several experts pointed towards a discernible lack of effective policies promoting E2Ws. One expert explicitly stated that they have not observed any distinct governmental influence on E2W adoption. This sentiment is echoed by others, noting an absence of efforts to advance EVs within educational systems and the larger society. Another expert underlined the lack of pricing incentives and support for businesses looking to expand the E2W ecosystem. One other expert highlighted that the government has no specific policies for E2Ws, leaving their adoption at the whim of individual consumers and businesses.

While policies may be in place, such as registration fee waivers for EV batteries in the first three years and 50 % fee discounts in the subsequent two years (A. Nguyen and N. Hoang, 2022), most experts expressed that their tangible effects on E2W adoption were modest or minimal. For example, one expert highlighted the limited impact of government policies on increasing the E2W demand among students due to their convenience, flexibility, and affordable price points, while others noted minimal impacts of import taxation policies, with little to no tangible boost in user numbers or domestic manufacturers. Another expert felt that safety-related regulations related to batteries and charging have made consumers hesitant despite policies like fuel emission taxes increasing the cost of gasoline bikes. Thus, while some policies may push for E2W adoption, others inadvertently discourage it. Indeed, the policy aiming for 100 % clean energy vehicles by 2050 seems to have a tangible influence on the E2W market, affecting suppliers and users alike. However, one expert noted that the limited numbers of E2Ws on Vietnamese roads indicate that the effects of these policies are still evolving.

3.2.6. *Approaches to fostering E2W adoption*

The experts provide a multifaceted approach to fostering E2W adoption in Vietnam. The future of E2Ws in Vietnam seems promising but requires a balanced approach that addresses the advantages and concerns.

Refer to Fig. 23, 87 % of the experts encoura–ged E2W adoption based on the following:

Awareness & Education: The experts emphasise the need for increased public awareness of the benefits of E2Ws, including intensifying media campaigns, promoting environmental benefits, and disseminating information on government policies. Most believe that reshaping public perceptions through educational campaigns can significantly influence adoption. One study underscored that increased sustainability awareness boosts the likelihood of purchasing electric vehicles (Egbue and Long, 2012).

Cost & Pricing: Affordability is a major determinant of E2W adoption. Experts advocate for reducing initial purchase, operational, and maintenance costs to incentivise consumers. Offering financial mechanisms and support can help motivate potential buyers, making E2Ws financially competitive with gasoline bikes.

Policy & Regulation: Transparent government policies are crucial in steering public inclination towards E2Ws. Suggestions include implementing annual emissions testing, reducing taxes for locally-made vehicles, and offering policies that make E2Ws more affordable.

Quality & Safety: Ensuring E2W safety and reliability is essential for attracting a wider user base. Experts highlight the importance

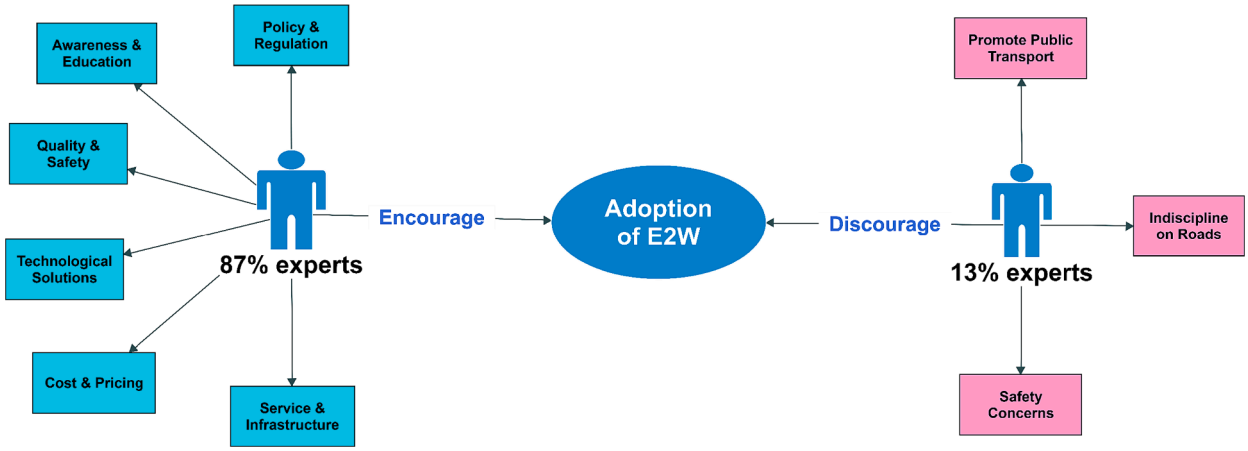

Fig. 23. Broad views of experts on E2W adoption.

of elevating the overall quality of E2Ws, building trust in their safety, and addressing potential risks.

Service & Infrastructure: Infrastructure development and related services are critical determinants of E2W adoption. Suggestions include developing smart charging networks, strategically placing charging stations, and integrating E2Ws into delivery and ride-hailing services. A thriving market for electric charging stations is seen as instrumental.

Technological Solutions: Many experts stressed the role of technology in promoting E2W adoption. Research and development to enhance functionality, advanced battery features, and structured management solutions can collectively promote E2W adoption.

While the majority are pro-adoption, 13 % of experts raised concerns. First, there are safety concerns. Concerns were raised about the safety of E2W, especially in the context of Vietnam's unique challenges. Issues like frequent flooding making two wheelers unsafe and the silent nature of electric vehicles making them less noticeable to other road users were highlighted. Some researchers argue that quiet motors elevate the risk of accidents (Oliver and Rosen, 2010, Stelling-Kończak et al., 2015). There were also worries about the potential for quick acceleration leading to accidents. Second, it is discipline on roads. The current use of the habits of 2Ws, irrespective of being electric, can lead to indiscipline on roads. A stricter regulatory framework is deemed essential to address this issue. Derived from these concerns, 13 % of experts felt that the government should prioritise promoting public transportation over E2Ws, including electric public transportation. This alternative viewpoint sees public transportation as a more organised approach to managing Vietnam's transportation needs.

4. Conclusion and recommendations

Urban centers in developing countries, much like Hanoi and Ho Chi Minh City, often grapple with severe congestion and pollution. E2Ws present a viable solution, offering environmental benefits, cost-effectiveness, and suitability for crowded city landscapes. However, the path to widespread adoption of E2Ws is fraught with obstacles, including inadequate infrastructure, financial constraints, public perception issues, and regulatory challenges. Tackling these requires a comprehensive strategy that considers technological, infrastructural, societal, and behavioral factors.

The methodology and findings of studies conducted in Vietnam can offer invaluable guidance for other developing nations looking to promote E2Ws as a sustainable transport alternative. The approach should be adaptable to local contexts, acknowledging that factors like socio-economic backgrounds can influence the importance of certain aspects. By customizing survey tools and methodologies, these studies can provide a framework not only for developing cities but also for any urban area globally aiming to encourage E2W adoption. This approach underscores the need for flexible, context-sensitive strategies in the global effort to transition towards more sustainable and efficient transportation systems.

5. Recommendation and policy implications

Based on the insights derived from the research, several policy recommendations are proposed to facilitate the effective integration of E2Ws into Vietnam's transportation landscape.

Government-Led Roadmap: The Vietnamese government should develop a clear roadmap for E2W adoption, drawing inspiration from countries with successful E2W integration. This roadmap should define roles for all stakeholders, including manufacturers, suppliers, consumers and regulatory bodies, and provide strategic direction for the industry.

To bridge the cost gap between traditional motorcycles and E2Ws, the government can offer direct financial incentives such as reduced taxes on locally-produced E2Ws, subsidies, and grants to make E2Ws more affordable to the public.

Infrastructure Development: A robust and widespread charging network is crucial for E2W adoption. The government should strategically place charging stations in public areas, commercial hubs and transportation nodes to ensure convenient access.

Public Awareness Campaigns: A nationwide public awareness campaign can educate the public about the environmental and financial benefits of E2Ws, reshaping public perceptions and driving adoption. Policy makers should run an awareness campaign for E2W riders.

Safety and Reliability Enhancement: Continuous investment in research and development is necessary to improve E2W battery life, safety features, and overall reliability. Special attention should be given to addressing unique challenges of Vietnam, like heavy rainfall.

Promote Local Manufacturing: Supporting local businesses in producing E2W components can reduce costs. Tax incentives, financial support, and infrastructural assistance can foster a thriving local E2W manufacturing ecosystem. Government should consider financial incentives to promote E2W.

Integration into Service Industries: E2Ws can be integrated into various service sectors, such as delivery services, ride-hailing platforms, and rental systems. This can increase demand and position E2Ws as viable transportation alternatives in urban centres.

Regulatory Revisions: Proactive regulatory adjustments are needed to accommodate the E2W surge, including updating licensing norms and setting safety standards.

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CRediT authorship contribution statement

Nguyen Thanh Trung: Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Tania Urmee:** Writing – review & editing, Supervision, Resources, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trd.2024.104116.

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