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# Assessment of Electric Two-Wheelers Development in Establishing a National E-Mobility Roadmap to Promote Sustainable Transport in Vietnam

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**Abstract:** Faced with increasing environmental pollution due to traffic concentration in big cities, Vietnam, as well as many countries worldwide, has encouraged its people to use environmentally-friendly vehicles. Because the transport mode is dominated by two-wheelers (i.e., motorcycles and mopeds) (2Ws), electrifying 2Ws has the potential for significant air pollution reductions as an alternative to gasoline-powered vehicles in Vietnam. Therefore, there has recently been an increasing trend of shifting from traditional gasoline two-wheeler vehicles to electric two-wheelers (E2Ws). Depending on different local contexts, some countries/regions quickly adopted the policies/incentives, and new technologies for E2W usage, while others acted more slowly. In order to advance the use of E2Ws in Vietnam, assessing E2W user preferences is essential to classify and prioritize further solutions, which would be instrumental in fulfilling user expectations. However, a few academic works pay attention to this field of the Vietnamese E2W market. In response to this research gap, this paper aims to overview the current status of E2W usage, assess the market development of E2Ws, and evaluate the battery charging business models in Vietnam. The questionnaire survey was carried out to evaluate the preferences of E2W users in the Vietnamese market, while the assessment of E2W development was conducted based on the SWOT (strengths, weaknesses, opportunities, and threats) analysis. The results demonstrated that E2W deployment is still at an exploratory stage in the transportation industry and is growing significantly in Vietnam. This study also revealed significant challenges for E2W adoption, especially the E2W battery charging/swapping system. Thus, it is recommended that incentives for E2W uptake and the battery charging infrastructure system should be improved and implemented. The evaluation of E2W perceptions in the three-city context is realized as exploratory, generating the baseline for further research when the survey can engage more respondents in other places to confirm the current research findings. The study can also assist policymakers and investors in comprehensively assessing the opportunities and challenges and provide recommendations for accelerating the growth of E2Ws in Vietnam for establishing a national e-mobility roadmap and thereby promoting sustainable transport in alignment with the COP26.

**Keywords:** e-mobility; electric vehicles; electric two-wheelers; battery charging; battery swapping; Vietnam



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## 1. Introduction

Cities worldwide are grappling with the challenge of improving the sustainability of their transportation systems which have developed to be heavily dependent on private motor vehicles. Those same cities face the added challenge of catering to the mobility needs of an ageing population, many of whom have become accustomed to the independent mobility provided by the car. Beyond the mobility needs of that older cohort, there are added

issues of health and well-being for which maintenance of physical activity is increasingly seen as critical importance. Vietnam has about 3.25 million private cars and 52 million motorbikes registered. The average number of private vehicles is 35 cars/1000 people and 565 motorcycles/1000 people [1]. From 2014 to 2018, the growth rates of cars and motorbikes, and mopeds annually were 13.7% and 9%, respectively. About 300,000 new cars and more than 3 million new motorcycles are registered annually. Public transport only meets 10% of the mobility needs of people in Hanoi and Ho Chi Minh City (HCMC)—the two largest cities in Vietnam. Personal vehicles, especially motorcycles, still play the most important, popular, and convenient role for urban residents [2]. Motorcycles account for 80–90% of the total number of trips. In fact, there are 6.6 million vehicles in Hanoi, of which the number of motorcycles accounts for 5.7 million [3]. In addition, about 1.2 million vehicles from other cities participate in the city's traffic. Meanwhile, in 2019 HCMC had nearly 7.9 million vehicles, of which there were more than 730 thousand cars and 7.15 million motorcycles [4]. The above facts show that Vietnam depends significantly on motorcycles [5,6]. Consequently, motorcycles are still the main vehicle type in Vietnam and are a fundamental mode of transportation with a significant environmental impact [7]. Motorcycles contribute a substantial share of air pollution due to sheer numbers and relatively high emission rates compared with automobiles.

In this context, electric vehicles (EVs) can reduce $CO_2$ emissions as electricity can be produced from renewable energy sources [8]. In this sense, EVs have become a cleaner alternative to gasoline-powered vehicles, particularly motorcycles in the transport sector. Electric motorcycles are similar to gasoline-powered but have zero local tailpipe emissions and operate solely on battery power [9]. Hence, electric motorcycles offer potential air pollution reductions and energy efficiency and can be a strategy to improve the environmental performance of the transportation sector [10,11]. The two-wheeler types most commonly used in Vietnam include bicycles and gasoline-powered motorcycles. According to the Vietnamese government, electric two-wheelers (E2Ws), including electric bicycles and motorcycles, are distinguished by speed, weight, and motor power. The electric bicycle is a two-wheeled bicycle operated by the pedal structure with assistance from a direct current motor, having the largest motor power of no greater than 250 W and a maximum designed speed of no more than 25 km/h. The weight (including the battery) is no greater than 40 kg. The electric motorcycles are equipped with an electric motor that is required to have a maximum speed of no greater than 50 km/h, a maximum engine capacity of no greater than 4 kW, and a vehicle weight of up to 118 kg.

Air pollution induced by vehicle emissions, mainly motorcycles, in major cities in Vietnam is one of the biggest concerns for government actions. In Hanoi and HCMC, the real-time air quality index in 2019 reached severe pollution (i.e., a "fairly polluted" level) [3]. The increase in personal vehicles using internal combustion engines with uncontrolled emissions makes the air polluted. To improve air quality, it is necessary to simultaneously implement many solutions, of which the critical factor is to minimize vehicle emissions. Accordingly, Vietnam submitted its updated nationally determined contribution (NDC) in September 2020 and is among the 20 earliest countries to submit it to the Secretariat of the UNFCCC. Wherein the GHG emission reductions are increased by 9% compared to the BAU scenarios in the case of unconditional contribution and by 27% with international support according to the new mechanisms under the Paris Agreement by 2030, compared to 2014. Moreover, to align with the 26th United Nations Climate Change Conference hosted by the United Kingdom from 31 October to 13 November 2021 (COP26), Vietnam committed to reaching the net-zero emission target by 2050. Accordingly, to achieve those goals, one of five mitigation action groups in the transport sector that NDC committed to implementing is shifting from conventional fuels to biofuel, natural gas, and especially electricity. Because of incomplete public transport systems and infrastructure, replacing motorcycles or limiting using motorcycles is challenging to implement. Due to the operational similarities between the motorized two-wheelers (M2W) and E2W, and the high rate of M2W owners, conventional M2W users can be considered prospective E2W users. Therefore, transitioning

from gasoline vehicles to E2Ws is an indispensable trend in big cities dealing with the increasing environmental pollution due to traffic concentration in Vietnam [12]. There is a growing trend for shifting from gasoline motorcycles to electric two-wheelers (E2Ws); therefore, the E2W market will almost certainly be developed and expanded.

Over the last decade, academic efforts have grown in the field of E2Ws, with numerous research analysing user perception of the main motivations and/or barriers to purchase [13]. Literature showed that understanding user perceptions is an essential input for decision-making in promoting and improving the performance of E2Ws [14]. One of the primary motivators for choosing a specific mode when purchasing the product depends on its importance in its usage. Therefore, evaluating E2W attributes from the current user preferences is necessary to identify and prioritize further solutions, which would be instrumental in fulfilling user expectations. According to Ottesen et al., drivers in Kuwait would prefer EW, especially E2Ws, over gasoline vehicles in the future for their environmental, economic, and technological benefits [15]. Moreover, Huang and Ge analysed the consumer EV purchase intention in China and showed that the EV adoption rate mainly depends on gender, age, education level, income, and ownership of cars [16]. The existing research findings believe that government plays a fundamental role in encouraging the popularity of E2Ws by providing efficient infrastructure systems and incentives [15,17]. Literature also suggested that transport planners and local planning bodies could use the prioritized E2W attributes to identify the primary operational, functional, and infrastructure-specific interventions required for projecting E2W as an attractive alternative to the users.

Promoting the penetration of E2Ws in Vietnam necessitates that both governments and private companies take into account E2W's attributes, especially user preferences. However, little attention has been paid to understanding the user perception and market assessment of E2W in Vietnam. Huu and Ngoc's research examined the current road traffic in major Vietnamese cities and thereby showed some potential for transitioning from gasoline-powered motor to electric two-wheeler mobility [12]. Furthermore, few academic efforts analysed the barriers and drivers to adopt EVs specified in some cities in Vietnam [3,6,18]. In response to this research gap, this study has attempted to evaluate the market potential of E2W usage in Vietnam. The specific objectives are as follows: (1) to analyze the current status of E2W development; (2) to assess the E2W usage market, and (3) to investigate the E2W battery swapping business models in Vietnam. It should be noted that this study focused on the E2W instead of EVs in general. As mentioned above, two-wheeled vehicles, especially motorcycles, are among the preferred modes of transport in Vietnam. As a result, electrifying two-wheel vehicles is a potential alternative to mitigating GHG emissions and air pollution in Vietnam.

The structure of this paper is as follows. Initially, the current E2W development in Vietnam is reviewed. The methods employed in this study, including the questionnaire survey and the strengths, weaknesses, opportunities, and threats (SWOT) approach, are then introduced. The following section presents and discusses the results in terms of the market assessment for E2W, the battery charging service, directions of E2W battery charging and swapping service, and the e-mobility roadmap. Finally, the conclusions, the benefits of this research, and an outline for future research are presented.

## 2. Literature Review

The literature review provides a solid foundation for developing the knowledge base in a particular research area by consolidating and analysing previous related studies [19]. The lessons learned from developed countries like the USA and China demonstrate that their governments have strong policies supporting zero emissions, tax, and incentives to develop the E2W and corresponding charging infrastructure [20]. Therefore, in order to stimulate the E2W application, it is necessary to review the current status of E2W development in terms of the institutional framework, legal framework, and E2W market in Vietnam.

### *2.1. Institutional Framework*

The E2W stakeholders map is described in Figure 1. These key stakeholders are divided into three main functions as follows. Firstly, relevant ministries (e.g., Ministry of Transport, Ministry of Finance, Ministry of Industry and Trade, Ministry of Planning and Investment, Ministry of Science and Technology) are responsible for establishing the national policy framework on incentives for E2W adoption, regulating standards, and renewable energy promotion. Secondly, local authorities facilitate the support at the province/city level (e.g., Department of Transport, Department of Industry and Trade, Electricity company, etc.). Lastly, operators, manufacturers, donors, and academia can make efforts to advance E2W adoption. The responsibilities of these critical stakeholders were specified regarding E2W manufacture, operation, and management—including charging/swapping station infrastructure and service.

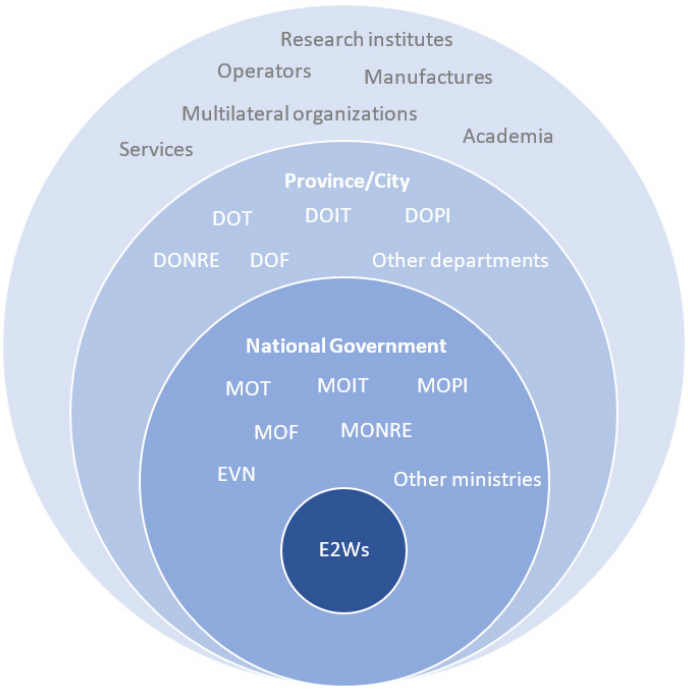


**Figure 1.** E2W stakeholders map. Note: MOT = Ministry of Transport, MOIT = Ministry of Industry and Trade, MOPI = Ministry of Planning and Investment, MOF = Ministry of Finance, MONRE = Ministry of Natural Resources and Environment, EVN = Vietnam Electricity, DOT = Department of Transport, DOIT = Department of Industry and Trade, DOPI = Department of Planning and Investment, DOF = Department of Finance, DONRE = Department of Natural Resources and Environment.

### *2.2. Legal Framework for E2W Adoption*

The legal framework is essential in supporting the transition from conventional to sustainable technologies in the transportation industry, especially E2Ws [21]. Questions on sustainable development were related to compliance with the legal framework and enforcement, adoption of sustainable construction standards, guidelines or policies, sustainable design, people and organizational structure, and sustainable measurement and reporting [22]. Consequently, to drive future and recent developments in the direction of change triggered by E2Ws, existing legal instruments must be reformulated and strategically deployed to achieve all necessary goals as and when due. The legal framework for E2W was generally reviewed at the national level, e.g., National Determined Contributions (NDCs), Greenhouse Gas Emission Management Plan, United Nations Framework Convention on Climate Change, Vietnam Green Growth Strategy, Energy Efficiency and Conservation, Renewable Energy Development Strategy, National Automobile Industry Development Strategy, and National Automobile Industry Development Plan. In addition,

the legal framework at the city level was reviewed to identify the institutional settings and collaborations between stakeholders (i.e., government organizations, local authorities, and relevant enterprises).

Based on the commitment at the 2021 United Nations Climate Change Conference (COP26), the Vietnam government established tangible actions against climate change, notably reducing $CO_2$ emissions. In its updated Nationally Determined Contribution (NDC) submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in September 2020, Vietnam unconditionally committed to reducing greenhouse gas (GHG) emissions by 9% by 2030 below Business as Usual (BAU) levels, while targeting a conditional 27% reduction in emissions below BAU levels based on international support. Previously, Vietnam's Prime Minister promulgated Decision No.1775/QD-TTg of 21 November 2012, on the Greenhouse Gas Emission Management Plan to implement the UNFCCC, which targeted reducing greenhouse gas emissions in energy and transportation sectors by 8% compared to the 2005 base year. In 2014, the Prime Minister approved the National Automobile Industry Development Strategy by 2025 and vision to 2035. National Automobile Industry Development Plan by 2020 and vision to 2030 (respectively by Decision No. 1168/QĐ-TTg dated 16 July 2014 and Decision No.1211/QĐ-TTg dated 24 July 2014) decided to encourage investing and producing eco-friendly vehicles (i.e., hybrid vehicles, electric vehicles). However, the legal framework lacks a comprehensive EV development strategy, and minimal specific EV policies, incentives, and targets are in place. In particular, detailed national policies that encourage the manufacturing, purchasing, and use of EVs are minimal. This fact is challenging in promoting market growth of E2Ws in Vietnam.

The state management agencies do not have comprehensive strategies and specific mechanisms/policies to facilitate the development of E2W vehicles. However, international organizations (e.g., World Bank, UNDP, ADB, and GIZ) support relevant ministries in establishing mechanisms and policies and developing a national EVs roadmap. Hanoi City People's Council (PC) issued Resolution No.04/2017/NQ-HDND on approving the project "Strengthening the management of road vehicles in order to reduce traffic congestion and environmental pollution in Hanoi in the period of 2017–2020 with a vision to 2030". Da Nang City People's Committee (CPC) is considering a pilot project on building electric vehicle battery charging stations in Da Nang. The typical activities related to policies/legislation for E2Ws in Vietnam are illustrated in Appendix A.

The lack of regulations and technical standards cannot force and guide the related stakeholders, such as users, and business organizations, to promote the adoption of E2Ws in the Vietnamese market. Therefore, the Vietnamese Government is currently considering supportive regulations and laws at national and city levels for the operation and development of EVs, as summarized in Appendix B. In the new Decree 57/2020/NĐ-CP dated 25 May 2020, the manufacturers producing electric and hybrid vehicles that need imported spare parts and accessories can be supported by 0% of import tariffs. In terms of national standards for the operation of EVs, there only exist standards for low-speed EVs used mainly by students under 18 years old. However, regulations for 4-wheeler electric vehicles (i.e., Circular 86/2014/TT-BGTVT) have not been promulgated, which would be a big challenge for developing EVs in the short term. The local government also has additional policies to support the adoption of E2Ws. Notably, in order to achieve Environmental City in 2020, Da Nang promulgated an environment city plan, introducing the first EV parking/EV charging station with a grid-tied solar rooftop system in cooperation with the Electricity of Vietnam's Central Power Corporation in November 2017. The regulations for specifications and operation of electric bicycles and e-mobility devices include the following: QCVN 68:2013/BGTVT/SĐ1—National Technical Standard on Electric Bicycles; QCVN 76:2014/BGTVT—National Technical Standard of Battery used for Electric Bicycles; TCVN 11918:2017—Electrical Systems for Personal E-Mobility Devices; and TCVN 12241-3:2018—Secondary Lithium-ion Cells for the Propulsion of Electric Road Vehicles.

### *2.3. Current Status of the E2W Market*

By 2015, Vietnam's electric bicycles in use had grown to an estimated 2.5 million units, and that for cars is over 1000 electric cars with an increasing number of users [23]. The annual sale number of E2Ws is about 250,000–300,000 units. In 2016, Vietnam reportedly spent nearly US $500,000 on purchasing EVs from overseas markets, including Japan, China, and the United States. A survey conducted by the Vietnam Association of Motorcycle Manufacturers (VAMM) showed that the total sale of electric motorbikes and electric bicycles reached nearly 500,000 in 2017, an increase of 30% compared to 2016 and estimated at 40% in 2018. Moreover, the market notably recorded a significant change from electric bicycles to electric motorcycles. In 5 years, from 2014 to 2019, registered electric motorcycles jumped from 18% in 2014 to nearly 80% in 2019 out of the total registered electric vehicles. While electric bicycles decreased from 80% in 2014 to 18% in 2019. However, the annually registered E2Ws have taken less than 10% of the total registered two-wheeler vehicles in recent years. According to Jones et al. [6], given advanced e-scooter technology and tax incentives, the share of E2Ws can reach over 40% of the total motorcycle market in Vietnam.

EVs, including E2Ws and electric cars, were imported to Vietnam under regulations for Decree 116/2017/ND-CP dated 17 October 2017. EVs shipped to Vietnam are subject to special consumption tax rates of 15–70%, thus resulting in price uplifts of 15–20%. This partly explains the recent decrease in the number of imported electric vehicles but an increase in domestically produced and assembled electric vehicles. Electric bicycles equipped with traditional batteries have been shown to have more defects, such as short range, heavy weight, malfunctions, and expensive replacement parts. Battery-powered electric vehicles are therefore being targeted by consumers as a better choice for this type of vehicle. In 2014, many imported electric bicycle models were introduced in Vietnam. It should be noted that with the trend of increasing fossil fuel prices, electric bicycle development has become more financially sustainable.

Many foreign electric bicycle enterprises have been promoting their market share expansion in Vietnam. In 2015, about two million E2Ws were used, of which 70% were electric scooters and 30% were electric bicycles, as reported by the National Traffic Safety Committee (NTSC). From 2015 to 2019, the E2Ws market rapidly grew (from 15 to 30%). Although the 2W market declined significantly, the sale of E2W increased notably, rising from 5.4% of the 2W market in 20,196 to 8.5% in 2020, and reaching 10% in 2021 [24]. However, the number of electric motorcycles is still tiny compared to the total number. In the following years, from 2022 to 2030, E2Ws are forecasted to continue to grow strongly (from 10 to 16%), as presented in Figure 2. Although motorcycles play a leading role as a means of transportation, the growth rate of gasoline motorcycles (i.e., only 2% to 4%) is much lower than that of E2Ws in Vietnam [25].

The increasing demand for E2Ws has also led to an increase in the number of manufacturers. There are more than 70 manufacturers of E2Ws across the country. E2W production is estimated at 400,000 units/year; electric bicycles account for about 30% [26]. The market for E2Ws is increasingly competitive and diversified in designs, colors, and brands. Users have had a more positive perception and attitude toward E2Ws, with the most emphasis on safety, followed by vehicle size, while less important are style and speed [26]. However, E2Ws have low-quality technical aspects, such as using batteries with a short distance, only 50 ÷ 60 km running per charging cycle. Locally assembly plants cannot produce E2W vital parts, such as electric motors and electronic control elements. Locally assembled electric motorcycles have not attracted customers. Some of the reasons can be attributed to the slow development of E2Ws in Vietnam. Mechanisms and policies to encourage investment in E2Ws are still limited and unclear to attract investors. The domestic automobile assembly factories are not ready to renovate technological chains. Finally, there is no roadmap for development, planning, and investment in E2W infrastructure.

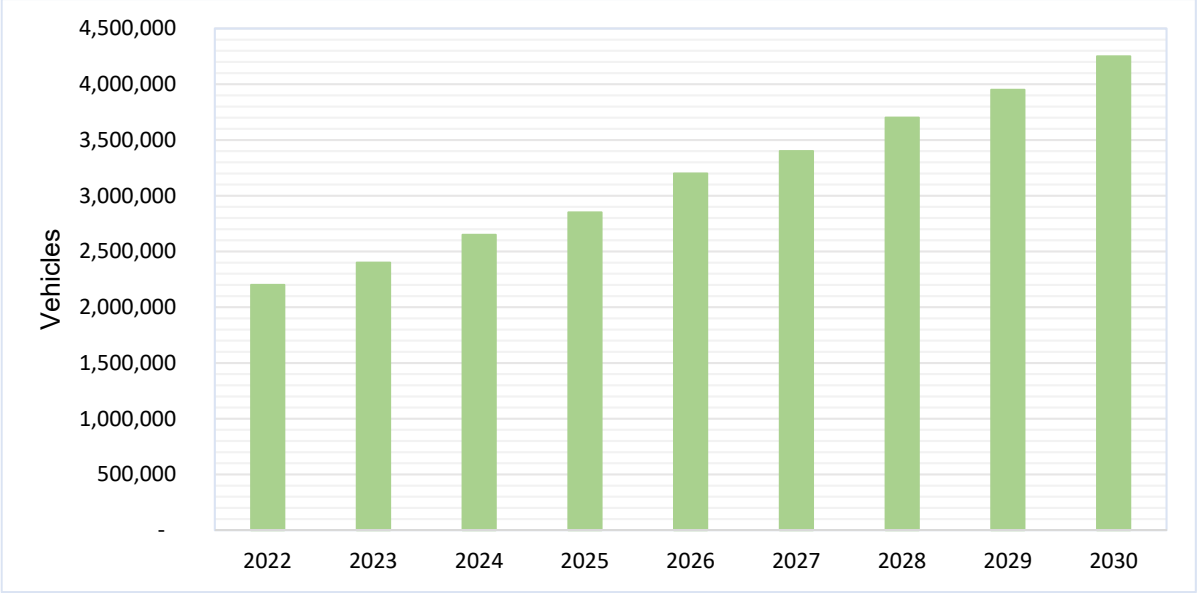


**Figure 2.** Growth forecast of E2Ws from 2022–2030 [25].

The facts above demonstrate that governments at different levels in Vietnam are now paying much more attention to E2W vehicles through several critical policies related to sustainable energy with four main pillars (i.e., energy efficiency, renewable energy, energy market, and climate change). In consistent with this direction, some countries, e.g., China, the United States, Japan, Germany, and France, implemented effective policies and regulations for promoting E2Ws [9,27]. In 2013, India launched the National Electric Mobility Mission Plan (NEMMP), joined with the clean energy ministerial EV initiative. Under this plan, heavy industries developed a Faster Adoption and Manufacturing of Hybrid and Electric Vehicle (FAME) strategy, implemented Phase-I in 2015 and Phase-II in 2019 to create and promote EV adoption to reach 30 percent EV penetration by 2030. Even after tremendous efforts from the central and state governments in India, the E2W market is still not established; mainly, there is a gap between E2W manufacturers, government policy, and prospective E2W users. Therefore, implementing related incentives/policies to stimulate the E2W penetration in the electric vehicle market in Vietnam is an urgent need. In response, evaluating the current E2W market is one of the fundamental steps to provide policy/decision-makers, researchers, and practitioners with a better understanding of E2W.

## 3. Methodology

The assessment of E2W usage market was conducted based on a user perception survey in major Vietnamese cities. The strengths, weaknesses, opportunities, and threats (SWOT) approach was also utilized to assess internal and external factors, as well as potentials for developing E2W business development, notably the E2W battery charging systems.

### *3.1. Questionnaire Survey*

The questionnaire survey, a systematic method for gathering data based on a sample method, has been commonly carried out in construction management research [28]. For this research, the survey aims to collect the primary data to understand customer awareness and preference, including E2W users, non-E2W users, and delivery staff in terms of electric vehicle usage in Vietnam. Apart from two-wheel vehicle usage, as mentioned in existing research, the current paper considered the preference of delivery staff who mainly use motorcycles for their working purposes. Ideas can be figured out according to the expectation of delivery staff and their working context. This analysis also identified barriers and challenges to widespread E2Ws. The main output from this survey also can provide

an assessment of the likely dominant future pathway for the E2W charging strategies (Figure 3).

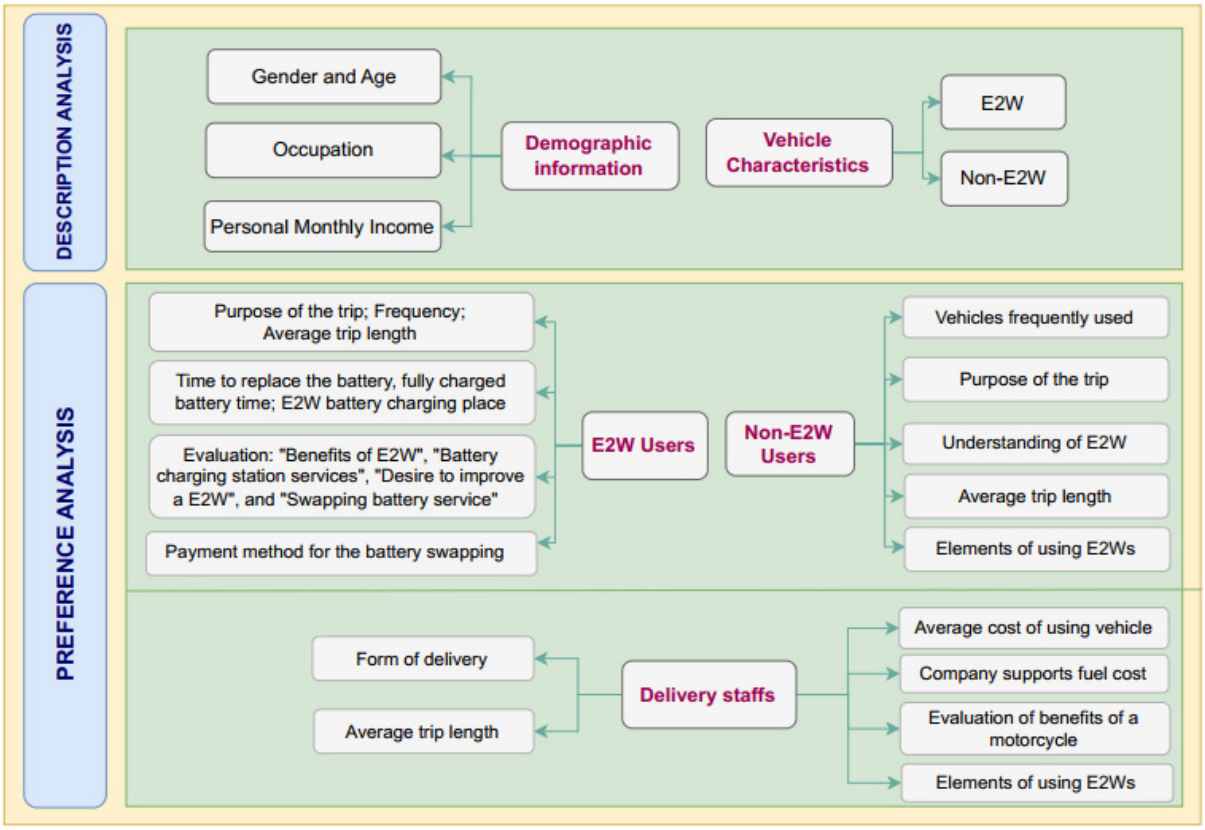


**Figure 3.** Framework for making questionnaire analysis.

The questionnaire was first produced in Vietnamese to collect data from local respondents. In complying with different transport mode users, two questionnaires were made in this study for (1) E2W and non-E2W users, and (2) delivery staff. Each questionnaire has two main sections. The first section consists of general information (e.g., gender, age, occupation, personal monthly income, and type of E2W). The second section includes questions regarding how interviewees perceive E2Ws according to the various subjects. Before the large-scale distribution, the initial version of the survey questionnaire was reviewed and piloted by customers who were E2W or non-E2W users in Hanoi City. The questionnaire content was updated and refined through valuable feedback from the pilot survey. For example, we separated questions into distinctive sections for E2W and non-E2W users. We also added some attributes associated with the benefits of E2W and the necessary solutions for promoting E2W usage in Vietnam. In the A-15 question (i.e., evaluate the following comments on the desire to improve an electric two-wheeler vehicle), we included two improvements, i.e., (1) Vehicle appearance, more fashion, and (2) More incentive programs.

The questionnaire contains demographic information and user perception: benefits of E2Ws, intention to buy E2W, E2W policies, potential criteria promoting E2W purchases, charging options, and charging locations. A Likert scale is applied from strongly disagree (scale 1) to strongly agree (scale 5) and extremely unlikely (scale 1) to extremely likely (scale 5). For customers who currently owe E2Ws, the focus is given to their user comfort and driver experience. In terms of non-E2W users, the level of understanding of E2Ws was evaluated using a Likert scale varying from very positive (scale 1) to very negative (scale 5).

The surveys were conducted in three cities (i.e., Hanoi, Da Nang, and HCMC) in October 2022. According to the administrative structures in Vietnam, Hanoi, Da Nang, and HCMC are the highest-ranking cities, called "centrally managed municipalities". Hanoi,

Da Nang, and HCMC represent a macro-region of the country, i.e., Northern Vietnam, Central Vietnam, and Southern Vietnam, respectively. These three-selected cities joined the Smart Cities Network of the Association of Southeast Asian Nations, aiming to use new technologies for smart and sustainable urban development, such as electric vehicles. Thus, analysing this three-city context can provide the comprehensiveness of the E2W market in Vietnam.

For each city, the survey sites include places with a large concentration of respondents, such as schools, bus stations, supermarkets, office buildings, residential areas, and hotels. This ensures the diversity of survey subjects. To facilitate the intended analysis for this study, the interviewees were grouped into three main categories: E2W users, non-E2W users, and delivery staff. It was reasonable to assume that these three groups may have different perceptions of E2W adoption in Vietnam. The criteria for selecting interviewees are to meet diversification into gender, age, occupation, and income. Regarding E2W users, priority should be given to those with experience using different types of E2Ws to get their preferences at deep levels. In addition, the survey considered the choice of delivery staff in terms of their expectations and working context. In the survey process, the important thing is that the surveyor should explain the questions clearly to interviewees, making them comfortable and not pressured when answering questions.

The survey sample is shown in Table 1. In Hanoi, the number of E2W users is relatively large and diverse such as pupils, students, office workers, and homemakers. Therefore, the number of survey samples for E2W users is more prominent than for non-E2W users and delivery staff. In HCMC and Da Nang, through the assessment of the current situation, the number of E2W users is limited and not diverse. Most of them are pupils, students, and low-income people. Consequently, in these two cities, the number of survey samples for E2W users is smaller compared to non-E2W users and delivery staff.

**Table 1.** Survey samples.

| Location | E2W Users | Non-E2W Users | Delivery Staff | Total |
|---|---|---|---|---|
| Hanoi | 80 | 55 | 40 | 175 |
| Da Nang | 81 | 142 | 102 | 325 |
| HCMC | 93 | 114 | 103 | 310 |
| Total | 254 | 311 | 245 | 810 |

### *3.2. The SWOT Analysis*

The SWOT method is useful to identify the current status and recommend related strategies/policies during the decision-making process [29]. Accordingly, the SWOT approach has been widely applied to developing strategies for the transportation industry [29,30]. In practice, strengths and weaknesses are generally related to the internal environment, while opportunities and threats are associated with the external. Based on the SWOT analysis, decision-makers can develop combinatory strategies that maximize the strengths and opportunities as well as minimize the weaknesses and threats [29]. Also, as the fundamental steps of SWOT involve contributing factors identification, the application of this method requires a deep and comprehensive understanding of the background of the industry to pinpoint significant factors [31]. Moreover, the SWOT analysis provides only qualitative evaluations for the identified factors. Therefore, based on the literature review in the previous section, this study employed the SWOT approach to realize the strengths, weaknesses, opportunities, and threats for developing the business of E2Ws in Vietnam. Table 2 describes a four-quadrant SWOT diagram.

**Table 2.** SWOT analysis for E2W business development.

| Strengths (S) | Weaknesses (W) |
| --- | --- |
| - Attention to renewable and green energy, transport-related GHGs emission and pollution reduction, energy efficiency, and travel cost saving.<br>- Unique transport with dominant two-wheeler vehicles (e.g., motorcycles) while lack of efficient public transport systems. | - Low investment in E2W manufacturers and high prices of E2Ws, including batteries.<br>- Lack of E2W infrastructure and battery services (e.g., only a few pilot battery charging and swapping stations available). |
| **Opportunities (O)** | **Threats (T)** |
| - The Vietnam government has signed the Paris Agreement and has several key policies for sustainable energy development with four main pillars (i.e., energy efficiency, renewable energy, energy market, and climate change).<br>- Remarkable development in EV technology in the world, including battery technologies towards environmental and customer concerns.<br>- Various international organizations (e.g., USAID, ADB, WB, GIZ) are interested in working with the Vietnam government. | - Lack of comprehensive strategies/incentives and clear mechanisms/policies to facilitate the development of E2Ws.<br>- Recall and disposal issues of waste batteries (i.e., potential risks of causing environmental pollution due to lead batteries, lead acid, and batteries).<br>- Suspicious thoughts of users on E2Ws (i.e., low lifespan, unstable operation in bad weather conditions such as heavy rain and flood). |

## 4. Analysis Results and Discussion

### *4.1. Market Assessment of User Preferences*

Understanding user perceptions is an essential input for decision-making in promoting and improving the performance of E2Ws. The survey results for three groups (i.e., E2W users, non-E2W users, and delivery staff) are summarized in the following sections.

#### 4.1.1. E2W Users

The selected data in this research showed that the major E2W customers belong to two groups of pupils and students aged less than 24 (see Figure 4). Most of the interviewees own only either electric bicycles or electric motorcycles, especially E2Ws powered by lead-acid batteries and battery capacity smaller than 4 kW. In aligning with these findings, other research demonstrated a higher rate of students using E2Ws in different countries [15]. In terms of types of E2W, the results expressed that people who own bikes account for a higher rate than electric motorcycles. These facts are because the electric bike vehicle does not require a driving license, and its price is significantly lower than for electric motorcycles.

Most interviewees use E2Ws daily in Hanoi, followed by Da Nang and HCMC. Because of the dominant E2W use of students, using E2W for "going to school" is higher than other purposes in a three-city context. Moreover, three other main travel purposes using E2Ws in the three cities include "going to eating places/social activities/recreation", "going to work", and "going to shopping/market". Other remaining purposes accounted for a low percentage as shown in Figure 5. Regarding "going to shopping/market" and "going to eating places/social activities/recreation", it is higher in Hanoi and Da Nang but less in HCMC. In Hanoi and Da Nang, people use E2Ws for long trips with a maximum distance of about 40 to 80 km, while the maximum distance is only 30 to 60 km in HCMC. It is the same in the three cities for "going to school" but much higher for "going to work" in Hanoi.

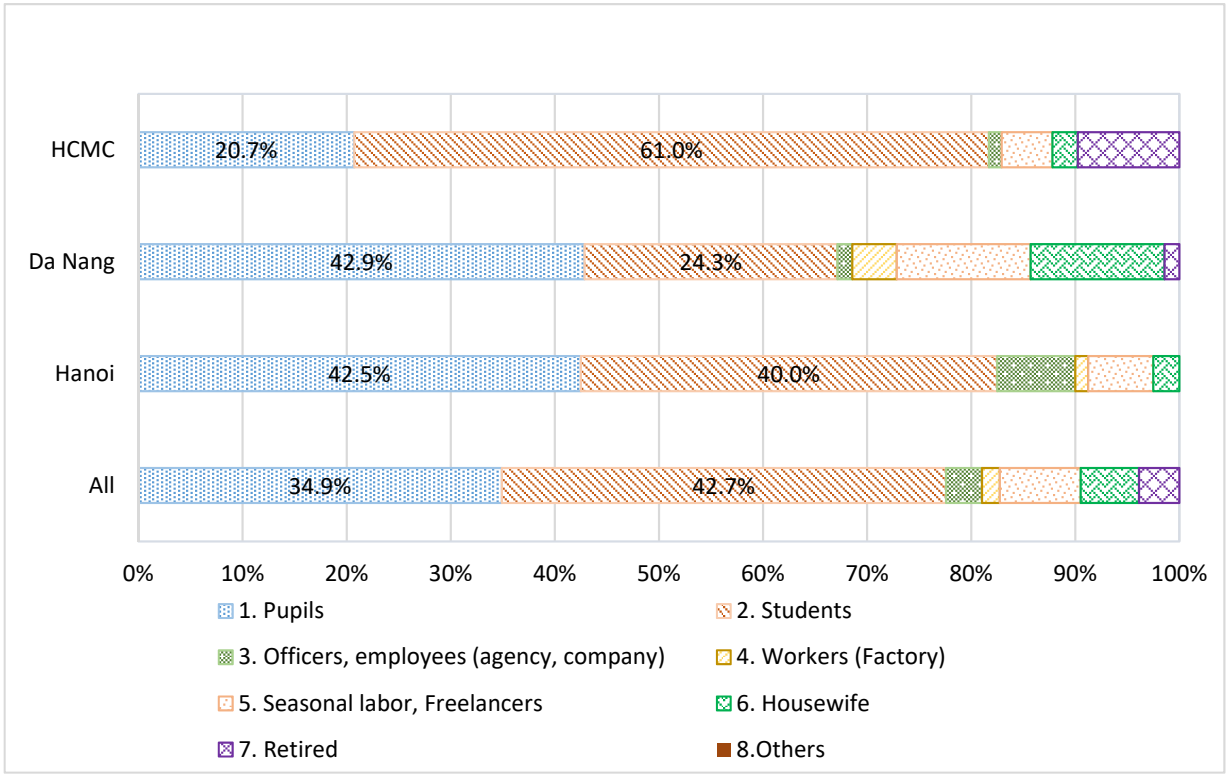


**Figure 4.** Occupation of E2W users.

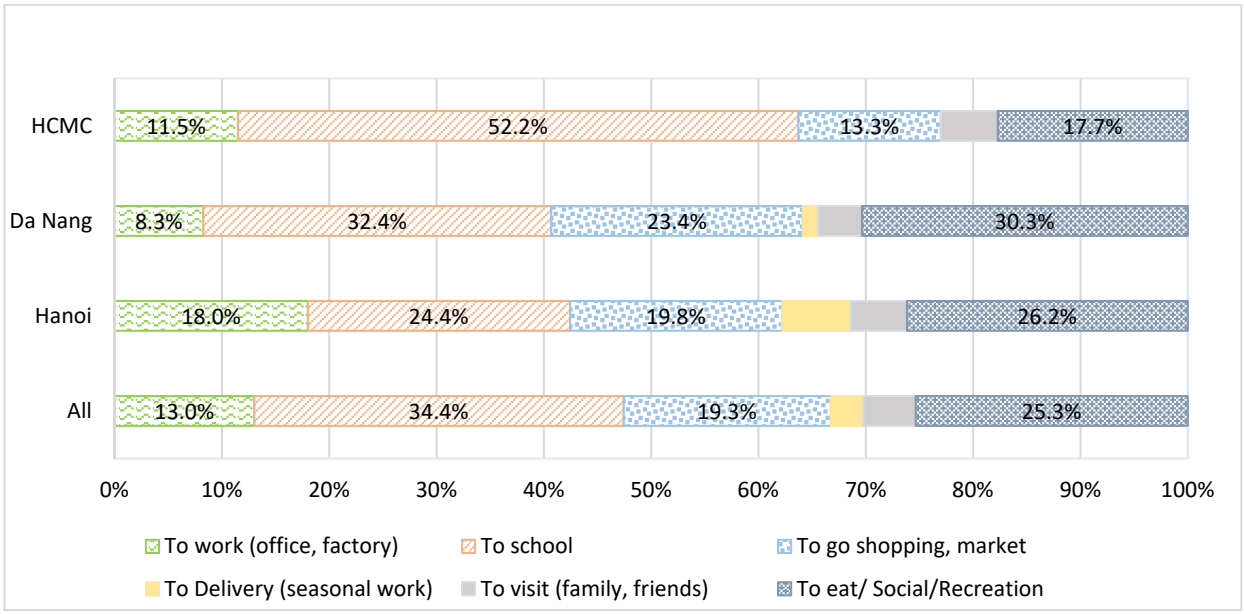


**Figure 5.** Trip purpose of E2W users.

Although interviewees were using E2Ws, roughly 28% wanted to shift entirely to E2W for their daily travel (see Figure 6). As illustrated in Figure 7, interviewees thought that the important requirements to shift to E2Ws are (1) increasing E2W travel range, (2) reducing battery charging time, and (3) stable operation in different conditions when it rains, floods, and less damage. Because of the competitive market of transport modes, the manufacturers always consider updating and improving vehicle quality to increase their market share. Regarding E2W-used respondents, nearly 66% of electric vehicle users do not

consider completely switching to E2W. This fact raises challenges for public agencies and manufacturers for further E2W development. The interviewee's perspectives expressed the significant reasons that impede them to continue using E2W. As shown in Figure 7, key barriers are (1) limited range, (2) low movement speed and acceleration, (3) complicated charging or swapping batteries, and (4) low vehicle lifespan. Interestingly, E2W users in HCMC usually use old E2W vehicles, and they do not care about the lifespan of E2Ws compared with those in Hanoi and Da Nang. Also, beautiful and fashionable designs are preferred by the users in Hanoi and Da Nang but less in HCMC.

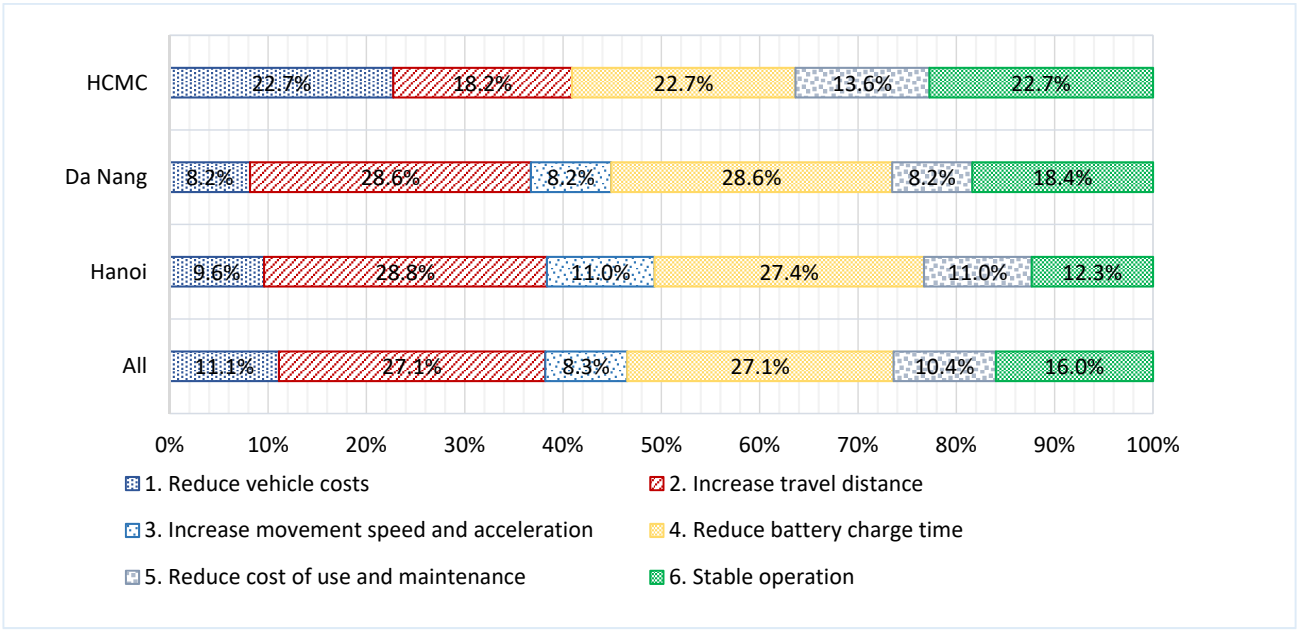


**Figure 6.** User's requirements to completely switch to E2Ws.

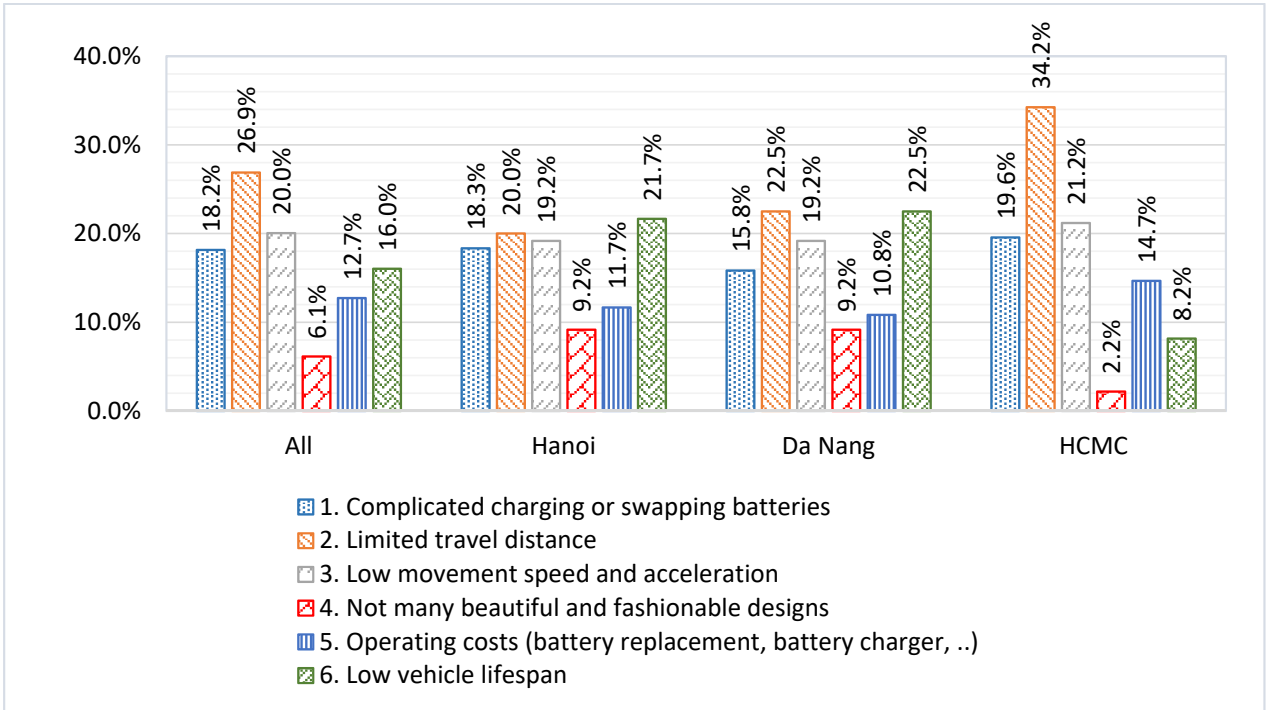


**Figure 7.** The reasons to not completely shift to E2Ws.

#### 4.1.2. Non-E2W Users

In order to promote E2W adoption, this analysis provided a better understanding of non-E2W users in Vietnam. Notably, more than 80% of respondents who do not own electric vehicles often use motorcycles as their primary means of transportation. While nearly 15% of interviewees in Hanoi use the bus, and 11% use cars in Da Nang for their daily travel. The level of understanding of E2Ws in this customer group was evaluated using a Likert scale varying from 1 (very positive) to 5 (very negative). Figure 8 demonstrates the different understandings of non-E2W users about these electric vehicles. Interviewee's perspective believed that the most significant benefits of E2Ws are (1) environmentally-friendly vehicles and (2) cost-saving for use and maintenance, wherein the most significant attribute of E2Ws is their environmental contributions. Aligning with these findings, other studies also demonstrated that the major characteristics of electric motorcycles are environmental benefits, low charging cost, high price, poor battery lifetime, and low maintenance and repair costs [32,33]. However, the understanding of fast movement speed and acceleration of E2W can be contradicted by other studies. Similar to research in different regions/countries [32], the results indicated that the respondents had relatively less understanding and knowledge of E2Ws. The possible reasons for the observed lack of understanding of E2W are that the motorcycle drivers in Vietnam lack E2W experience, and the government still has no effective measures to promote E2W.

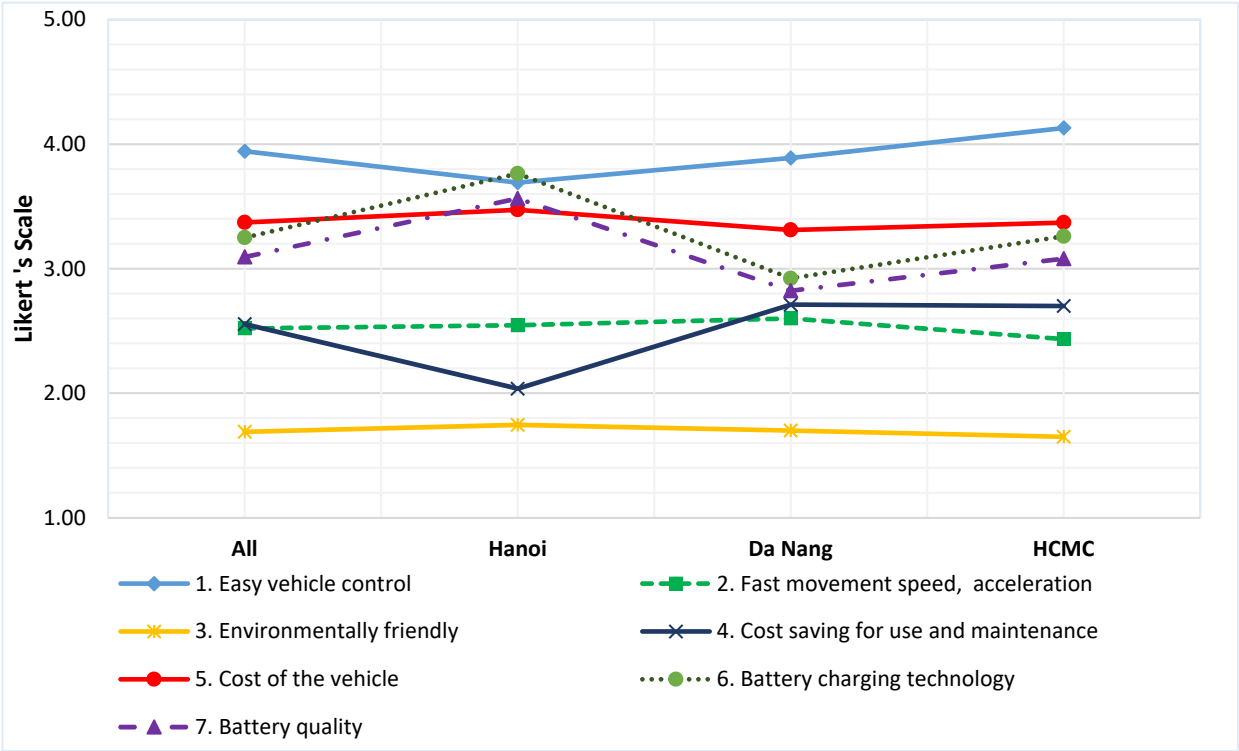


**Figure 8.** Understanding on E2W attributes of non-E2W users.

Otherwise, interviewees thought the other four attributes are relatively inefficient for vehicle usage. In terms of E2W perception, as presented in Figure 8, the interviewees believed that the main attributes that influence the drivers' willingness to own E2Ws are (1) not–easy vehicle control, (2) high-cost of the vehicle, (3) low-battery charging technology, and (4) low-battery quality for durable and long use after each charge. In accordance with this finding, other surveys stated that most drivers believed that the driving range is the main drawback of owning an E2W [17]. The capacity of electric batteries significantly limits the driving range of E2Ws. It hinders the consumer from employing an E2W, especially for long-trip scenarios, since, in some cases, drivers might need to reroute from their original

travel trajectory to refill the batteries. Therefore, using lithium-ion batteries is usually considered the best option for E2Ws. The drivers must ensure the E2W is fully charged before going out for their next long drive.

In this non-E2W user group, more than half of the interviewees do not plan to use this transport mode in the future (i.e., 57.6%), whereas 29.8% are planning to use E2Ws, and 12.7% are uncertain of their plan. In terms of the survey in each city, non-E2W users in Hanoi have a high proportion (i.e., 58.2%) in planning to use E2Ws, as opposed to Da Nang (31.0%) and HCMC (16.7%). As opposed to this outcome, 66.8% of respondents in Macau are willing to buy electric vehicles [32]. The primary reasons for the low percentage of willingness to purchase E2Ws were that the existing income in Vietnam is insufficient to cover the higher cost of E2W compared to conventional vehicles. So introducing lower taxes on E2Ws would be essential for further incentives.

As shown in Figure 9, non-E2W users thought that the five main requirements that electric vehicles need to be improved soon are (1) increase travel distance, (2) reduce vehicle cost, (3) stable operation (when it rains, floods, less damage), (4) Increase movement speed, increase acceleration, and (5) Reduce battery charge time (quick charge). Consistent with these findings, the survey also revealed some limitations of E2W that prevent non-E2W users from choosing this vehicle in the near future. Non-E2W users believed that most E2Ws have (1) limited travel distance, (2) complicated charging or swapping batteries, (3) low movement speed and slow acceleration, (4) low vehicle lifespan, and (5) expensive operation (swapping battery, battery charging), as shown in Figure 10. The above facts demonstrate that most challenge for promoting E2W adoption in Vietnam is their limited travel distance, mostly when using electric bikes. Hence, understanding these barriers in E2W diffusion in Vietnam leads to valuable lessons in designing policy instruments and institutions for public transportation agencies. Echoing these findings, Patil & Majumdar [13] and Ottesen et al. [15] showed the attributes, namely, purchase cost and operation cost, range, top speed, battery-charging duration and acceleration, health benefits and reduction in tailpipe emission and charging infrastructure, and parking infrastructure, are seen as the key attributes influencing E2W implementation in the typical Indian context.

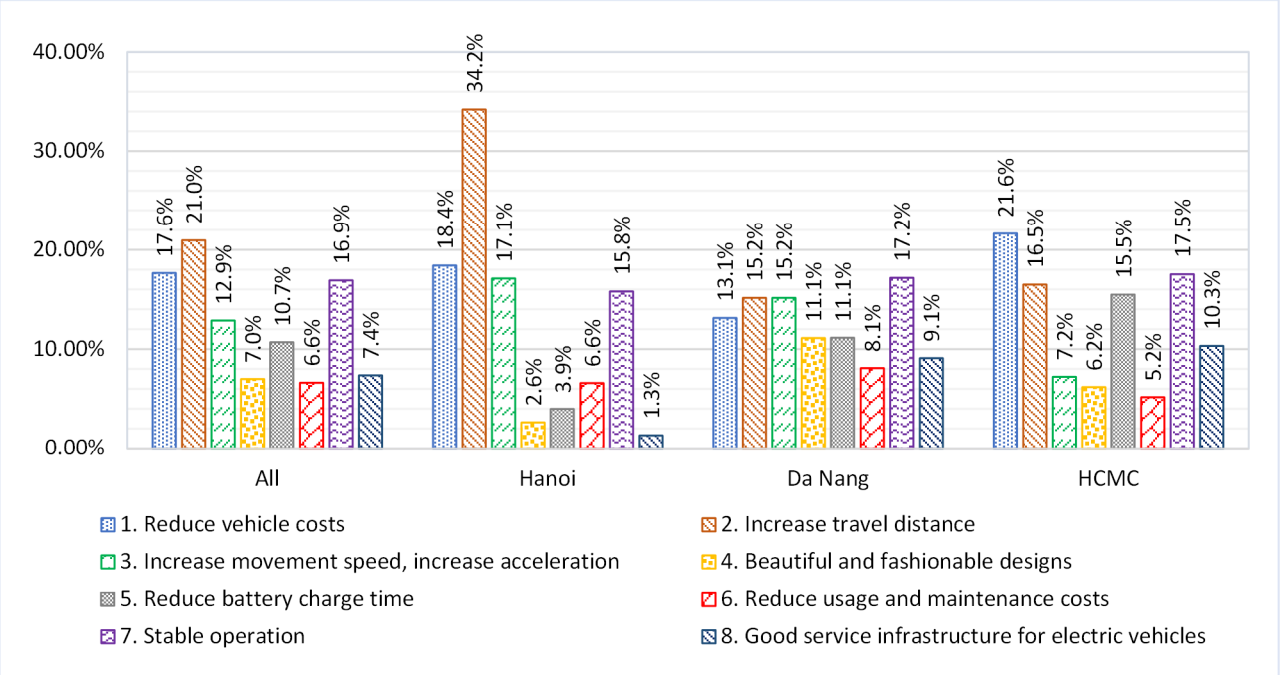


**Figure 9.** Requirements for further using E2Ws.

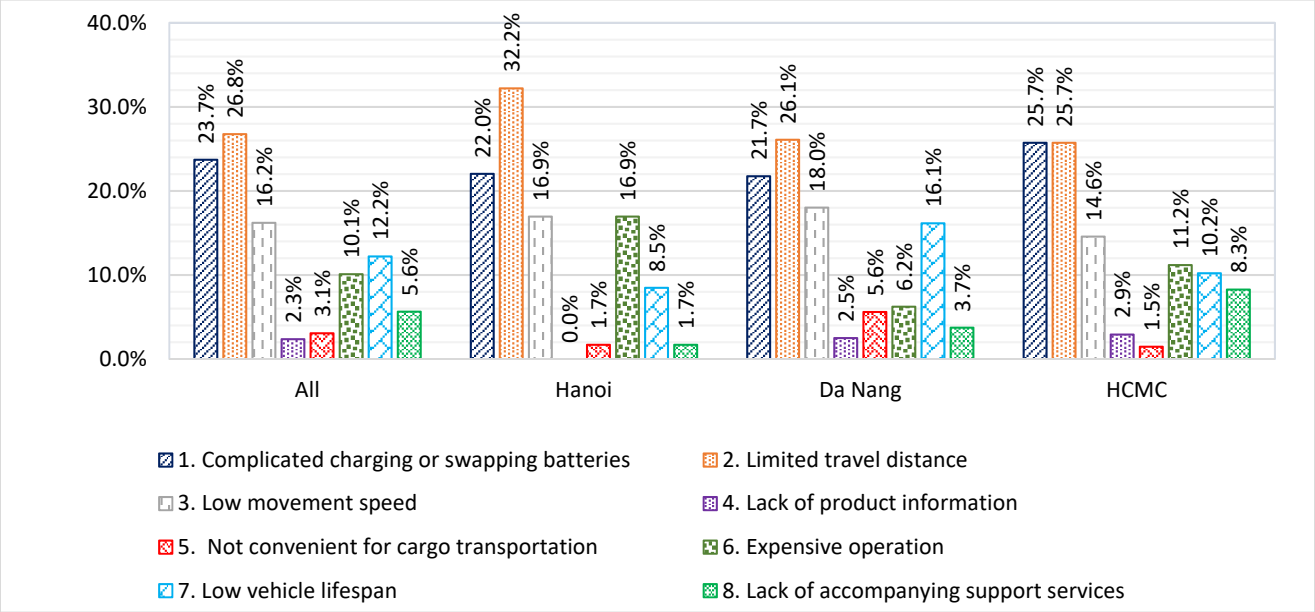


**Figure 10.** Reasons not to use E2Ws.

#### 4.1.3. Delivery Staff

The delivery drivers often travel much longer compared to other E2W users. A delivery trip's average length is from 2 to 5 km in three cities. In Hanoi and Da Nang, the longest trip for the delivery staff can be up to 15 or 20 km, while in HCMC, the longest trip is only up to 10 km. For all three cities, the total length per day is from 60 to 100 km, the average speed is from 30 to 50 km per hour, and the cost of using a vehicle is from 200,000 to 500,000 VND per month without any support from delivery companies. Thus, using E2Ws can influence the business-to-business model for delivery companies.

The survey covered the most popular delivery services for goods and passengers, such as Grab, Be, Now, and BaeMin. The delivery staff are relatively young, with a range of ages between 19 and 35 years. In Hanoi and Da Nang, most are students working in part-time positions (i.e., 65% in Hanoi and 71.57% in Da Nang), while delivery staff in HCMC mainly work full-time (i.e., 65.05%). By using a Likert scale varying from 1 (very positive) to 5 (very negative), the study regarded opinions on E2W characteristics. As shown in Figure 11, delivery staff prefer the E2W's benefits in terms of (1) saving cost for use and maintenance, (2) capability of carrying heavy and bulky goods, and (3) reasonable vehicle cost.

In terms of intention to own E2W vehicles, a significant amount of delivery workers, accounting for 66%, keep using M2W, whereas 26% in this interviewee group express the demand for further using E2W. The delivery staff in Hanoi are more likely to shift to E2Ws than Da Nang and HCMC; 45% and 39.2% of delivery staff in Hanoi and Da Nang, respectively, are likely to change to E2Ws. Surprisingly, 100% of the delivery staff in HCMC do not want to shift to E2Ws.

For delivery drivers who want to switch to E2Ws, the main attributes relate to the technology and charging infrastructure, such as (1) increasing travel distance for each charge, (2) increasing movement speed and acceleration, (3) reducing battery charge time, quick charge, (4) good service for charging station, battery swapping station. On the other hand, the most significant reasons for the delivery staff not using E2Ws are (1) limited travel distance and (2) complicated when charging or swapping batteries. Other barriers to E2W usage are also highly evaluated as low movement speed/acceleration and lack of accompanying support services, i.e., charging station and swapping batteries station (Figure 12).

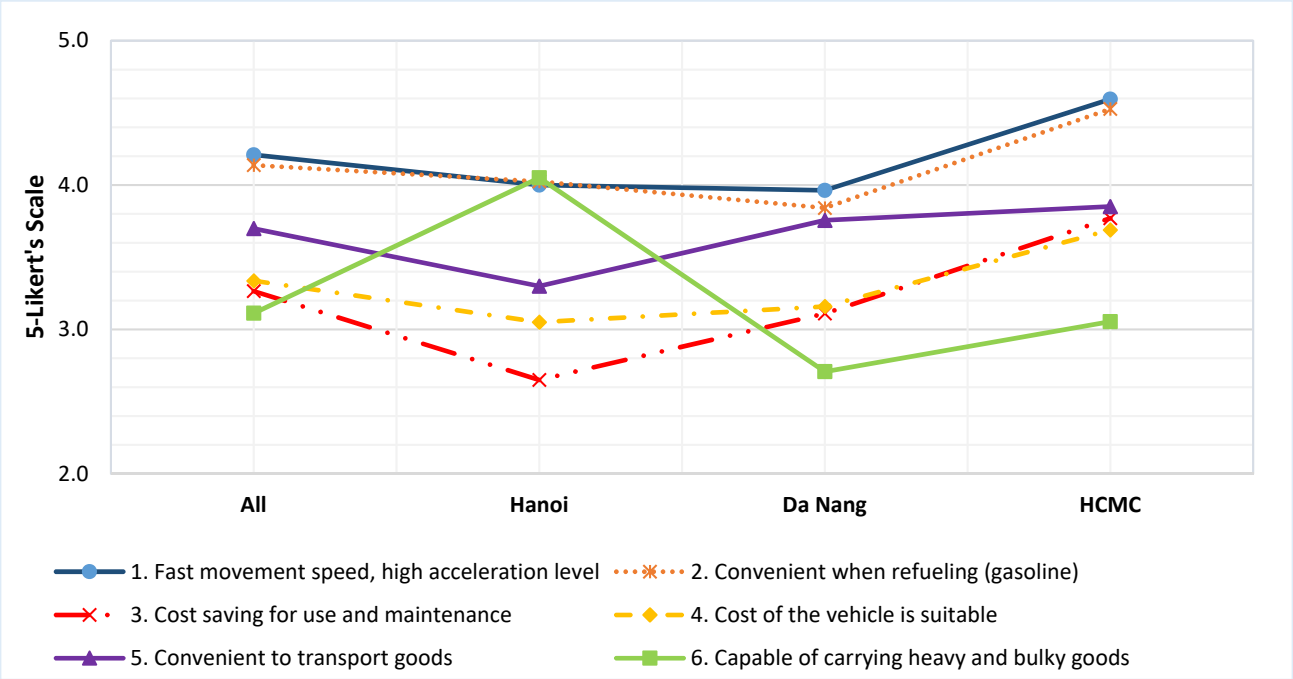


**Figure 11.** Planning to shift to E2Ws of delivery staff.

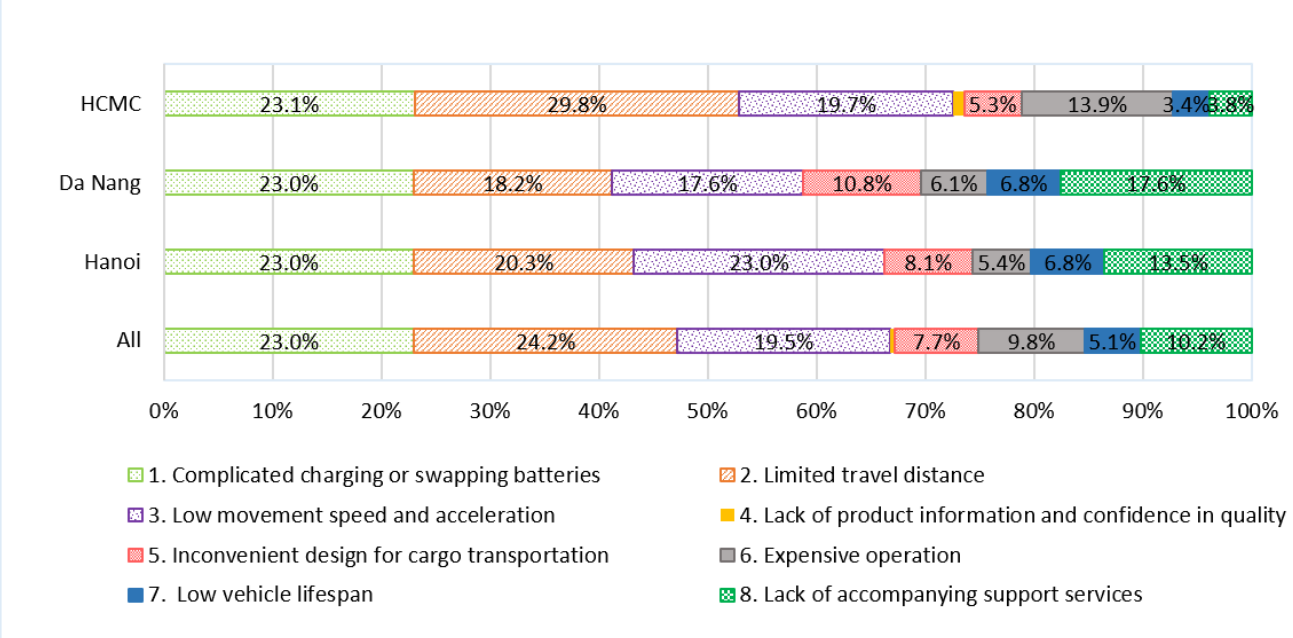


**Figure 12.** Reasons to not use E2Ws of delivery staff.

### *4.2. E2Ws Charging Options in Vietnam*

#### 4.2.1. Current Situation of Battery Charging Infrastructure

Providing the battery charging infrastructure plays the most important role in implementing the E2W incentives [20]. Since the end of 2014, many companies in Vietnam have considered providing charging stations for e-bikes and e-motorcycles and are expected to establish 10-min quick charge stations at e-bike stores or on the road. However, these proposals have not yet been realized since these companies did not have enough capacity to implement them. The main reason is the low chance of making a profit. Moreover, the

stores installing the E2W charging system are usually not committed since cooperative partners can easily change their business [23].

Recently, investing in E2W and supportive infrastructure have been carried out in Hanoi, HCMC, and Da Nang. By the end of 2019, over 1000 charging stations were installed at VinMart+ convenience stores, nearly covering Hanoi and HCMC areas. The Vinfast charging stations operate in Da Nang and Hai Phong. With the very high density of Vinmart+ stores (approximately 700 m distance between two stores in major cities), the charging network is quite convenient for users [34]. The success of VinFast comes from the fact that VinFast would like to invite partners of individuals and enterprises with suitable premises to cooperate in installing and operating electric vehicle charging stations (business cooperation for EV charging stations). Although the incentives have been implemented successfully in other countries [35], the promotion of E2W charging stations is encountering challenges in Vietnam [12]. Strong user awareness is critical to creating a favorable environment for E2W penetration. Thus, the current research has investigated user preference related to E2W charging services, as described in the following section.

#### 4.2.2. User Preference on E2W Charging Technology and Service

The survey of three-interviewee groups, as mentioned above, demonstrated that the battery charging service is one of the significant challenges for owning E2Ws. E2W users perceived some limitations of E2W batteries are (i) low technology on battery and battery charging, (ii) short lifespan of the battery, and (iii) short duration of battery usage after each charging. Thus, they plan to use E2Ws if there are convenient and economical services for battery charging/swapping stations. Also, most non-E2W users prefer advanced technology for E2W batteries in terms of long duration for battery usage and short time for charging. On the other hand, delivery staff can use E2Ws if the battery charging time can be reduced and battery charging and swapping service stations can be provided adequately. Thus, providing effective infrastructure systems, technologies, and services for battery charging and swapping is an urgent need to promote E2W usage in Vietnam [36].

In terms of E2W users, 70% of respondents in Hanoi usually change E2W batteries at a distribution store, and 30% change batteries at an electric vehicle repair shop, while in HCMC, 100% of respondents change E2W batteries at the distribution stores. Currently, battery swapping services for E2Ws is only available in Hanoi and HCMC. However, the number of people using this service is minimal, with less than 12.5% in Hanoi and 4% in HCMC. The survey showed that most Hanoi and Da Nang users want to select battery charging and swapping stations, as opposed to HCMC, with only 20% of respondents preferring this service In addition, E2W users do not entirely shift to E2Ws since they think it is complicated when charging or swapping batteries and evaluate that it is expensive on operation costs (i.e., battery replacement, battery charging). Therefore, E2W users believe some factors to offer a successful battery swapping service: (1) reduce battery swapping service cost (i.e., provide an integrated package); (2) expand the network and coverage of battery swapping stations and (3) quality service (i.e., fast and friendly) at battery swapping stations. Hung [36] and Wang et al. [21] also suggested other factors for promoting battery swapping services, i.e., (1) only a few different types of standardized batteries and interfaces should be available; (2) battery swap stations (BSSs) should be strategically positioned.

### *4.3. Directions for E2W Development in Vietnam*

E2W adoption depends considerably on the policies and incentives that the government provides. In addition to efforts associated with technological improvements (e.g., developing electric cars with greater ranges and speeds), economic incentives for the E2W alternative should be implemented at different levels of government. The SWOT analysis of the current E2W analysis can enable suitable recommendations for EV development in Vietnam. Moreover, Figure 13 presents the survey outcomes about six proposed incentives

to expand the E2W market in Vietnam. Based on these findings, significant directions for E2W development were suggested in this study.

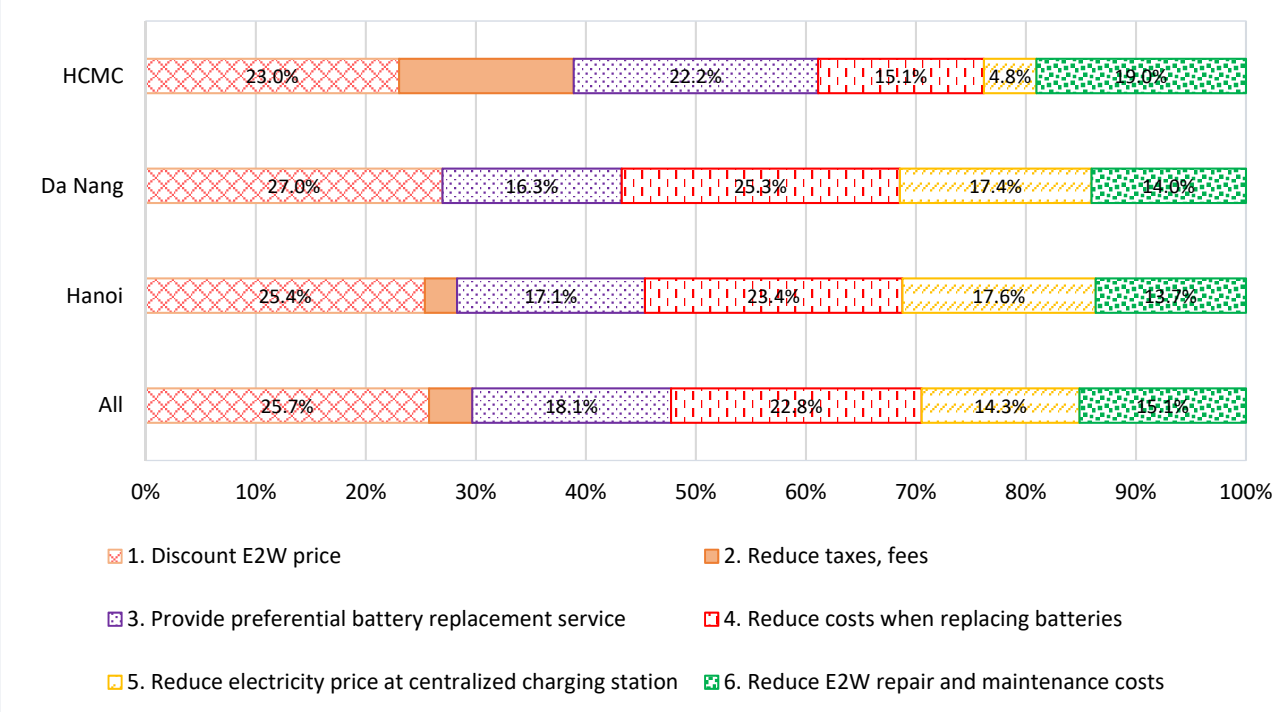


**Figure 13.** Preferences for E2W battery charging and swapping service.

Interviewees believed that discounting E2W prices for buying new vehicles is the most crucial incentive. Regarding purchase price, the cheapest model, the Espero 133I from Detech, is 13.6 million VND (around 580 USD), as opposed to the most expensive one (i.e., Theon S from VinFast) is 89.8 million VND (around 3820 USD) [24]. Especially the purchasing cost of imported E2Ws to Vietnam could be significantly higher than E2Ws that are domestically manufactured or assembled. Moreover, purchasing E2Ws equipped with lithium-ion batteries is much more expensive than those equipped with lead-acid batteries, but they have a longer lifespan and are lighter. This fact is a significant factor that hinders Vietnamese users from owning E2Ws. Hence, providing financial incentives to promote E2W uptake to reduce purchase prices is essential, e.g., vehicle purchase subsidies, tax exemptions, or tax reductions.

Incentives regarding battery services, i.e., preferential battery replacement service and reducing the replacing battery cost, are also considered significant measures for further policies. Regarding battery charging and switching cost, the government should have investment and support in building and operating charging infrastructure and battery swapping services. Notably, the government can provide subsidies for manufacturers and providers of this service, such as lowering the land use tax and direct grants to implement the battery charging infrastructure and switching model. However, one of the crucial barriers is the lack of technical specifications regarding E2W battery charging and switching systems.

### *4.4. Battery Charging and Swapping Service Recommendation*

The current study utilized the SWOT approach to analyse the strengths (S), weaknesses (W), opportunities (O), and threats (T) of the E2W market status, as shown in Table 2. Based on this analysis, two-wheeler vehicles are still dominant in Vietnam due to the lack of efficient public transport systems. From this SWOT analysis, this study suggested the main

direction is to develop the battery charging and swapping service of E2Ws in Vietnam, wherein battery swaps are advances in replacing EV batteries.

Firstly, customer segmentation is the activity of dividing service markets into different groups of buyers. Market segmentation can be based on geographical, demographic, psychographic, and consumer behaviour. Considering examples from several companies such as Tesla, WanXiang, and OEMs, the market segment for battery swapping in Vietnam can be selected in terms of its best class for electric vehicles. Secondly, online and place of service is a means to provide services/products to consumers who need services when faced with obstacles during use. As for the battery swapping service, there should be a convenient area easily accessible for customers. Notice of how to use it is given online or in the battery swap area.

Thirdly, companies should provide services such as discounts, guarantees, and customer service to maintain a good relationship with consumers. Providing these benefits can hopefully strengthen the relationship between the company and consumers personally. Revenue streams focus on the automotive segment revenue, the energy generation and storage segment, and the battery swap application. This battery swap application covers how you use, notices, components, and so on about the battery swap information. To provide consumer interest, affordable prices can be set according to the cost of electricity or the manufacturing process or referring to existing costs.

Fourthly, to achieve good services, the company updates its design, carries out charging stations, builds charging stations strategically, develops and maintains software or technology on battery swaps, and maintains sales and marketing for battery swapping. The most critical resources are people, systems, and equipment. People here means labour that runs the presentation of services. The interaction between labour, infrastructure systems, and instruments largely influences business performance. If the system can work and the workforce is also satisfying, the consumer perception of the company is excellent.

Finally, because the products for exchanging E2W batteries in Vietnam are still underdeveloped, related facilities and information provided to customers must be convenient. Battery swapping costs need to be cheap because the customer only needs to buy the electricity costs without having to repurchase the batteries. Moreover, risk reduction is by giving guarantees to consumers related to products used to give a good impression to consumers.

### *4.5. E-Mobility Roadmap in Vietnam*

Different government levels (i.e., local and national governments) have put attention on developing the roadmaps for E-mobility. The roadmap is a prerequisite step to promote and adopt the E-mobility, especially E2Ws, in different countries/regions. Accordingly, some Southeast Asian countries, such as Singapore, Malaysia, and Thailand, issued their roadmaps to promote E2W usage [37]. The Chinese government renovated the New Energy Vehicle Industry Development Plan for 2021–2035, determining comprehensive policies to develop a robust domestic EV market. In the US, 17 states and European cities have also adopted roadmaps and action plans about e-mobility enhancement in pursuit of their low carbon emissions targets [38]. Consequently, establishing an e-mobility roadmap is vital in offering a pathway for related stakeholders (e.g., public agencies, manufacturers, utility companies, practitioners, and academics) to develop targets, create policies/incentives, and monitor the E2W implementation.

The study findings can facilitate the creation of e-mobility roadmap in Vietnam according to four phases (see Figure 14). According to Liu et al. [37], roadmaps focused on E2W mobility prioritize three aspects of adoption: E2W usage, E2W industry, and E2W charging facilities. Among these three scopes, this study gave a better understanding of E2W users and battery charging/wrapping services. In terms of all respondents' perspectives in this study, three significant obstacles to E2W adoption are (1) complicated charging or swapping battery service, (2) limited travel distance, and (3) low movement speed/acceleration. Thus, the creation process of the e-mobility roadmap essentially identifies these barriers to E2W

acceptance and considers solutions to overcoming these challenges. Accordingly, governments at different levels need to work with related stakeholders, such as manufacturers, to improve the quality of E2Ws, batteries, and charging equipment. Governments also should update and release improved standards/specifications and technical assistance related to E2Ws.

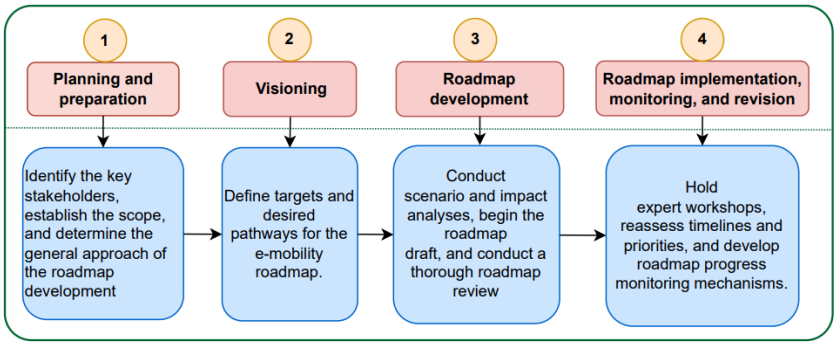


**Figure 14.** Four phases of e-mobility roadmap development (Diagrammed by Liu et al. [37]).

The current study also expresses the limited awareness of users about E2W. Hence, the e-mobility roadmap needs to raise the E2W user perception. Experiences from successful cases in developing E2W showed some effective measures could be applied to the Vietnamese E2W market, e.g., awareness campaigns, E2W help desk, education, pilot E2W projects, wayfinding, and signage. Additionally, the e-mobility roadmap should mention policies/incentives to support the battery charging infrastructure. As mentioned in the previous section, some key facets of public and private charging incentives are a technical guide for charging equipment installation and operation, preferential electricity rates, and subsidies for establishing charging systems directly or through the reduction of loan interest.

## 5. Conclusions

E2Ws, expected to be environmentally friendly vehicles, have increased their share in the vehicle market in recent years. Their adoption depends on the policies and incentives that the government provides. Vietnam has not fully adopted E2W technology yet, and there are still deficiencies in incentives, regulations, and policies. It can be seen that E2W usage is still at an exploratory stage in the transportation industry in Vietnam.

This paper has comprehensively assessed E2W development in Vietnam (e.g., legal framework, market assessment, and charging options) through surveys in Hanoi, Da Nang, and HCMC. Both E2W and non-E2W users considered the limitations of the technology of E2Ws in the charging and battery issues. E2Ws have short travel distances due to low battery capacity; long waiting times for battery charging; low speed and slow acceleration; the low lifespan of vehicle and battery; and unstable operation with climate conditions (such as rains, floods, and humid temperatures). Additionally, the users responded that it is costly to purchase and operate E2Ws due to extra fees for charging and exchanging batteries. Regarding the vehicle and battery service, there is a relatively high demand for battery charging/swapping stations, especially for quick charger and swapping services.

There is a trend of moving from gasoline two-wheeler (G2W) vehicles to E2Ws in three selected cities. In addition, non-E2W users do not entirely change to E2Ws because of the complicated and expensive system for charging or swapping batteries, while E2W users expect the improvement of the following factors: reduced battery switching service cost, expanded charging network, coverage of battery swapping stations, and quality service (i.e., fast and friendly). The survey was also conducted for delivery staff to understand their functional characteristics to elaborate on whether E2Ws can be introduced to their business and fleet managers. It showed that the delivery staff surveyed in Hanoi are more likely to shift to E2Ws compared to Da Nang and HCMC. It can be considered

to introduce business collaboration in both providing E2W vehicles and a network of convenient battery-swapping services.

The research findings provide an overview of challenges and opportunities for decision/policymakers, industry stakeholders, and researchers to recommend policies for E2W development in Vietnam. The assessment of E2W perceptions in a three-city context is realized as exploratory, generating the baseline for further research. Future research can enlarge the respondents involved in the survey to confirm the findings of this paper. Moreover, research on electric four-wheelers (i.e., electric buses and electric cars) is recommended to understand EV development in Vietnam better. It can later contribute to establishing a national e-mobility roadmap and encourage a sustainable transport system complying with COP26 statements and declarations.

**Author Contributions:** Study conception and design: D.V.H.; data collection and modeling: D.V.H., N.H.T., N.A.T., T.M.H., N.V.D. and H.T.; analysis and interpretation of results: D.V.H., N.H.T. and N.A.T.; draft manuscript preparation: N.H.T., D.V.H., N.A.T. and T.M.H. All authors have read and agreed to the published version of the manuscript.

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**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

**Table A1.** Summary of policies, incentives, and legislations regarding EVs and relevant sectors to EVs at the national level in Vietnam.

| Document No. | Date | Content | Approved by |
|---|---|---|---|
| A. Resolution | | | |
| Resolution No. 136/NQ-CP | 25 September 2020 | Sustainable Development | The Government |
| Resolution No. 55/NQ-TW | 11 November 2020 | On the strategy of the national energy development orientation of Vietnam to 2030 with a vision to 2045 | The Political Bureau |
| B. Decision | | | |
| Decision No. 985a/QD-TTg | 1 June 2016 | Approval of the national action plan on air quality management to 2020, with a vision to 2025 | The Prime Minister |
| Decision No. 229/QD-TTg | 6 February 2016 | On the mechanism and policy for implementation of the strategy and plan for development of Vietnam Automobile Industry | The Prime Minister |
| Decision No. 879/QD-TTg | 9 June 2014 | Approving the strategy on Vietnam's industrial development through 2025, with a vision toward 2035 | The Prime Minister |
| Decision No. 16/2015/QĐ-TTg | 22 May 2015 | Providing regulations on recall and treatment of discarded products | The Prime Minister |

**Table A1.** *Cont.*

| Document No. | Date | Content | Approved by |
|---|---|---|---|
| Decision 02/2007/QD-BCT | 29 August 2007 | Approving the planning for the development of Vietnam's motorcycle industry in the 2006–2015 period, with a vision to 2020 | The Ministry of Industry and Trade |
| Official Gazette No. 4501/VPCPKTTH | 9 September 2016 | Tax incentives for solar buses | Deputy Prime Minister |
| Decision 909/QD-TTg | 17 June 2010 | Approving motorcycle emission control mechanism in localities and the city; | The Prime Minister |
| Decision 04/2017/QD-TTg | 9 March 2017 | Promulgating energy labelling regulations and application of energy consumption norms and implementation roadmap; | The Prime Minister |
| | | C. Decree | |
| Decree No. 132/2008/ND-CP | 31 December 2008 | Detailing the implementation of a number of articles of the law on product and goods quality | The Government |
| Decree 57/2020/ND-Cp | 25 May 2020 | Export and preferential import tariff | The Government |
| Decree 116/2017/ND-CP | 17 October 2017 | On requirements for manufacturing, assembly and import of motor vehicles and trade in motor vehicle warranty and maintenance services | The Government |
| Decree No. 127/2007/ND-CP | 1 August 2007 | Detailing the implementation of a number of articles of the law on standards and technical regulations | The Government |
| Decision No. 49/2011/QD-TTg | 1 September 2011 | Providing the roadmap for application of exhaust emission standards to manufactured, assembled and imported brand-new cars and motorbikes | The Prime Minister |
| Decree No. 38/2015/NĐ-CP | 24 April 2015 | On management of waste and discarded materials | The Government |
| | | C. Circular | |
| Circular No. 45/2012/TT-BGTVT | 23 October 2012 | On the inspection of the technical quality, safety, and environment protection in the manufacture and assembly of motorbikes | The Ministry of Transport |
| Circular No. 44/2012/TT-BGTVT | 23 October 2012 | On the inspection of the technical quality, safety, and environment protection of imported motorbikes, and imported engines for motorbike manufacture and assembly | The Ministry of Transport |
| Circular No. 86/2014/TT-BGTVT | 31 December 2014 | Regulations on conditions applied to restricted vehicles and operators thereof | The Ministry of Transport |
| Circular No.39/2018/TT-BTC | 20 April 2018 | Amendments to circular No. 38/2015/Tt-BTC dated 25 March 2015 | The Ministry of Finance |
| Circular No. 38/2015/TT-BTC | 25 March 2015 | On customs procedures, customs supervision and inspection, export duty, import duty, and tax administration applied to exports and imports | The Ministry of Finance |

**Table A1.** *Cont.*

| Document No. | Date | Content | Approved by |
|---|---|---|---|
| Circular No. 01/2022/TT-BTNMT | 7 July 2022 | Guidelines for implementation of law on environmental protection regarding response to climate change | The Ministry of Natural Resources and environment of Vietnam |
| Circular No. 48/2022/TT-BGTVT | 30 December 2022 | Providing instructions for energy labelling for electric or hybrid electric cars, motorcycles, and mopeds | The Ministry of Transport |
| Circular No. 02/2023/TT-BGTVT | 21 March 2023 | Amendments and supplements to a number of articles of Circular No. 16/2021/TT-BGTVT of August 12, 2021 of the Minister of Transport, Regulations on technical safety inspection and environmental protection of road motorcycle vehicles | The Ministry of Transport |
| E. Law and Legal documents | | | |
| Law on Road Traffic | 13 November 2008 | Law on road traffic | The National Assembly |
| Document No. 1318/TTg-CN | 27 September 2018 | Pilot electric 4-wheeled vehicle to serve tourists in the restricted area | The Prime Minister |
| Document No. 4638/BGTVT-VT | 14 April 2015 | Propose solutions for managing four-wheelers (electric and fuel). | The Ministry of Transport |
| Document No. 573/TTg-KTN | 29 April 2014 | Summary of EV-related aspects: Present results of the pilot project for electric 4-wheelers in passenger services | The Prime Minister |
| F. National standard | | | |
| QCVN 14:2015/BGTVT | 2015 | National technical regulation on safety and environmental protection for motorcycles and mopeds | The Ministry of Transport |
| QCVN 68:2013/BGTVT | 2013 | National technical regulation on electric bicycles | The Ministry of Transport |
| QCVN 75:2014/BGTVT | 2014 | National technical regulation of motors used for electric bicycles | The Ministry of Transport |
| QCVN 76:2014/BGTVT | 2014 | National technical regulation for batteries of electric bicycles | The Ministry of Transport |

## Appendix B

**Table A2.** Summary of policies, incentives, and legislation regarding EVs and relevant sectors to EVs by city level in Vietnam.

| Document No. | Date | Content | Approved by |
|---|---|---|---|
| Hanoi city | | | |
| Resolution No. 04/2017/NQHĐND | 4 July 2017 | The program on enforcement ofmanaging road transport vehicles to reduce congestion and environmental pollution withHanoi city period 2017–2020vision to 2030 | Hanoi People's Council (PC) |
| Plan No. 212/KH-UBND | 28 September 2017 | The implementation of resolution No. 04/2017/NQ-HĐND | Hanoi City People's Committee (CPC) |
| Document No.4623/UBND-GT | | Implementation of the pilot project for the electric car to operate within old streets area for tourism purposes | Hanoi CPC |

**Table A2.** *Cont.*

| Document No. | Date | Content | Approved by |
|---|---|---|---|
| Decree No.867/QĐ-SGTVT | 24 May 2018 | A proposal of regulations for electric 4-wheelers operated in Hanoi city | Hanoi DOT |
| | | Ho Chi Minh city | |
| Program No. 14CTrHD/TU | 25 October 2016 | Implement resolution 10 to reduce congestion and accident in the period 2016–2020 | HCMC PC |
| Decision No. 2398/QD-UBND | 11 May 2013 | Promulgating the implementation plan of Decision No. 280/QD-TTg: Approving the bus public passenger development program for the period 2012–2020 in HCMC; | HCMC PC |
| Decision No. 568/QD-TTg | 8 April 2013 | Approving the adjustment of transport planning of HCMC to 2020, with a vision to 2030 | HCMC PC |
| | | Da Nang city | |
| Decision No.8087/QĐUBND | 19 November 2013 | Approving the plan to develop public passenger bus for the period 2013–2020 with a vision to 2030; | Da Nang CPC |
| Decision No. 5030/QDUBND | 28 July 2014 | Approving the planning for Da Nang city to 2020 and vision to 2030. | Da Nang CPC |

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