Evaluating Usability of a Battery Swap Station for Electric Two Wheelers: A Case Study

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Abstract. This study aims to evaluate usability of BSS by using System Usability Scale (SUS), and obtain the potential needs of e-scooter riders for using the BSS. An experiment was conducted with a sample of 85 participants who had experienced a battery swapping service, operation procedure, and filled out a SUS questionnaire to evaluate the quality of using BSS. The results showed that the SUS score was 76.85. Most of participants perceived that they might use BSS frequently, and the BSS was easy to use and easy to learn. However, several participants perceived that they need to learn a lot of things or technical person support for getting going with BSS. For increasing the usability of the proposed BSS, operation procedure and user interface design should be investigated further.

Keywords: Electric two wheelers (E2Ws) · Battery swap station · Usability · SUS · Usability evaluation

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 (E2 Ws) is one of the aims of the policy. The widespread adoption of E2 W brings potential social and economic benefits, such as reducing the quantity of fossil fuels and greenhouse gas emissions, as well as environmental benefits. However, limitations on E2 Ws batteries have meant that many people are unwilling to buy the related products. In spite of the incentives offered by

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Taiwan's government, the penetration level of E2 W 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 limitations, including an expensive purchase price, short lifetime, limited driving range per charge, long charging time, and inconvenient charging, in order to improve the penetration of E2 Ws in Taiwan. This model includes providing self-service battery swap stations (BSSs). The BSS, as one promising charging infrastructure, can provide great convenience to E2 W customers without considering the all-electric range limit while the BSS is available. As of February 2014, there were 30 operational BSSs open to the public in New Taipei City, Taiwan. It is important to provide user-friendly BSS for E2 W riders to enhance their willingness to accommodate related products and service. The purpose of this experimental study is to detect user external behaviors of operating the BSS, evaluate usability of BSS by using System Usability Scale (SUS), and obtain the potential needs of e-scooter riders.

2 Literature Reviews

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 model separates the ownership of 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 2 min. BSS is one of the solutions to the limitations of the E2W battery [2–5]. 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 [6]. BSS can also be regarded as energy-storage power stations, which can alleviate the variability and uncertainty of power output of renewable energy [7] and improve the management of a power grid [8]. BSS is usually connected to the megavolt-ampere scale substation [9] and requires high power during a day, which may lead to network overload. However, the charging load forecasting model for a BSS has not been included in [7–9], and the BSS is not simply a storage power plant which should also satisfy the battery swapping demand of E2Ws [7, 8].

BSS can offer great convenience for travel range that is longer than the driving range per charge of the vehicle. Nielsen's system acceptability model may provide an overview of the issues that influence the service acceptance of a system. Nielsen [10] 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. With regard to practical acceptability, it 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 [11]. Utility is the question of whether that functionality in principle can do what is needed; usability is the question of how well users can use the functionality of a system [12]. 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.

With regard to the definition of usability, Bevan et al. [13] focus on how usability should be measured, with a particular emphasis on either ease of use or acceptability. The usability of a product is affected not only by the features of the product itself, but also by the characteristics of the users, the tasks they are carrying out, and the technical, organizational and physical environment in which the product is used [10]. Then, Nielsen [10] 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 definition of learnability is that "how easy is it for users to accomplish basic tasks the first time they encounter the design". The definition of efficiency is that "once users have learned the design, how quickly can they perform tasks". The definition of memorability is that "when users return to the design after a period of not using it, how easily can they reestablish proficiency". The definition of errors is that "how many errors do users make, how severe are these errors, and how easily can they recover from the errors". The definition of satisfaction is that "how pleasant is it to use the design". The principles of usability are concerned with the five usability attributes, and are connected to the usefulness of a product. The International Organization of Standards (ISO) [14] defines usability as the extent to which a product can be used by specified users to achieve specified goals with effectiveness (the ability of users to complete tasks using the system, and the quality of the output of those tasks), efficiency (the level of resource consumed in performing tasks), and satisfaction (users' subjective reactions to using the system). In a specified context of use. Usability plays a role in each stage of the design process. Also, the only way to a high-quality user experience is to start usability evaluation early in the design process and to keep evaluation every step of the way. The outcome of a usability study is generally expected to be some recommendations on how to improve the product and how to make it easier and more enjoyable to use.

3 Methods

The BSS is self-service only. It is important to provide user-friendly BSS for E2W riders. This study forms investigation into user-based usability evaluation methods (UEM) based on experimental and survey studies for evaluating usability of the BSSs. The materials of the study are described as below,

- SUS evaluation contained the following 10 items that designed to collect categorical quantitative data, assessed using a 5-point Likert scale ranging from strongly agree to strongly disagree — (1) I think that I would like to use this system frequently; (2) I found the system unnecessarily complex; (3) I thought the system was easy to use efficiency; (4) I think that I would need the support of a technical person to be able to use this system; (5) I found the various functions in this system were well integrated; (6) I thought there was too much inconsistency in this system; (7) I would imagine that most people would learn to use this system very quickly; (8) I found the system very cumbersome to use; (9) I felt very confident using the system; (10) I needed to learn a lot of things before I could get going with this system.

- All of the participants have to complete the operation procedure of swapping 2 batteries for an e-scooter, after researcher introduced the experimental procedure. After make user 2 batteries has been inserted in the BSS successfully, BSS may open a track with a fully-charged battery for participant to remove it from the track to the e-scooter. After 2 nearly depleted batteries has been exchange to the 2 fully-charged batteries, participant has to fill out the SUS questionnaire.

4 Results

Of 89 surveys, 4 involved material data omission, and the effective response rate was 95.5 %. Summarized demographic information of the 85 riders is shown in Table 1.

Table 1. Demographic information of the participants (N = 85)

Items \ Frequency (n) & Sequence		1	2	3	4	5
Gender	Item	Male	Female			
	Total	60	25			
	%	(70.6%)	(29.4%)			
Age	Item	<24	25-34	35-44	55-64	45-54
	Total	66	12	4	2	1
	%	(77.6%)	(14.1%)	(4.7%)	(2.4%)	(1.2%)
Education	Item	College	Senior	≥Master	Junior	
	Total	66	10	7	2	
	%	(77.6%)	(11.8%)	(8.2%)	(2.4%)	

Each item's score of SUS contribution ranged from 0 to 4. For items 1, 3, 5, 7, and 9 the score contribution is the scale position minus 1. For items 2, 4, 6, 8 and 10, the contribution is 5 minus the scale position. Each item's score is shown in Table 2. Then, multiply the sum of the scores by 2.5 to obtain the overall value of SUS. The results showed that the average SUS score to use BSS for the experimental participants was 76.85.

Table 2. Scores of each item for SUS (N = 85)

Items	$\bar{X}$	σ
1. I think that I would like to use this system frequently	3.55	0.71
2. I found the system unnecessarily complex	3.05	0.93
3. I thought the system was easy to use efficiency	3.28	0.86
4. I think that I would need the support of a technical person to be able to use this system	2.99	1.10
5. I found the various functions in this system were well integrated	3.11	0.83
6. I thought there was too much inconsistency in this system	2.94	0.87
7. I would imagine that most people would learn to use this system very quickly	3.27	0.97
8. I found the system very cumbersome to use	3.08	0.91
9. I felt very confident using the system	3.16	0.84
10. I needed to learn a lot of things before I could get going with this system	2.31	1.21

4.1 t Test

The t -test results indicated that the item 4 "I think that I would need the support of a technical person to be able to use this system" differed significantly ($t = 2.135$, $p = .038$) between men ($\bar{X} = 3.15$, $\sigma = 1.09$) and women ($\bar{X} = 2.6$, $\sigma = 1.08$).

5 Discussion

SUS provides to be a valuable evaluation tool, being robust and reliable. It correlates well with other subjective measures of usability. SUS has been made freely available for use in usability assessment, and has been used for a variety of research projects and industrial evaluations. In this study, the results showed that the SUS score to use BSS for the experimental participants was 76.85. Most of participants perceived that they might use BSS frequently, if they were e-scooter owners. In other words, BSS may provide an conveniently charging service, especially for the city residents. Also, most of participants perceived the BSS was easy to use and easy to learn. Therefore, they felt very confident using BSS. However, still had several participants found the BSS very cumbersome to use.

The results indicated that the major problem of using BSS was participants needed to learn a lot of things before they could get going with BSS (item 10), followed by too much inconsistency in BSS (item 6) and needed the support of a technical person to be able to use BSS (item 4). Furthermore, gender difference had been found in this study. With regard to the need of personal support for using BSS, women were more likely to need the technical person support then men needed. To sum up, the BSS may provide user an okay quality to use it. Streamline operation procedures and complexity of the interface are the way to enhance the BSS usability in the near future.

6 Conclusion

A battery swapping model has been proposed to provide a faster charging service and lower the charging cost. The model provides self-service BSSs to increase user convenience. Therefore, BSS's usability plays an important role to lead a convenient charging services and market acceptance. The results of this study indicated that the SUS score was 76.85. It shows the quality of use for BSS and the way to improve BSS. In order to increase the quality of use for the proposed BSS, operation procedure and user interface design should be investigated further.

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