Exploring Information Needs of Using Battery Swapping System for Riders

Fei-Hui Huang(✉)

Department of Marketing and Distribution Management,
Oriental Institute of Technology, Pan-Chiao 22061, Taiwan, ROC
Fn009@mail.oit.edu.tw

Abstract. In order to improve penetration in Taiwan's electric two wheeler (E2W) market to decrease emissions of pollutants generated by scooters, a battery swapping model is proposed to overcome battery limitations (e.g., expensive purchase price, short lifetime, limited driving range per charge, long charging time, and inconvenient charging). This study aims to understand individuals' information needs of using battery swap station (BSS) and, furthermore, providing several suggestions to improve BSS service for enhancing their willingness to accept a battery swapping system. In this study, a sample of 2,100 riders who had experienced a battery swapping service and filled out a post-experience questionnaire. The questionnaire elicited their traffic demands, the system acceptability, and purchase intention. The results showed that approximately 79.9 % of riders adopted the battery swapping system, but only 3.9 % were willing to purchase an e-scooter. Riders identified a number of problems with the self-service BSSs, including 42.8 % usability, 33.1 % environment, 18.7 % utility, and 5.4 % price. Finally, these problems were discussed, and addressed several recommend ways of resolving them.

Keywords: Electric two wheelers (E2Ws) · Battery swapping model · System acceptability · E-scooter · Information needs

1 Introduction

Taiwan has a population of 23 million, of which about 13.7 million are scooter users. Thus, one in every 1.67 people is a scooter commuter, which is the highest density in the world, and New Taipei City has the highest density in Taiwan. According to Taiwan's Environmental Protection Administration (EPA) report, emissions generated by scooters account for 330,000 tons of carbon monoxide and 90,000 tons of chemical compounds containing carbon hydroxide per year. The real-world operation of motorcycles/scooters results in a significant contribution of road transport CO and HC emissions, reaching 38 % and 64 %, respectively, to the total emissions from road transportation [1]. In order to improve the air quality, the Taiwanese government is dedicated to promoting an eco-environmental protection policy. Increasing the penetration level of electric two wheelers (E2Ws), including electric scooters (e-scooter), electric bicycles (e-bike), and electric-assisted bicycles, is one of the aims of the policy. The widespread adoption of E2W brings potential social and economic benefits, such

S. Yamamoto (Ed.): HIMI 2016, Part II, LNCS 9735, pp. 531–541, 2016.
DOI: 10.1007/978-3-319-40397-7_51

as reducing the quantity of fossil fuels and greenhouse gas emissions, as well as environmental benefits. However, limitations on E2Ws batteries, including an expensive purchase price, short lifetime, limited driving range per charge, long charging time, and inconvenient charging, have meant that many people are unwilling to buy the related products. In spite of the incentives offered by Taiwan's government, the penetration level of E2W in the market is not encouraging. Only 29,942 e-scooters and 108,602 e-bikes were sold between 2009 and 2014. A battery swapping model is proposed to overcome the battery charging and driving range limitations in order to improve the penetration of E2Ws in Taiwan. The purpose of this study is to understand individuals' information needs of using battery swap station (BSS) and, furthermore, providing several suggestions to improve BSS service for enhancing their willingness to accept a battery swapping system.

2 Literature Reviews

2.1 Battery Swapping Model

A battery swapping model may provide a faster charging service than even the fastest recharging stations and lower the charging cost by charging depleted batteries overnight at a discounted electricity price. In this study, the battery swapping system is providing a separation of the ownership for the battery and the E2W. Using a battery leasing service may also reduce the expense incurred by E2W owners. The model provides self-service BSSs, where an owner can ride to the nearest BSS and swap to a fully-charged battery within two minutes. The concept of an exchangeable battery service was first proposed as early as 1896 in order to overcome the limited operating range of electric cars and trucks [2]. In addition, BSS is one of the solutions to the limitations of the E2W battery [3–6]. The battery swapping system comprises four industries: battery swapping system operators, E2W battery manufacturers, E2W manufacturers, and E2W retailers. In order to effectively integrate the industries and adopt the battery swapping system, battery certification specifications for E2Ws have been drafted to formulate a size standard for 48 V/10 Ah–15 Ah lithium-ion batteries, interchangeable interface standards to link batteries and vehicles, and a Taiwan E-scooter Standard (TES) for performance and safety. The draft was announced by Taiwan's EPA on December 9, 2013, to ensure the consistency of battery and vehicle quality. Here, E2Ws include e-scooters and e-bikes. According to E2W traffic laws, e-scooters are limited to 1,000 W output, and cannot travel faster than 45 km/h on motor power alone on level ground. A driver's license and helmet are required to ride an e-scooter. E-bikes cannot travel faster than 25 km/h. There is no lower age limit, so anyone can legally ride an e-bike on roads. Furthermore, based on the swapping service availability, the construction cost of the system is the primary problem for investors. Taiwan's EPA approved grants to encourage related industries to become members of the system by, for example, subsidizing a US$50,000 for each BSS to battery swapping system operator in order to establish as much as BSSs. Because the construction of BSSs and their infrastructure is expensive, there are 30 operational BSSs open to the public in limited locations in New Taipei City, Taiwan. These have been set in seven of New Taipei City's 29 districts. The average distance between each station is about 3.5 km.

2.2 System Acceptability

One of the challenges that face the designers of human-computer interaction (HCI) systems is to produce a final system that responds to the expectations of its end-users. In other words, it has to respond to its users' needs in order to be acceptable. The production of a suitable system for end-users requires knowledge of users' needs and the environments in which they work. Furthermore, in HCI research, it is important to pursue user satisfaction and system usage. In the battery swapping system, a BSS is the only way E2W riders can use a battery swapping service. Furthermore, the battery swapping system services require the support of the above-mentioned four industries. This highlights the importance of industrial integration and user acceptance for the battery swapping system. Moreover, system acceptability is the major issue addressed in this study.

Nielsen's system acceptability model may provide an overview of the issues that influence the service acceptance of a system. Nielsen [7] defines acceptability as "whether the system is good enough to satisfy all the needs and requirements of the user." System acceptability is the goal designers should aim for and can be achieved by meeting the social and practical acceptability objectives of the system. Hence, the Nielsen system acceptability model is a combination of social acceptability and practical acceptability. Social acceptability recognizes the broader social issues that affect system users [7]. The concept of social acceptability is needed to understand the social context of users, why the activity is performed in a certain way, and how tools can be adapted or designed to support it. Social aspects may influence the adoption [8] and manner of using the product and service. Individuals evaluate social acceptability when their motivation to use technology competes with social restrictions. Individuals make decisions on the social acceptability of their actions by gathering information about their current surroundings and using their existing knowledge [9]. In addition, practical acceptability is a combination of the characteristics of the system, including its usefulness, cost/price, compatibility, reliability. Usefulness has been identified as a key objective of practical acceptability. Usefulness refers to how well a system achieves a desired goal, and is divided into two subcategories: utility and usability [10]. Here, utility refers to whether appropriate functionality is at hand, and usability refers to how well users can apply that functionality. With regard to the definition of usability, Bevan et al. [11] focus on how usability should be measured, with a particular emphasis on either ease of use or acceptability. Then, Nielsen [7] further defines a usable system as a quality attribute that assesses how easy user interfaces are to use, and outlines five usability attributes: learnability, efficiency, memorability, error recovery/few errors, and satisfaction. The International Organization of Standards (ISO) [12] defines usability as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use. The two concepts of usability and utility are highly interrelated. A usable user interface may contribute to a service being perceived as having the utility to provide appropriate functionality. Conversely, if a service has the utility to provide appropriate functionality, but can only be used or consumed via a badly designed user interface, users may avoid using the product or service.

3 Methods

A battery swapping system is an innovative service to provide a convenient charging service to E2W riders. The purpose of this study is to understand individuals' information needs of using BSS, and to further provide suggestions to improve BSS service. The Taiwan Electric Scooter Development Association (TESDA) provided ten services centers to individuals to have a free trial ride on an e-scooter. Individuals could sign up for an immersive experience for a maximum trial period of fourteen days (two weeks). These experiences gave trial riders an opportunity to understand, adapt, and overcome any battery charging and driving range limitations. After returning the e-scooters, each trial rider filled out a questionnaire and obtained a bag of polished rice as a reward. System acceptability and purchase intention were measured using a paper-and-pen survey. The survey was used to elicit feedback from the trial riders in order to improve BSS service.

The paper-and-pen questionnaire for the post-experience feedback contained the following four sections:

- Personal information: five items designed to collect socio-demographic data on age (<20, 20–29, 30–39, 40–49, 50–59, 60–69, and ≥70), sex (male and female), education (elementary, junior high, high school (senior), college, master's degree, and other), name, and phone number.
- Individual traffic demands: two items designed to collect categorical data on transportation usage (scooter, bike, walk, car, public transportation, and other) and daily commuting distance (<10, 10–19, 20–29, 30–39, and ≥40 km).
- System acceptability evaluation: two items designed to collect categorical data on practical acceptability—"Which factors made you unsatisfied with the battery swapping system and why?" (utility, usability, environment, and price)—and social acceptability—"Is the system convenient?" (yes or no). Here, social acceptability is identified as the convenience factors that influence users' willingness to use the battery swapping system, but does not provide insight into what those factors are or how they might influence riders' opinions.
- Purchase intention: three items designed to collect categorical data on respondent's willingness to own an e-scooter (yes, maybe, and no), reasons for not wanting to own an e-scooter (speed, appearance, performance, price, driving range per charge, BSS services, and other), and e-scooter usage (sports and leisure, shopping, picking up a child from school, commuting, long-distance travel, and other).

The study was conducted over a thirteen-month period between February 2014 and March 2015.

4 Results

Of 2,213 surveys, 113 involved material data omission, and the effective response rate was 95 %. Summarized demographic information of the 2,100 riders is shown in Table 1.

Table 1. Demographic information of the trial riders (N = 2, 100).

Items	Frequency (n) & Sequence	1	2	3	4	5	6	7
Gender	Item	Male	Female					
	Total	1,134	966					
	%	(54.0%)	(46.0%)					
Age	Item	30-39	40-49	50-59	20-29	60-69	≥70	<20
	Total	531	525	413	381	151	41	55
	%	(25.2%)	(25.0%)	(19.6%)	(18.1%)	(7.1%)	(2.5%)	(1.9%)
Education	Item	College	Senior	Junior	≥Master	Elementary	Other	
	Total	953	664	258	63	143	19	
	%	(45.4%)	(31.6%)	(12.3%)	(3.0%)	(6.8%)	(0.9%)	

4.1 Descriptive Statistics

The results showed that approximately 81.3 % of trial riders were using high air-polluting road vehicles as their major means of transport, including scooters (61.6 %), cars (10.0 %), and buses (9.7 %). Approximately 74.8 % of trial riders commuted less than 20 km (one way) per day. After riding the e-scooter, there were several unsatisfied checks for practical acceptability from the 2,100 trial riders, including usability (42.8 %), environment (33.1 %), utility (18.7 %), and price (5.4 %). However, approximately 79.9 % riders were still willing to use the battery swapping system, with 20.1 % of riders not finding the system convenient. With regard to the purchasing intention, approximately 3.9 % riders were willing to own the e-scooter and 76.0 % were willing to consider purchasing the e-scooter. Approximately 98.2 % would ride the e-scooter as means of transport for short-distance travel (e.g., shopping, picking up children from school, commuting to work, and sports). A more detailed analysis of the results is presented below.

4.2 Chi-Square Test

The chi-square test results (see Table 2) indicated that trial riders' one-way daily commuting distances differed significantly according to educational level, sex, and age. The results showed significant differences in the purchase intentions of e-scooter according to age. The results indicated significant differences in the BSS locations according to educational level and sex. The trial riders aged 60 to 69 years displayed a higher percentage of one-way daily commuting under 10 km (3.7 %; AR = 3.4) relative to those aged 40 to 49 years (9.4 %; AR = −1.3). Trial riders who had received college degree displayed a higher percentage of one-way daily commuting ≥40 km (1.0 %; AR = 3.9) relative to those with a junior high education (0.0 %; AR = −2.9). Men exhibited a higher percentage of daily commuting 30 to 40 km (4.1 %; AR = 3.9) relative to women (1.7 %; AR = −3.9). Women displayed a higher percentage of daily commuting under 10 km (20.5 %; AR = 4.3) relative to men (19.0 %; AR = −4.3). In addition, trial riders aged 60 to 69 years displayed a higher intention to purchase an e-scooter with the BSS (6.0 %; AR = 2.2) relative to those aged 20 to 29 years (13.2 %; AR = −2.8). With regard to BSS location, riders who had received elementary education displayed a higher percentage of satisfying with the locations (0.6 %; AR = 2.4) relative to those with a senior education (0.8 %; AR = −3.0). Riders who had received a senior high education showed a higher percentage of neutral with the locations (18.0 %; AR = 3.7) relative to those with college degree (9.0 %; AR = −2.3). The trial riders aged 60 to 69 years displayed a higher percentage of satisfying with locations (0.6 %; AR = 2.7) relative to those aged 50 to 59 years (0.5 %; AR = −2.2).

Table 2. Summarized Chi-square results

Items	Factors	Pearson's $\chi 2$	p value
Daily commuting distance	Age	39.422	.025
	Education	42.835	.002
	Sex	40.396	.000
Purchase intention	Age	24.012	.020
BSS location	Age	48.301	0.002
	Education	40.685	0.004

4.3 Cross-Tabulation

With regard to most often used transportation of different age ranges, most of them would ride scooters; riders aged <30 would take bus as their second options; trial riders aged e-scooter usage ≥30 would drive cars to be their second options. Men most often used scooters, followed by cars, buses, bikes, and walking. Women most often used scooters, followed by buses, bikes, walking, and cars.

5 Discussion

This study results in 2,100 riders who experienced the e-scooter products and the BSS service. After they were educated about the battery swapping system, BSS, E2W, the benefits and potential drawbacks by the person who work at service center, and had experienced the system for a maximum trial period of two weeks, 79.9 % of the trial riders were willing to adopt the system.

5.1 Purchase Intention

Results showed that approximately 79.9 % trial riders were more likely to adopt e-scooter products and the BSS service, with 3.9 % of riders willing to purchase an e-scooter and 76 % riders willing to consider becoming an e-scooter owner. Only 82 trial riders were willing to buy an e-scooter. During the study period, most of the e-scooter buyers needed to buy a scooter or bike. Of the 1,596 trial riders who were willing to consider buying e-scooter, approximately 1,306 (62.2 %) were scooter riders. In Taiwan, the density of scooter owners, one in every 1.67 people, is high. Because scooters are a relatively economical way to commute, the majority of scooter-based commuters are from middle- and low-income families. Even though an e-scooter is half the price of a regular scooter, most people prefer to ride their original scooter, and not to replace it with a new e-scooter. Then, 210 trial riders (10 %) were car owners, and may be willing to purchase an e-scooter if they found them practical and convenient. Of the 2,100 trial riders, 422 (20.1 %) were not willing to purchase an e-scooter and the BSS service. The results indicated that the major reason of not willing to become an e-scooter owner was driving range per charge (25.3 %), followed by e-scooter speed (14.6 %), BSS usability (14.2 %), e-scooter performance (13.9 %), e-scooter price (10.8 %), BSS service fee (8.7 %), and e-scooter design (8.5 %).

5.2 Individual Needs

Individual differences in the daily commuting distance, the purchase intentions, and BSS location of trial riders were observed. The average one-way daily commuting distance differed according to educational levels, age, and sex. The results showed that men displayed a higher percentage of daily commuting of ≥10 km relative to women. Moreover, the most used means of transport by men was a scooter, followed by a car, bus, and bike. Compared with women, their most used means of transport was a scooter, followed by a bus, bike, and walking. In addition, trial riders with a higher level of education (e.g., a college's degree), displayed a higher percentage of daily commuting of ≥40 km relative to other rider groups. Riders aged 60 to 69 displayed a higher percentage of daily commuting of under 10 km relative to other age groups. In other words, riders who were women, who had a lower level of education, or who aged more than 60 tended to travel a shorter distance in their daily lives.

Purchasing intentions differed according to age. The results showed that trial riders aged 60 to 69 years exhibited a higher intention to purchase an e-scooter relative to other rider groups.

BSS locations differed according to age and educational level. The results showed riders with a lower level of education displayed a higher percentage of satisfying with BSS location relative to other rider groups. Riders aged 60 to 69 displayed a higher percentage of satisfying with BSS location relative to other age groups.

The results may be summarized as that women, less educated people, and people aged 60–69 years could be target customers for the current e-scooter with battery swapping system market.

5.3 Information Needs

The high degree of willingness to adopt the battery swapping system (79.9 %) also indicated that the service may satisfy most of the needs and requirements of riders, but several parts of the service still need to improve. Here, two issues were discussed: social acceptability and practical acceptability. In terms of social acceptability, the convenience factor was identified as influencing riders' willingness to use the BSS. The results showed that most trial riders (86.7 %) found the proposed system convenient. The remaining 13.3 % of trial riders found that the system did not satisfy their needs. The major reason for the latter result is that 30 BSSs are not sufficient, especially when the BSSs are located far from home. In other words, the density of BSSs needs to be increased to improve the convenience to riders. Suggestions have been proposed based on these results, for example, identifying target e-scooter customers and setting up BSSs on frequently traveled routes. In addition, BSSs may be set up at nearby residential, shopping, elementary school, tourist, and sport parks. Furthermore, BSSs may be set up on routes from communities to the above-mentioned areas. The BSS infrastructure, including battery swapping machines, battery chargers, and many extra batteries, is expensive to build. Thus, further research on developing an optimal BSS choice location model is suggested.

With regard to practical acceptability, 42.8 % usability problems, 33.1 % environment problems, and 18.7 % utility problems were found and 5.4 % of trial riders were not satisfied with the price. These problems were discussed based on the trial riders' qualitative feedback. Firstly, the usability of the proposed system needs to be improved to provide more useful information on the BSS. Since the batteries stored in the station are expensive, the battery swapping system operator preferred to stock the stations with as few batteries as possible. Riders needed extra information to provide them with numbers of fully charged batteries in the BSS, because some riders found there were no fully charged batteries available. Even though the location of the 30 BSSs were summarized and posted at each BSS to help riders decide where next to go, they doubted whether there were batteries available at the next BSS. Such doubts caused them to stop trying. Therefore, it is important to develop an ideal number of batteries for the station model, battery reservation service, or innovative service in the near future to lead to better battery swapping system adoption. In addition, several riders were unable to swap their battery on their first try because they found the BSS operating procedure did not match their cognition. They also suggested displaying step-by-step information on the BSS screen while swapping their battery. The above-mentioned information suggests displaying information on the BSS screen, as well as multiple ways of retrieving integrated information technology and communications technology. For example, a 7/24 call center service is suggested to satisfy the information needs of E2W owners, especially for riders who are not part of the network generation. It is expected that riders will receive information via interphone on the BSS, telephone, or mobile phone. In addition, an application service is suggested to satisfy the information needs of riders who have internet connections. It is expected that riders will retrieve information or search for the nearest available BSS via a BSS screen, smartphone, tablet PC, or PC. This also reveals an important issue of BSS capacity limitations, which should be investigated in the near future. Secondly, the BSS environment should be improved by considering the setting location. In this study, self-service BSSs were set up at public spaces, such as gas stations, scooter parking lots, parks, and sidewalks. Several BSSs set at parking lots, parks, or sidewalks had been skipped by trial riders. The reasons were that BSSs set on sidewalks had a long distance between the e-scooter and the BSS, making it difficult to exchange batteries. Some riders could not use the BSS service because of noncompliance with parking regulations after parking the scooter right in front of the BSS. BSS settings in these locations are limited by local governments. Applying for a public space for a BSS must go through many audit requirements. Therefore, to have full support from local governments and to plan appropriate locations jointly are suggested. Of course, renting private space, such as gas stations and convenience stores, is also an option. The major reason why the battery swapping system operator did not choose this option is to avoid rent expenses. Thirdly, the system utility needs to be improved by enhancing the design of the connection interface between the battery and the BSS, as well as considering weather problems. Several trial riders could not swap their battery successfully because the connection interface between was not designed properly, causing BSS to not sense the battery after riders dropped the battery off at the station. In such cases, most of the riders did not know what happened. Then, they try to reinsert the battery again. In order to increase riders' understanding and BSS life, the connection interface and usability (e.g., providing information or signals on BSS screen or battery track to illustrate problems and solutions, or to show whether the battery is placed correctly) should be improved. In addition, most of BSSs were set in open spaces. To provide a good service, self-service BSS should be designed to be applicable in any place and any weather. However, some trial riders encountered were unable to read information on BSS screen because of strong sunlight. Some riders did not want to swap a battery during a rainy day because there was no rain shelter. Hence, waterproofing and anti-glare are important issues in the design of a BSS. Finally, trial riders needed to know the charging standard before using the BSS service and the charging fee at the time swapping battery. Most trial riders would like to compare the charging fee to the oil price when deciding on the affordability of the swapping service. However, as oil prices have continued to fall in recent years, a new challenge is created by battery swapping fees gradually becoming higher than oil prices. This also shows the importance of finding good countermeasures to overcome the impact of oil prices in the near future. In addition, trial riders were wondering why the charging fee was not shown on BSS screen. After they had been told that they may receive the charging fee and detail information the next time, most of them found the service acceptable. Of course, they further addressed the need to receive immediate information on charging fees. This is another issue that needs to be improved.

5.4 Study Limitations

The current study is limited in the New Taipei City, Taiwan. The sample is also limited to individuals who have a scooter driver's license to allow them to have a short test drive on an e-scooter. Based on traffic law, individuals must have a scooter driver's license to ride on an e-scooter. The longest trial period provided by the program was two weeks. Many people were unwilling to trial ride on an e-scooter. Therefore, the 2,100 trial riders were more open minded and willing to adopt a new product or service.

6 Conclusion

In this study, ten service centers were provided by Taiwan Electric Scooter Development Association to individuals with a free trial ride on an e-scooter and a paper-and-pen questionnaire was provided to elicit rider's feedback including personal information, individual traffic demands, system acceptability, and purchase intention after he/she had a long period of using the battery swapping system. The results indicate that battery swapping system may provide e-scooter owners with a convenient charging service and high degree of system adoption. The viability of this charging service scheme had been demonstrated. However, several problems of BSS were found and needed to be improved. BSS location, sufficient battery at stations, and ease of use should be investigated further.

Funding/Support. The author would like to express her gratitude to Taiwan Electric Scooter Development Association for assistance this study and Environmental Protection Administration of Taiwan for the funding under the grant number EPA-102-FA13-03A291.

References

1. Tsai, J.H., Hsu, Y.C., Weng, H.C., Lin, W.Y., Jeng, F.T.: Air-pollution emission factors from new and in-use motorcycles. Atmos. Environ. **34**, 4747–4754 (2000)
2. Kirsch, D.A.: The Electric Vehicle and the Burden of History, pp. 153–162. Rutgers University Press, New Brunswick, London (2000)
3. Li, J.Q.: Transit bus scheduling with limited energy. Transp. Sci. **48**(4), 521–539 (2014). http://dx.doi.org/10.1287/trsc.2013.0468
4. Liu, J.: Electric vehicle charging infrastructure assignment and power grid impacts assessment in Beijing. Energ. Policy **51**, 544–557 (2012)
5. Worley, O., Klabjan, D.: Optimization of battery charging and purchasing at electric vehicle battery swap stations. In: IEEE Vehicle Power and Propulsion Conference (VPPC), Chicago, IL, 6–9 September 2011, pp. 1–4 (2011)
6. Lombardi, P., Heuer, M., Styczynski, Z.: Battery switch station as storage system in an autonomous power system: optimization issue. In: IEEE Power and Energy Society General Meeting, Minneapolis, MN, 25–29 July 2010, pp. 1–6 (2010)
7. Nielsen, J.: Usability Engineering. Academic Press, Cambridge (1993)
8. Malhotra, Y., Galletta, D.F.: Extending the technology acceptance model to account for social influence: theoretical bases and empirical validation. In: Proceedings of HICSS 1999. IEEE Computer Society (1999)
9. Goffman, E.: The Presentation of Self in Everyday Life. Penguin Books, London (1990)
10. Grudin, J.: Utility and usability: research issues and development contexts. Interact. Comput. **4**(2), 209–217 (1992)

11. Bevan, N., Kirakowski, J., Maissel, J.: Proceedings of the 4th International Conference on HCI, Stuttgart (1991). http://www.nigelbevan.com/papers/whatis92.pdf
12. ISO 9241-11: International standard first edition. Ergonomic requirements for office work with visual display terminals (VDTs), Part 11: Guidance on usability (1998). http://www.idemployee.id.tue.nl/g.w.m.rauterberg/lecturenotes/ISO9241part11.pdf