ISSN 2541-223X

BASIC PLANNING OF E-BIKE SHARING SYSTEM AT SEBELAS MARET UNIVERSITY

Lydia N.N. Hidayati[1]*, Djumari[1], Fajar S. Handayani[1]

[1] *Department of Civil Engineering, Sebelas Maret University, Indonesia*

ABSTRACT

Encouraging students to shift their modes to use more eco-friendly vehicles is a real action of green campus realization at Sebelas Maret University (UNS). Electric bike (e-bike) is introduced as an alternative mode of transportation for student on-campus. The electric bike is pedal assist bicycle, which is equipped with electric motors and batteries. It has numbers of benefit such as minimal pollution, zero emission, and energy saving. In concern to succeeding the e-bike program, e-bike sharing system was planned. The problem arose was how to plan the e-bike share system so that the system will be well-used and efficient. This paper aims to describe the planning and design guideline of e-bike share system by Institute for Transportation Development and Policy (ITDP). Planning process could be broken down into two steps: demand analysis and detailed planning and design. The method used was descriptive analysis methods in which the data collected through a survey to obtain the demand model of the e-bike. Meanwhile, the elements of e-bike share being planned covered the number of station and the displacement, the number of bikes and the number of docks in every station. The e-bike share elements design was then measured by three basic planning parameters by ITDP. From the measurement, there were some parameters which were not fulfilled by the design. Those parameters were station density ratio and bicycles to population ratio. Station density ratio was below the standard due to the large coverage area being measured including the open space which there is no student activity in it. Meanwhile, the bicycles population ratio parameter was not meet the standard, due to the number of bikes proposed was based on the demand analysis. The last parameter, docks per bike ratio, was fulfilled by design.

Keywords: Basic planning; E-bike; Sebelas Maret University; Sharing system.

1. INTRODUCTION

Green campus programme at University Sebelas Maret (UNS) is aiming to bring into reality sustainable campus which is a campus that able to create a clean, relaxing, and comfortable atmosphere as well as support the dynamic campus life. There are six criteria for the green campus; among others is the arrangement of transport system within campus based on green transportation idea. In line with the concept of green transportation, students are encouraged to shift their modes to use more eco-friendly vehicles. The bicycle as a mode which is non-polluting, no emissions and no need for fuel is expected as an alternative mode for the students who are travelling within campus area. However, the conditions of UNS campus with hilly topography, an average temperature of 30^0C and high humidity about 75% become factors decreasing

*Corresponding author's email: lydia.hidayati@gmail.com

interest of the student in cycling on campus. Regarding this condition, an idea arose to introduce the use of new transportation modes, electric bicycle (e-bike). The e-bike is pedal assist bicycle, which is equipped with electric motors and batteries (Kang An, et al, 2013). Flexibility, comfortability equivalent to using private vehicles and the latest technology is the advantages offered by e-bike, in addition to the low consumption of energy used and the lack of pollution produced (Weinert et al, 2007). Therefore, e-bike is suitable as transport mode within campus UNS since it is not producing pollution and emission, using renewable fuels, yet is able to provide the convenience of transportation in the tropics climate with a hilly topography.

E-bike program was planned as bicycle sharing system in which the campus authority providing numbers of e-bike for the student for their trip within the campus. The essence of bicycle sharing system is that anyone can pick up a bike in one place and return it to another. The bike-share system has been widely adopted by many cities in the world to promote cycling as a viable and valued transport option. Each city has developed their own bike-share system adapting it to the local character, such as topography, weather, infrastructure, and culture. The largest bike sharing systems are in Hangzhou and Shanghai, China (ITDP, 2013). Institute for Transport Development and Policy stated that many of the most successful system shares have certain standard features. Those features are a dense network of stations, comfortable, user-friendly in terms of technology, safety, access and price. This research attempted to adopt the bike-share planning on a smaller scale, within campus UNS. Bike-share within the campus is expected to improve air quality, enhance mobility compared to walking, improve the health of the user, improve image and branding as a sustainable campus, generate potential entrepreneur, improve the image of cycling as well as attract new cyclist. Even on a smaller scale, bike-share within campus need to be carefully planned so that the system will be well-used and efficient.

2. BIKE SHARE SYSTEM

The bike-share system also known as Public bicycle system, at the first time, has been introduced in The Netherlands in 1965. Since then its evolution has been categorized into four key generations. The first generation is called white bicycle plan. Bicycles were unlocked and located haphazardly throughout the city. They could be picked up and off anywhere in the city, and their use was free of charge. The main disadvantage of the first generation system is bicycle theft and vandalism. The second generation developed as a countermeasure of the problems of the previous generation. At this generation, bicycles are locked on specific docking at a station where bicycles were borrowed and returned. The next generation, advanced technology was applied for check-in and check-out in docking stations as well as in the improvement of the information system. The fourth generation is the demand-responsive system. Based on real-time demand, bicycles are moved from one station to another to ensure that bikes and empty racks are always available for users pick-up and drop-off at any station (Jingxu Chen, et al, 2014).

Initially, before planning the bike-share, there are several essential elements need to be considered. These elements include bikes, stations, the technology needed, as well as policy. Bike element related to the type of bike which will be used is it manual or the e-bike one. Station, an area where the bike, docking, and terminal are located, can be designed manually or automatically or some variation in between. It can be in modular design or permanent. Dockings are spaces at the station where bikes are parked and locked while terminals are places where users can get information about the system. Technology being used also become the essential thing, since it is determined the operation of the system and related to investment. The policy is made to ensure that system works successfully.

The planning process of the bike-share system can be composed of three steps, those are conducting a feasibility study, detailed planning, and design, as well as creating business and financial plans. This main focus of the study was detailed planning and design of the e-bike share system yet no financial analysis was considered. Therefore, the designed system are developed in regard towards user convenience.

The detailed planning and design of the e-bike share system in this paper referred to the guidelines of bike sharing system by Institute for Transportation and Development Policy (ITDP) in the US. ITDP guidelines have set up several rules of the bike share system elements. The guidelines cover planning guidelines, bike guidelines, and station guidelines. ITDP also developing the performance metrics to assess the efficiency of the system after being implemented. The performance metrics measure an average number of e-bike daily use and an average daily trip of the resident. The planning guidelines will be described in detail in the following chapter.

Bike guidelines require bike which durable, attractive and utilitarian. Durable means that the e-bike is not easily broken. For e-bike, the most common problem related to durability is the battery capacity. Therefore, it is recommended to accommodate the e-bike station with charging facilities or additional battery. In terms of attractiveness, e-bike has already had the new technology of human based vehicle. The usage of e-bike in UNS is convenient due to the pedal assist technology.

Rudolf and Lackner in 2013 stated that the function of stations are substantial in e-bike share system since it is where the start and the end place of the system. Therefore, the number of bikes and docking spaces in each station should be enough for the student to be able to use or to park the bike. As the gate of e-bike share program, stations has to equip with clear signage and clear use instructions as well as should has locking mechanism and security system. The station also requires quick and easy e-bike check-in or check-out system.

3. DEMAND ANALYSIS

The feasibility study was held to set up the important parameters which will guide the planning and design process. The prior process of the feasibility study is to determine the objective of a program follows with specifically the coverage area and size of the system. Feasibility study ideally should include three main components, demand analysis, analysis risks and barriers and integrated with the financial analysis to analyze whether the program will be financially feasible and under what conditions. Due to some limitations, this paper skipped the financial analysis and the analysis of risks and barriers and only focusing on demand analysis.

The objectives of e-bike programs are to improve mobility options for students in UNS as well as an initiative the sustainable transportation within the campus. Based on this goal, e-bike program was specifically destined to the area within the campus and should be able to provide service for the student in UNS. E-bike sharing system allows an e-bike to be used together for among the student in UNS since the ownership is the property of UNS. Further, since the e-bike only covering the mobility within campus so the time travel would not be too long. Due to these reasons, it is not necessarily to provide e-bike as much as the number of people in UNS. Moreover, UNS has not applied prohibition of private motor vehicles so that e-bike only became an alternative mode. Therefore, demand analysis is needed to identify the potential number of system users and forms the basis for all other analysis.

Demand analysis was performed by developing e-bike demand model. The e-bike demand model determines the proportion of students who were going to use e-bike. A survey has been conducted by distributing questionnaire towards 380 students of UNS. The questionnaire consists of two parts, the general characteristic, and modal choice characteristic of respondents. General characteristic intended to gain an overview of students mobility, whereas modal choice related to services needed by the student to use e-bike.

The general characteristic questionnaire consists of question about the semester, allowance, vehicle ownership, how long stayed on campus, places in campus frequently visit, distance to campus and gender. While travel time, mileage, cost, route, parking facilities, the policy became data obtained from the modal choice questionnaire. Both general characteristic and modal choice portray the independent variables of the demand model. The data obtained from the questionnaire then being transformed into a scale to be quantified.

Demand model developing based on regression analysis, yet only the significant independent variables being used. The possibility of using e-bike derived from dependent variable (Y), while travel time, vehicle ownership, distance to campus became the independent variables respectively. The equation of e-bike demand model is provided in equation 1.

$$\ln Y/(1-Y) = 5{,}909 - 0{,}650\ X_1 - 3{,}095\ X_2 - 1{,}292\ X_3 - 1{,}088\ X_4 \quad (1)$$

From the equation 1, several conclusion can be obtained. All of the significant independent variables are have a negative impact toward the probability of e-bike usage. The longer the travel time (X_1) within campus the lower the potential user of the e-bike. Both X_2 and X_3 are related to vehicle ownership. X_2 represent students who using a car while X_3 represent students use a motorcycle. Based on the coefficient of X_2 and X_3, it is concluded that student using cars are less desire become e-bike user than the student with motorcycles. The last variable is distance to campus, the farther the distance to campus the less the interest of student using e-bike.

The model obtained before then be used to calculate the probability of e-bike user by providing the value of the independent variables. The value of the independent variables is derived from data which were obtained previously. The average travel time within the campus using e-bike is less than 5 minutes. The farthest distance within the campus is one kilometer if the average speed of e-bike are 20 km/hour then the longest travel time needed is 3 minutes. X_2 and X_3 represent the percentage of the student using car and motorcycle as their modes in the campus. From the data, it was obtained 10 % and 70% of students are using car and motorcycle respectively. The average distance to campus of the student is 4 km. Therefore, the predicted probability of e-bike user within campus UNS based on the model is 16.70%. The number of student in UNS is 30,722 thus the predicted of e-bike users is 5,130 person.

E-bike sharing system would enable an e-bike being used by some students. Learn from the campus bike program in Berkeley university, an e-bike is able to use by students 16 to 20 times a day. Considering this fact, the number of e-bikes ideally provided is 256 bike. Due to investment cost consideration, it is advised to prepare e-bike as much as thirty percent of the ideal number combined with the manual bike to fulfill the rest requirement.

4. DETAILED PLANNING AND DESIGN

Detailed planning and design needed to conduct properly so that the e-bike share system will be well-used and efficient. Institute for Transportation and Development Policy (ITDP) in the US has developed planning and design guidelines that are characteristic of the best-used and most efficient system of bike share system. The guidelines are based on the performance of existing bike share systems around the world. The e-bike shares planning guidelines of ITDP sets the minimum system coverage area to 10 km2, 10 – 16 stations per km2, 10 – 30 bikes for every 1,000 resident within the coverage area and 2 – 2.5 docking spaces for every bike.

The coverage area of e-bike share system in campus UNS is illustrated in Figure 1. UNS has a land area of 9.37 kilometer square with land use are vary from faculty, main campus library, student center, banks, language training center, etc. The spaces in UNS later being divided into ten zones based on the area of each faculty with consideration of building surround it. Each zone represents the coverage area services by a particular station. The zone division and the location of the station can be seen in Figure 1. The summary of stations and its coverage area is given in Table 1. Numbers of bikes and docks in each station also being summarized in Table 1.

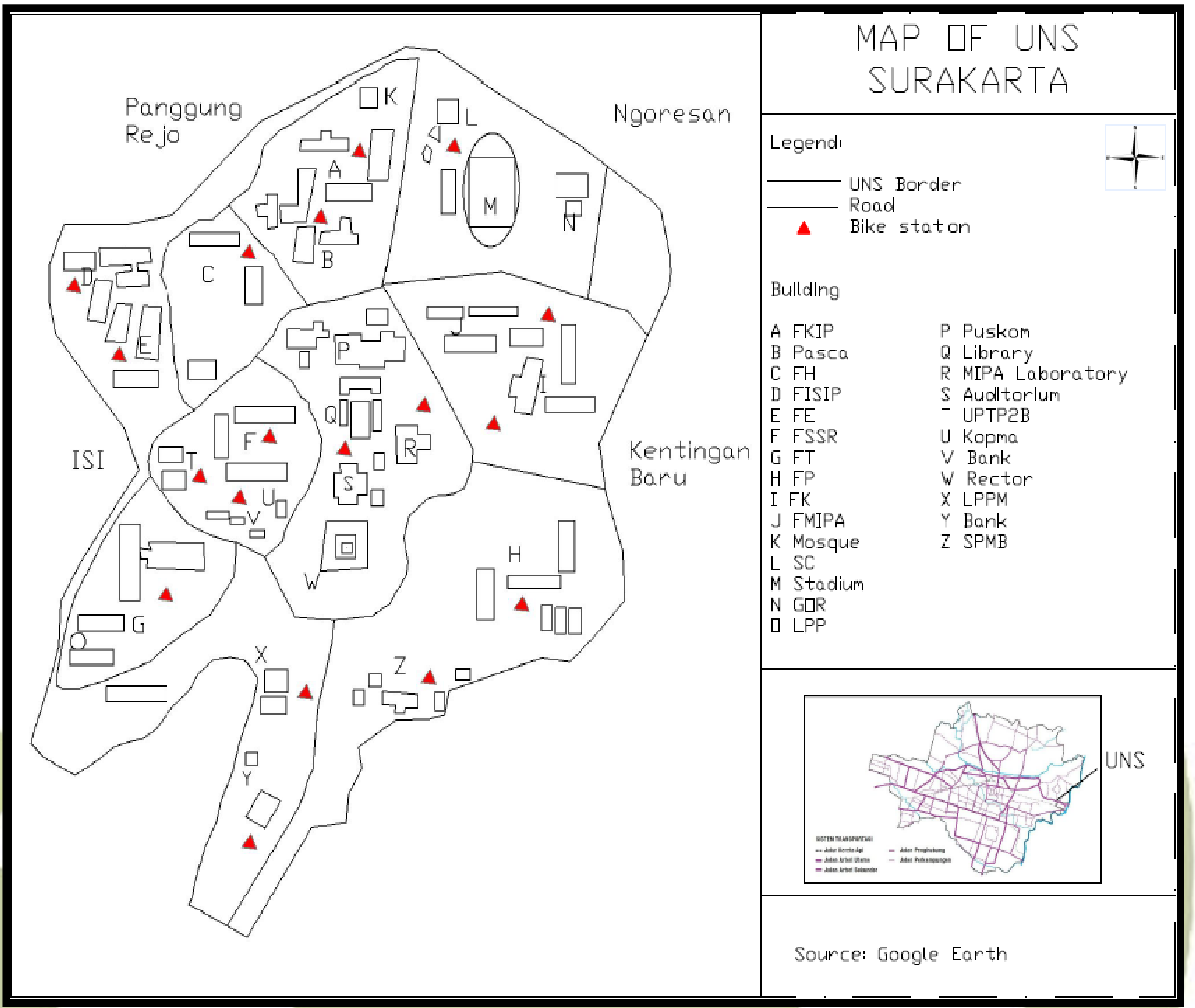

Figure 1 Layout of zone division and location of e-bike station in UNS

From the Table 1, the average coverage area of a station is 0.40-kilometer square. The coverage building can be a faculty or other facilities which frequently being visited by students. Zone VI, VII, and X are destination zones thus it was assumed that no student start their trip from the zones. However, the zones still equipped with ten bikes and twenty docks to as the minimum services. The placement of docks and bikes within the area of the station is divided equally based on the number of station in a particular zone. In addition to the availability of bikes and docks, the station also equipped with information board which contains the map of stations and user’s instructions.

Table 1 Summary of e-bike share system elements in UNS

Zone	Coverage building*	Number of student	Coverage area (km^2)	Number of station	Number of docks	Number of bikes
I	K, A, B	8428	0.31	2	124	62
II	C	1726	0.44	1	26	13
III	D, E	6854	0.56	2	100	50
IV	G	3162	0.75	1	46	23
V	F, T, U, V	2715	0.56	3	40	20
VI	O,P,Q,R,S,W	0	1.09	2	25	10
VII	X,Y	0	0.45	2	25	10
VIII	H, Z	3232	1.30	2	48	24
IX	I, J	4605	0.92	2	68	34
X	L,M,N	0	0.93	1	25	10

*Coverage building referring to Figure 1

5. BASIC PLANNING PARAMETERS

Numbers of bikes and stations determined the e-bike share system size. From a user perspective, the main consideration in using a bike for their trip is the density station and the availability of the bikes. The location of stations within campus should be able to ensure that no matter where the user is, there will be a station within convenience walking distance to both the origin and destination of their trip.

ITDP has proposed three basic planning parameters to ensure that the designed e-bike share system will create a network that users can rely on and trust. The parameters are station density ratio, bicycle to population ratio and docks per bike ratio. Station density ratio is the average number of stations within the particular coverage area. The station density throughout the coverage area is supposed to be uniform to create a reliable network. The average station density in campus UNS is 6.08 station per kilometer square, the detailed station density is presented in Table 2.

Table 2 Summary of three basic planning parameters

Zone	Station density ratio	Bicycles to population ratio (per 1000 resident)	Docks per bike ratio
I	12.93	7.36	2
II	2.27	7.53	2
III	7.14	7.30	2
IV	1.33	7.27	2
V	16.07	7.36	2
VI	3.67	10	2.5
VII	8.89	10	2.5
VIII	3.08	7.42	2
IX	4.35	7.38	2
X	1.08	10	2.5

The second parameter, bicycles to population ratio, measure the average number of bikes per person in the coverage area. This scale should be large enough to meet the demand, but not so large as to have fewer than four daily uses per bike. The average bicycle to population ratio in campus UNS is 8.16 bikes per 1000 person while the detailed is in Table 2.

The last parameter will be the docks per bike ratio. Docking spaces should be more than the bike available on the site to ensure that there will be parking space for a bike. The lower the docks per bike ratio the higher the effort in bike redistribution in order to avoid station saturation. Table 2 shows the detailed docks per bike ratio with the average scale is 2.15 docks per bike.

6. CONCLUSION AND RECOMMENDATION

In recent years, Sebelas Maret University is vigorously campaigning the green campus program, among all means including encouraging the student to shift their modes to use more eco-friendly vehicles. Related to this matter, e-bike share program was proposed. This paper described the proposed design of e-bike share system in UNS campus. The system was designed by referring to the standard of The bike-share planning guidelines by Institute for Transportation and Development Policy. The detailed planning and design of e-bike share system in this paper consist of demand analysis and layout of e-bike share element. Demand analysis conducted by a survey which then analyzed to obtain demand model using binary logistic regression. The elements of e-bike share being planned covering the number of station and its location, the number of bikes and the number of docks in every station. The e-bike share elements design was then measured by three basic planning parameters by Institute for Transportation Development and Policy. From the measurement, there were some parameters which were not fulfilled by the design. Those parameters were station density ratio and bicycles to population ratio. Station density ratio was below the standard due to the large coverage area being measured including the open space which there is no student activity in it. Meanwhile, the bicycles population ratio parameter was not meet the standard, due to the number of bikes proposed was based on the demand analysis. The last parameter, docks per bike ratio, was fulfilled by the design.

Future research would be useful in at least the three following directions. First, the more data collected to perform demand analysis, as well as considering the modal choice of the student by using logit model. The demand analysis is necessities to determined the number of bikes needed by the users. Second, the layout of docks and bikes in a station. The layout of docks will determine the spaces needed to locate the station. Further designing the most effective station layout which will make the system easier to be used. Third, the most problem arises by implementing bike share system is regarding the redistribution of the bike. Thus, the redistribution model of bike share system within campus UNS needs to be studied later to assure that e-bike share operation system will function properly.

7. REFERENCES

http://www.greencampus.uns.ac.id

Institute for Transportation and Development Policy (ITDP) 2013, *The Bike-Share Planning Guide*, Institute for Transportation and Development Policy, Mexico City.

Jingxu Chen, et al , (2015), *Determining the Optimal Layout Design for Public Bicycle System within the Attractive Scope of a Metro Station*, Hindawi Publishing Corporation, Vol 2015, Article ID 456013

Kang An, et al, (2013), *Travel Characteristic of E-bike Users: Survey and Analysis in Shanghai*, Procedia-Social and Behavioral Sciences 96, pp 1828 – 1838

Rudloff, C, Lackner, B, (2013), *Modelling Demand for Bicycle Sharing Systems – neighboring stations as a source for demand and a reason for structural breaks*, Journal of the Transportation Research Board, published at https://www. Researchgate.net/publication/259753692

The Parking and Transportation Department, (2006), *Campus Bicycles Plan*, University of California, Berkeley

Weinert, J, et al, (2007), *The transition to electric bikes in China: history and key reasons for rapid growth*, Transportation journal, Vol 34, issue 3, pp 301 – 318