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CRITICAL SUCCESS FACTORS AND PERFORMANCE EVALUATION MODEL FOR THE DEVELOPMENT OF THE URBAN PUBLIC BICYCLE SYSTEM

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ABSTRACT

The public bicycle is a low emission vehicle that provides social, environmental and traffic related benefits. Currently, many cities around the world have integrated a public bicycle system (PBS) into their urban blueprint as a new transport model for mainstream public transport system. Taipei City has also set up a PBS. The main purpose of this study is to create a model and evaluate the service performance of Taipei's PBS by adopting the Fuzzy Delphi and IPA methods. The study results can provide the operators with the necessary foundation for operational improvements. Moreover, the study architecture, methods and model can serve as important reference to promote PBS in other cities.

Contribution/ Originality: The paper's primary contribution is constructing a performance evaluation model for the urban public bicycle system. And the second contribution is investigating the critical success factors about development of the PBS.

1. INTRODUCTION

Public bicycle system (PBS) is a system that allows citizens to pick up and drop off bikes in different stations in the city. PBS also known as a bicycle sharing system has been introduced as part of the urban transportation system, which provides different forms of public transport for use by the general public to reach various destinations (Lin and Yang, 2011). The PBS concept is to make bicycle rental available to people in the urban area for free or with low rental charges, so as to transfer the service of short-trip private transport vehicles to public bikes (Pai, 2013). In many cities, taking public transport and cycling as part of the daily commute is considered an efficient means to reduce air pollution, traffic jams, and carbon emissions. The PBS has been proven effective in promoting cycling in many urban areas, as well as using this approach together with taking public transportation (Jäppinen *et al.*, 2013). Shaheen and Guzman (2011) think the PBS links the gap between the mass transport system and the destination, and also provides more transportation options for the mass public. The PBS resolves the problem of "the last mile" by reducing pollution. Its low rental can help users save money on commuting costs. Therefore, the PBS brings about social, environmental and transport related benefits.

As stated by Transport Canada, the promotion of the public bicycle will increase not only the number of people riding a public bicycle, but also the number of people having their own private bicycles, which further promotes the bicycling trend in the entire city. In this way, a virtuous cycle is formed (Transport Canada, 2009). The public bicycle scheme would indirectly drive the trend of using bicycles to travel from one place to another. When more and more people choose to use this as their transportation mode, the marginal effect of the public bicycle scheme will be increased along with the number of users (DeMaio and Gifford, 2004; Goodman *et al*., 2014). Beswick (2008) points out in the study that the riding safety will be enhanced if there are more bicycles on the road. Moreover, the convenience of the public bicycle scheme will get the bicycle into the mainstream urban transport.

A good public bicycle promotion scheme can promote the physical and mental health of the citizens. If they consider the public bicycle as a transport vehicle in their daily life, they will develop a good habit of physical exercise through biking, which can further reduce the possibility of obesity and cardiovascular disease. The urban air pollution will be worsened by the increasingly high number of automobiles (Pucher and Dijkstra, 2003). The air pollution especially in the large cities will be more serious. By carrying out the public bicycle scheme, automobile traffic can be reduced and consequently reduce the air pollution caused by the waste gas emission of the automobiles, thus improving the overall health condition of the citizens (Vidalis *et al*., 2010; Woodcock *et al*., 2014). The Public Bicycle System (PBS) is not merely a low emission vehicle, but also something that can help people keep fit. Thus, it plays an increasingly critical role in the development of the transport system (Hsieh and Chang, 2011).

At present, more than 200,000 Public Bicycle Systems (PBS) are set up in 30 countries and 135 cities around the world. The public bicycle scheme redefines the image of the bicycle and also satisfies the short-trip demands in the city. It creates a new transport model in the mainstream public transport system (Hsieh and Chang, 2011). Taipei PBS in Taiwan turns the losses into profits in the fourth year after the trial operation since 2009. Currently, the daily turnover rate of YouBike is 12 times per bicycle, which ranks first globally in terms of the daily turnover rate (Lu, 2014).

The current studies related to public bicycles are mainly based on the cases in Europe and America, while the understanding and exploration of the Asian cities are rare. Moreover, the European and American culture shows a difference from that of Asia (Hsieh and Chang, 2011). The study will explore Taipei PBS. Therefore, the purpose of this study is to determine the evaluation factors in creating PBS by reviewing literatures and gathering expert opinions and user satisfaction level through a questionnaire survey. The service performance of Taipei's PBS is also evaluated in this study. The operation evaluation model is constructed to serve as a reference for the related organizations to make improvements and for the cities that intend to promote PBS in the future to be able to prepare a comprehensive plan.

This study creates the preliminary architecture by gathering literature and determining the evaluation factors using the Fuzzy Delphi method and other related studies (Jafari *et al*., 2008; Hsu *et al*., 2010). After that, it conducts operation performance evaluation with IPA which is widely applied and researched (Deng, 2008; Deng and Pei, 2009; Wang *et al*., 2010). Therefore, the study adopts the suitable study methods.

2. PBS AND LITERATURE REVIEW

The study mainly explores the service performance of Taipei's PBS. In the section below, the PBS concept is introduced and its development condition in Taiwan and Taipei are discussed. Using related literatures, the study framework is developed.

2.1. Concept of the Public Bicycle

The concept of bicycle sharing system originated in Europe. With a long development history, it is re-valued in the last two decades due to the topics of low emission transport and sustainable development. This system is widely introduced in many large cities in recent years. The content and scheme name of the developed bicycle sharing

system vary in each country, such as public bicycle scheme, public bicycle system (Hsieh and Chang, 2011) public bicycle program and bike sharing service program, but it essentially refers to a generic concept. In this study, it is named the Public Bicycle System (PBS).

The PBS is a system that is provided for the citizens to get and return the public bicycle at the rental station freely. The primary purpose of such system is to provide a transport vehicle, especially for the short-trip travel between the mass transport point and the destination. The operation efficiency of the public bicycle is subject to the user number. A high user number will bring high operation efficiency. Thus, in order to encourage the mass public to ride the public bicycle, the rental of the system is generally very low or even free. The public bicycle is quite a fast and flexible transport vehicle for short-trip travel. Therefore, compared with the private transport vehicle and mass transit system, the public bicycle is considered as an efficient alternative. To develop complete mass transport network in the city, compound transportation is an indispensable model, while the public bicycle plays as a link in the compound transport network. The urban commuters can use the system as the transport vehicle connecting their place of work, the school, the destination and the nearby mass transport site (Pai, 2013).

A typical PBS consists of a fleet of bikes specially designed for PBS, a network of bicycle rental stations where the citizens can pay for, pick up and return the bikes, and where the bikes are recorded. It also has a maintenance mechanism, as well as a dispatching system that guarantees sufficient bikes available for rental service. The PBS should possess the following features. Bikes may be rented at one station and returned to another. Automated self-service should be provided, and rented bikes should be returned quickly (Curran, 2008; Beroud *et al.*, 2010; Hsieh and Chang, 2011).

2.2. Development of the Public Bicycle System in Taiwan

Kaohsiung's C-Bike (City-Bike) system launched in 2009 in Kaohsiung is the first PBS, which is followed by Taipei YouBike (UBike) system. These two systems developed by Taiwan's operators show great influence on the development of low emission vehicles in Taiwan (Pai, 2013). Due to the poor operation performance, the partner of Kaohsiung's C-Bike decided to give up the operation concession in 2010. In 2011, Kaohsiung Rapid Transit Corporation took over the operation rights. At the same time, Taipei UBike faced a similar dilemma. In view of this, UBike released the new generation public bicycle rental system and made several changes on the operation strategies in August 2012. By doing so, it expected to increase the utilization rate of public bicycles through simplifying the procedure and reducing the rental. UBike has achieved great growth after transformation (Pai, 2013).

Currently there are 196 stations in total in Taipei, and other cities in Taiwan have gradually set up the PBS, including 33 stations in New Taipei City, 15 stations in Taichung and 50 stations in Changhua County (Youbike, 2014).

2.3. The PBS in Taipei City

Taipei U-Bike system is a BOT project obtained by GIANT Company. It initially conducted a trial operation with 500 bikes at 11 stations in Xinyi District, which suffered great losses during the first three years. The Taipei Municipal Government saw the urgency to promote a pollution-free city through the use of bikes. The two parties worked out many items in detail after a thorough discussion for many times, such as setting up more stations, providing more bikes, and subsidizing the first 30 minutes of use during the first two years (Lu, 2014). In October 2014, the turnover frequency per bike in Taipei YouBike reached 12.69 times/day (Youbike, 2014).

The bikes used in Taipei's PBS are not the same as those available on the market. They are specially developed, designed and manufactured for public use. The frame has a low step-through design, equipped with front and rear fenders and front basket, as well as rear mudguard with wrapped design. A bright yellow color is used, which also serves a function on the dress guard. The speed control system uses an internal three-stage derailleur system. The

motor is built into the front tire, which supplies power to the front and rear LED lighting. The saddle height is adjustable. The bicycle is also equipped with a dual-function bike lock for docking and temporary stops. The rental site has a self-service interactive KIOSK. Users may register using an E-pass (EasyCard and Pass Card) and mobile phone for fast YouBike membership application. The docking pillar is equipped with a control panel which has an LED display that allows users to see the deducted amount, card balance and problems that may occur (Youbike, 2015).

Payment may be made using EasyCard, Pass Card, Credit Card or CHT's HiNet. The charge rate is NTD10 per 30 minutes within 4 hours, NTD20 per 30 minutes within 4-8 hours, and NTD 40 per 30 minutes for more than 8 accumulated hours (Youbike, 2015). In the past, usage under 30 minutes was free of charge, but since April 2015, a NTD5 fee has been implemented. The current exchange rate is about EUR1 to NTD36, and USD1 to NTD33 (Bank of Taiwan, 2015).

YouBike has 3 service centers with full-time personnel to provide assistance during its service hours from 08:00 to 20:00. A 24-hour self-service interactive KIOSK is found at every rental site. There is also a 24-hour hotline to help and assist users. There is an official site and mobile APP that provide detailed introduction, information and map of the rental sites with real-time rental information. So, users can easily check whether bikes are available at each rental site. Professional repair, inspection and maintenance services are also available at every site.

UBike allows users to rent bikes from one station and return them to another station, providing convenient service and customer satisfaction. It has its own fleet of trucks to transport UBikes to each rental site (Youbike, 2015).

2.4. Studies Related to the Public Bicycle

A. Tough and Practical Bicycle Frame Design

The PBS bikes are specially designed to distinguish them from the common ones. In terms of the material, it usually adopts the advanced material and puncture-proof tires, so as to avoid the possible wear of public bikes caused by different users. Even the bikes are equipped with such chipset identification application as GPS and RFID, or other types of tracking device, which can facilitate the management of the entire system, and prevent theft or damage incidents (Midgley, 2011). Generally, the special public bicycle design consists of the following elements (JZTI and Bonnette Consulting, 2010): Step through frame, Adjustable seat, Front basket, High Stability Kickstand, Heavy Duty Material, Chain Guard, Bicycle Bell, Secondary Lock, Disc Brakes, Lights, Fenders, 3 Speed Derailleur and Puncture Resistance Tires.

Whether the design of the bicycle frame can meet the demands of the mass public and achieve the wear-resistant function will affect the user's intention to use. Moreover, it will influence the impression of the mass public towards the PBS.

B. Convenient Rental Regulation

In terms of the rental, in order to encourage the mass public to use the public bikes for short trips, most PBS systems provide free use for the first 30 minutes. The longer the period is, the higher the rental rate will be. That is the case for the public bikes in Paris, Lyon and Montreal. In Barcelona, renting the public bicycle for more than two hours will be fined additionally. In this way, it encourages the people to rent and return the public bicycle quickly and increase the rental rate and turnover rate of the public bikes (JZTIBC, 2010).

Through rental reduction and exemption, or free extension of the rental period, people are encouraged to return the bicycle to the rental station with fewer bikes, so as to reduce the re-distribution rate of the bikes to each rental station by truck, and further achieve sustainability (Shaheen and Guzman, 2011). Taipei UBike simplifies the membership procedure. People can easily join the membership with their EasyCard and mobile phone number, so as

to increase their intention to use. All these are the favorable factors to promote the rapid membership growth (Lu, 2014).

Unlike non-members, PBS members prefer to own or use private bikes. This could encourage more people to choose bikes as their form of transportation (Fishman *et al.*, 2013).

C. Safe Riding Environment

Saneinejad *et al.* (2012) study shows that a more complete bicycle route network will attract more users. Schlossberg *et al.* (2005) study shows that a high number of turnover indicates the high density of the route network. However, the trunk road crossings are quite dangerous to the bicycle riders, so it reduces their intention to pass through. Besides, too much design of dead ends will reduce the connectivity of the entire network, and further significantly reduce the user's intention to use. As mentioned in Chung (2009) study, the safety of the commuting environment is the most valued by the commuters in the metropolitan area of Taipei. The bicycle guideline of New South Wales, Australia, suggests that the design of the bicycle transport system should follow the following five principles: coherence, directness, safety, attractiveness and comfort (Roads and Traffic Authority NSW, 2005).

D. Appropriate Rental Stations and Facilities

Whether for recreational traveling or commuting, the site of the rental station is a critical influential factor, indicating the selection of the rental station plays a critical role on the operation performance of the entire system (Pai, 2013). As shown in the Public Bicycle Feasibility Evaluation Report of Seattle, the U.S., the tourist attractions are an important destination for the public bicycle users (Bike-Share Studio, 2010). Jensen *et al.* (2010) mentioned the correlation between the parking facilities and the use of the public bicycle. The study validates it will double the rate of public bicycle riders if the bicycle rental station is within 200m away from the automobile parking facility. Beroud *et al.* (2010) study on the use of public bicycles in France shows that 75% of the riding journey is shorter than 3km.

The recommendations pertaining to station size and location decisions are based on the bicycle-sharing system (BIXI) data in Montreal gathered by Faghih-Imani *et al.* (2014). Lin and Yang (2011) proposed a model that attempts to determine the number and locations of bike stations.

E. Complete Work Affairs of Management and Service Center

The user won't necessarily return the rented bicycle to the same station after using. In order to cope with such asymmetric demands of public bicycle trips, the PBS should include a carrier for public bicycle re-distribution, which is used to carry the available bikes from the rental station with fewer customers to the rental stations with more customers (Curran, 2008).

In case the rider confronts an unexpected emergency when riding the public bicycle, special personnel shall be responsible for handling such. The common issues faced by the public bicycle riders include the software fault, hardware wear, riding at anchor, or riding accident. The official site of Taipei U-Bike announces, in order to respond to any problem of U-Bike users more quickly, the operating center is provided with a customer service hotline, which is expected to resolve problems for the user for the first time (Taipei Government, 2012). Shaheen *et al.* (2010) study proposed the exploration of such experience as bicycle loss and damage, bicycle distribution, information system, as well as insurance and reliability.

F. Favorable Social Mood and Climate Environment

No matter for a long-trip or short-trip commute, the climate has a greater influence on the intention of using a bicycle over other transport means. Thus, through the comparison of the climates in different cities, we can know

the climate suitable to the development of the public bicycle, and what the possible solutions are to cope with climate concerns (JZTIBC, 2010). Muraleetharan *et al.* (2005) find out in the study when the number of pedestrians increases during the coldest season in Japan, because the bicycle riders will prefer walking rather than riding a bicycle. Saneinejad *et al.* (2012) conducted a survey on the transport behaviors affected by the climate in Toronto, Canada, and found out it is the bicycle among various transport vehicles that is affected by the climate the most.

The Public Bicycle Feasibility Evaluation Report of Seattle shows that promotion and education are the keys to the success of public bicycle operation though they are not factors that make up public bicycle operation (BSS, 2010). The advocacy and promotion allow the citizens to understand why the PBS should be introduced. It is found from the experience of Montreal BixiBike that mass education and advocacy can reduce the loss and damage rate of public bikes. The public bicycle is widely used nowadays, and the national situation and social mood, as well as the habit of using the public facilities vary with each country. Thus, the habit cultivation and the advocacy of the related policies can correct the wrong views appropriately, which can further facilitate improving the citizen's intention of using public bicycles and the sustainable development of the public bicycle.

To sum up the literatures related to the public bicycle, the study works out the following dimensions to construct the study architecture, namely, design of a tough and practical bicycle frame, convenient rental regulation, safe riding environment, appropriate rental stations and facilities, complete work affairs of management and service center, and favorable social mood and climate environment.

3. METHODS

This section will illustrate the study procedures and subjects, study architecture and the related study methods respectively.

3.1. Study Procedures and Subjects

The study is mainly divided into three stages. In stage one, a literature review and expert discussion are conducted to make the preliminary study architecture. This stage is focused on building a preliminary structure for evaluating the service performance of Taipei's PSB. In stage two, Fuzzy Delphi expert questionnaire is taken as the quantitative study to screen out the critical factors of the model. In stage three, the expert questionnaires are collected for the weight of importance of the evaluation criteria, while the user questionnaires are collected for the satisfaction of the evaluation criteria. Moreover, the IPA method is used to evaluate the PBS service performance. The study subjects are divided into the experts and users. The experts include the government officers, operators and scholars. The investigation subjects for users cover the citizens who have used Taipei UBike.

3.2. Study Framework

After the literature review and the expert discussion, the study classifies the study architecture into six dimensions, (A) Tough and practical bicycle frame design, (B) Convenient rental regulation,(C)Safe riding environment, (D)Appropriate rental stations and facilities,(E)Complete work affairs of management and service center, (F)Favorable social mood and climate environment, with the overall study architecture as shown in Table 1:

3.3. Fuzzy Theory

Zadeh (1975) presented the fuzzy concept while several scholars proposed the fuzzy logic and other related applications (Mamdani and Assilian, 1975; Zadeh, 1975). The fuzzy theory has been widely applied in various fields, and solved many practical problems (Arias-Aranda *et al.*, 2010).

The membership function is the basic concept of the fuzzy theory. The key to processing problems using the fuzzy theory is to find out the proper membership function which is called fuzzy (Ho, 2010). Among the common

membership functions, the effect of applying the five-point Likert scale in the triangular fuzzy number is closer to the practical situation (Zhuang, 2004).

Table-1. Study framework

Items
A. Tough and practical bicycle frame design
a1. Tough bicycle frame without top tube for easy riding
a2. Practical front basket
a3. Night lighting device at front and rear sides
a4. Appropriate internal speed shifting system
a5. Easily-adjustable seat cushion
a6. Tough and puncture-proof tires
a7. Enclosed rear-wheel cover to protect the skirt from sucking
a8. Dual-purpose and theft-proof bicycle lock
B. Convenient rental regulation
b1. Low membership threshold
b2. EasyCard can be used for renting
b3. Mobile phone number can be used for renting
b4. Credit card can be used for renting
b5. The bicycle can be rented in station A, and then returned to station B
b6. Free of charge for the first 30 minutes of use
b7. Low rental fee
b8. The rental fee is charged cumulatively
C. Safe riding environment
c1. Special bicycle path
c2. Two-way special bicycle path
c3. Pavement that is wide enough for biking
c4. Sunlight shielding environment for riding
c5. Adequately lit environment for biking at night
c6. Flat and smooth road surfaces for biking
c7. Clear biking signs and directions
D. Appropriate rental stations and facilities
d1. The bicycle rental station is near an MRT station, bus station or railway station
d2. The bicycle rental station is near to a tourist attraction
d3. The spacing among the bicycle rental stations is 3~5km
d4. It is easy to pick up/drop off bikes at the parking meter
d5. Equipped with an automated multi-functional service machine
d6. The rental stations are distributed in the city evenly
E. Complete work affairs of management and service center
e1. Official website with clear information
e2. Periodical bicycle inspection
e3. 24-hr bicycle dispatching
e4. Bicycle is available in the rental station anytime
e5. Parking space for returned bicycle is available in the rental station anytime
e6. Equipped with a mobile APP with real-time rental information
e7. One can contact the service center anytime
F. Favorable social mood and climate environment
f1. Citizens are friendly to the bicycle riders
f2. Citizens show recognition towards the biking activity
f3. Citizens show care for the public bicycle facilities
f4. Citizens have high environmental awareness
f5. Citizens consider the bicycle as a safe transport vehicle
f6. Governmental policies show support towards the promotion of the public bicycle system
f7. The climate is favorable to biking

The method of the triangular fuzzy number is employed in the study to fuzzy the meaning of the expert cognition value in the questionnaire. A(x)=(l,m,u) represents the value of the membership function.

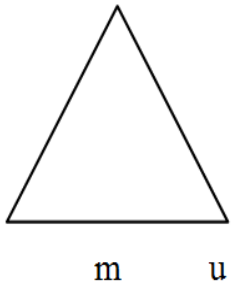

Figure-1. The triangular fuzzy number membership
Source: Zhao and Govind (1991)

Triangular fuzzy numbers (0, 1, 2) indicated as "very unimportant/ very dissatisfied"

(1, 2, 3) indicated as "unimportant/ dissatisfied"

(2, 3, 4) indicated as "normal"

(3, 4, 5) indicate as "important/ satisfied"

(4, 5, 5) indicated as "very important/ very satisfied"

After that, all expert opinions were gathered and calculated to determine the integrated triangular fuzzy number $A\tilde{}=(l\tilde{}, m\tilde{}, u\tilde{})$. Finally, the simple center-of-gravity method was used for de-fuzzy (Zhao and Govind, 1991). $C(A\tilde{})=(1/3)(l+ m+ u)$ is the value after de-fuzzy with the center-of-gravity method.

3.4. Fuzzy Delphi Method

The Delphi method is used in the hybrid investigation on the critical issue, with the aim of reaching a consensus among the experts (Beech, 1999). It's a group decision-making method (Noorderhaven, 1995). The advantage of the Delphi method is that it can motivate the experts to propose a suggestion thoroughly and systematically (Xu, 2006). That can achieve quick convergence of the forecasting opinions as desired by the decision-makers. However, its disadvantage is that the study process is complex and time-consuming (Murry and Hammons, 1995). Later on, the Delphi method has been modified and improved continuously. The Fuzzy Delphi Method combined with the Fuzzy concept is a common method.

Murray *et al.* (1985) combined it with the fuzzy theory to propose the Fuzzy Delphi Method, which uses the meaning variables to resolve the fuzziness of the questions and answers in the questionnaire of the Delphi method. It has some advantages: (1) reduces the number of investigation times; (2) provides a more complete expression of the experts' opinions; (3) through the application of the fuzzy theory, the knowledge of experts will be able to meet the demand more; (4) it has more benefits in terms of time and cost (Chen and Lee, 2013).

w_{jk} is the assessment value of the k_{th} criteria by the j_{th} expert. And w_k is fuzzy weight value of the k-th original criteria.

$w_{jk}=(l_{jk}, m_{jk}, u_{jk}), i=1,2,3\ldots n$

$l_k=min\{l_{jk}\}, m_k=(\Sigma^{n}_{j=1} m_{jk})/n, u_{jk}= max\{ u_{jk} \}$

It uses a simple gravity method to screen assessment indicators. The original criteria fuzzy weight w_k is converted into a single value $S_k=[(u_k - l_k)+(m_k - l_k)]/3 + l_k$.

The Fuzzy Delphi method can integrate the experts' opinions quickly. The researcher can set a threshold to delete the criteria with low importance.

3.5. IPA Method

The IPA (Importance-Performance Analysis) structure is proposed by Martilla and James. This method can be used to analyze and rank the importance and quality performance of the product or service properties presented to the consumer (Sampson and Showalter, 1999).

The IPA is used to quantize the experts' and the users' opinions, with the following steps (Martilla and James, 1977):

(1) Establish the extent values of importance and performance

The respondents evaluate the importance and the satisfaction of each criterion based on Likert scale 1~5 according to their practical experience. We can obtain the extent value of the importance $I=i^c_j$ and performance $P=p^c_j$, wherein j represents the criterion j, while c represents the respondent c.

(2) Calculate the overall importance and performance

We calculate the mean importance of the criterion j evaluated by c experts based on the equation $I^A_j=(1/c)\Sigma^c_{c=1}(i^c_j)$, so as to obtain the overall importance I^A_j. In the meanwhile, using the equation $P^A_j=(1/c)\Sigma^c_{c=1}(p^c_j)$ can obtain the overall performance.

(3) Calculate the means of importance and performance

In order to understand and compare the importance and performance among all criteria, it uses the equation $I_o=(1/j)\Sigma^j_{j=1}(I^A_j)$ to calculate the importance center, which is represented by I_o. Then $P_o=(1/j)\Sigma^j_{j=1}(p^A_j)$ is used to calculate the center of the relative performance value, which is represented by P_o.

(4) Plot the importance and performance chart

Finally, it takes the importance value as the horizontal axis and the performance value as the vertical axis, to re-mark the individual criterion in the 2-dimensional space. The chart can be drawn to generate 4 Quadrants, on which the importance and the performance level of each criterion and dimension can be illustrated.

The meaning represented by the 4 Quadrants of the IPA is listed as below (Martilla and James, 1977).

I. (High Importance, High Performance): The quality in this area is the primary source of competitiveness of the company, so the operator should keep up the good work.

II. (Low Importance, High Performance): Due to the lower importance to the current operation, the operator doesn't have to emphasize on the investment into this area, which is the secondary source of competitiveness of the company.

III. (Low Importance, Low Performance): It is the secondary source of weakness of the company. Under the restriction of the limited resources, the weakness in this area can be considered after the improvements of Quadrant IV.

IV. (High Importance, Low Performance): It is the primary source of weakness of the company. The properties falling in this area are the critical factors to determine the future development of the company. Thus, they are the priority for investing resources for improvements. The service quality under this Quadrant is the critical quality property.

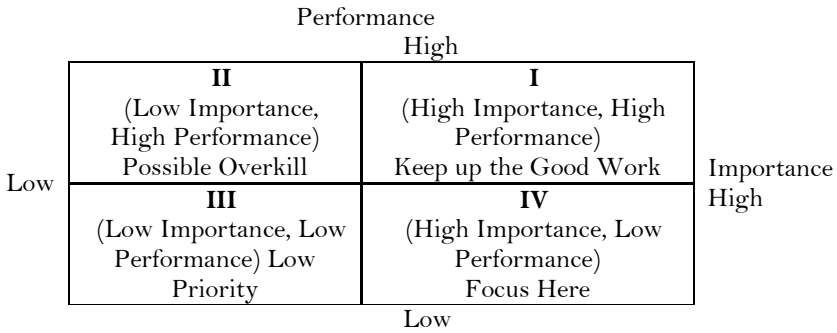

Figure-2. Importance – Performance Quadrant Chart
Source: Martilla and James (1977)

4. RESULTS

The study findings will be elaborated based on the analysis results of the Fuzzy Delphi and IPA.

4.1. Results of Fuzzy Delphi

The Fuzzy Delphi is an expert decision-making method, which consists of 5-15 experts generally (Teng, 2002). In this stage, the study distributes 7 expert questionnaires to the respondents including 2 scholars, 3 governmental officers and 3 operators. After sorting the importance of each criterion evaluated by all experts, the results are shown as Table 2:

Table-2. Results of Fuzzy Delphi

Item	Value	Item	Value	Item	Value
a1	4.2857	c1	3.8571	e1	4.6667
a2	4.2857	c2	3.8571	e2	4.6667
a3	4.2857	c3	4.2857	e3	4.2857
a4	3.9048	c4	3.7619	e4	4.2857
a5	3.9048	c5	4.2381	e5	4.2857
a6	4.6667	c6	4.2381	e6	4.6667
a7	3.9048	c7	4.2857	e7	4.2857
a8	4.2857	d1	4.2857	f1	4.6667
b1	3.9048	d2	4.2381	f2	4.6667
b2	4.2857	d3	4.2381	f3	4.6667
b3	3.7143	d4	4.2857	f4	4.6667
b4	4.1905	d5	4.2857	f5	4.6667
b5	4.6667	d6	4.2381	f6	4.6667
b6	4.1905			f7	4.2857
b7	4.6667				
b8	4.2381				

Generally, in the study based on Fuzzy Delphi, the researcher will set a threshold and delete the factors with lower importance, or delete the factors with large importance lag based on the screen plot. Figure 3 is drawn based on the importance of each factor.

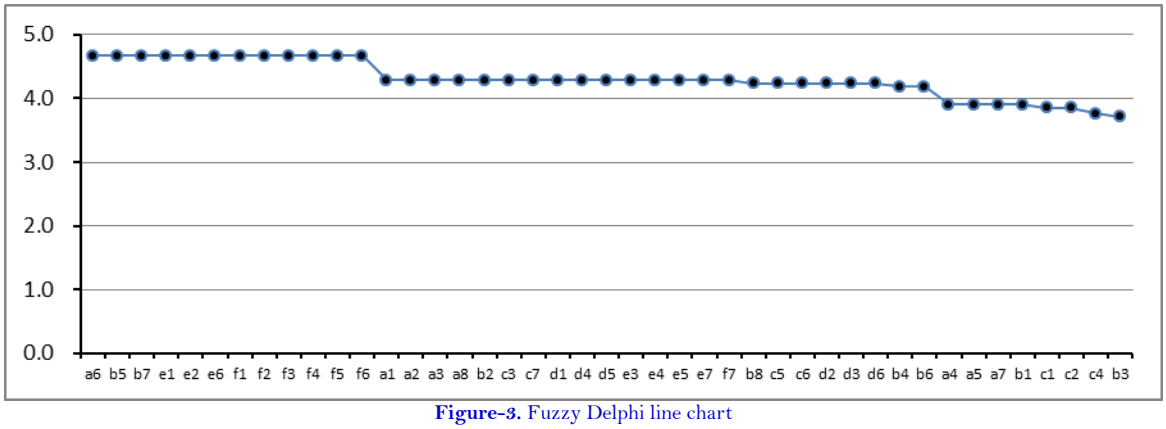

Figure-3. Fuzzy Delphi line chart

As shown in Figure 3, obvious slopes can be seen at f6-a1 and b6-a4, but the slopes are not steep. Moreover, the values of Table 2 show the minimum value is 3.7145 at b3. As all values are not low, we decided to retain all items. In other words, all these items are the critical factors to evaluate the PBS service performance.

4.2. Questionnaire Reliability Analysis

The study distributes the Fuzzy IPA questionnaire in stage three. In terms of importance, a total of 75 expert questionnaires are distributed to the experts including scholars, governmental offices and operators. In the part of the user, a total of 377 questionnaires are collected from those Taipei citizens who have used UBike. According to the questionnaire reliability analysis conducted in the study, the overall reliability is 0.891 for the part of the

experts, while the overall reliability Cronbach's α reaches 0.964 in the part of the users. That means scales in this study are generally of good reliability, as proposed by Nunnally and Bernatein (1994) that a research tool with a value above 0.70 is reliable.

Table-3. The results of importance-performance Analysis

Items	Importance	Satisfaction	Quadrant
A. Tough and practical bicycle frame design			
a1. Tough bicycle frame without top tube for easy riding	4.2400	3.7958	III
a2. Practical front basket	4.5333	3.9063	I
a3. Night lighting device at front and rear sides	4.5867	4.0433	I
a4. Appropriate internal speed shifting system	4.3600	3.8484	I
a5. Easily-adjustable seat cushion	4.4933	3.9266	I
a6. Tough and puncture-proof tires	4.4267	3.8479	I
a7. Enclosed rear-wheel cover to protect the skirt from sucking	4.1867	3.8285	II
a8. Dual-purpose and theft-proof bicycle lock	4.1733	3.8532	II
B. Convenient rental regulation			
b1. Low membership threshold	4.3867	3.9461	I
b2. EasyCard can be used for renting	4.4267	4.1512	I
b3. Mobile phone number can be used for renting	3.8800	3.9850	II
b4. Credit card can be used for renting	3.5333	3.7480	III
b5. The bicycle can be rented in station A, and then returned to station B	4.6400	4.1981	I
b6. Free of charge for the first 30 minutes of use	4.0267	4.1698	II
b7. Low rental fee	4.3467	4.0177	I
b8. The rental fee is charged cumulatively	3.9467	3.8497	II
C. Safe riding environment			
c1. Special bicycle path	4.2133	3.6897	III
c2. Two-way special bicycle path	4.0267	3.6737	III
c3. Pavement that is wide enough for biking	4.2400	3.6967	III
c4. Sunlight shielding environment for riding	3.8533	3.6340	III
c5. Adequately lit environment for biking at night	4.2800	3.7321	IV
c6. Flat and smooth road surfaces for biking	4.1333	3.6578	III
c7. Clear biking signs and directions	4.2933	3.5924	IV
D. Appropriate rental stations and facilities			
d1. The bicycle rental station is near an MRT station, bus station or railway station	4.4933	3.9434	I
d2. The bicycle rental station is near to a tourist attraction	4.0800	3.9399	II
d3. The spacing among the bicycle rental stations is 3~5km	4.2933	3.9027	I
d4. It is easy to pick up/drop off bikes at the parking meter	4.4667	3.8647	I
d5. Equipped with an automated multi-functional service machine	4.0933	4.0000	II
d6. The rental stations are distributed in the city evenly	4.2000	3.6472	III
E. Complete work affairs of management and service center			
e1. Official website with clear information	4.4400	3.7560	IV
e2. Periodical bicycle inspection	4.5600	3.8002	IV
e3. 24-hr bicycle dispatching	4.0133	3.8187	III
e4. Bicycle is available in the rental station anytime	4.2267	3.6163	III
e5. Parking space for returned bicycle is available in the rental station anytime	4.2933	3.7383	IV
e6. Equipped with a mobile APP with real-time rental information	4.3867	3.8214	I
e7. One can contact the service center anytime	4.3600	3.0000	IV
F. Favorable social mood and climate environment			
f1. Citizens are friendly to the bicycle riders	4.4800	3.8002	IV
f2. Citizens show recognition towards the biking activity	4.4000	3.9496	I
f3. Citizens show care for the public bicycle facilities	4.5867	3.7542	IV
f4. Citizens have high environmental awareness	4.2133	3.7356	III
f5. Citizens consider the bicycle as a safe transport vehicle	4.3067	3.7206	IV
f6. Governmental policies show support towards the promotion of the public bicycle system	4.3733	3.8638	I
f7. The climate is favorable to biking	4.1333	3.7905	III

4.3. Results of IPA

The study calculates the measurement results of IPA based on Power IPA v1.3, the program developed in the study. Table 3 shows the results of the importance and satisfaction obtained by each item, based on which the Quadrant is judged and the improvement direction is found. According to the calculation in this study, the mean

value of the importance is 4.2704, and 3.8199 for the satisfaction. That point is taken as the segment to draw a chart with 4 Quadrants. Then the position of each item is drawn based on the obtained analysis data to obtain the Importance-Satisfaction position chart (Figure 4). In this way, it can clearly think about how to make improvements. Results are divided according to the quadrant as follows:

(1) The first quadrant (high importance and high performance):

Fifteen items are in the first quadrant. There are (a2) Practical front basket, (a3) Night lighting device at front and rear sides ,(a4) Appropriate internal speed shifting system (a5) Easily-adjustable seat cushion, (a6) Tough and puncture-proof tires, (b1) Low membership threshold, (b2) EasyCard can be used for renting, (b5) The bicycle can be rented in station A, and then returned to station B, (b7) Low rental fee, (d1) The bicycle rental station is near an MRT station, bus station or railway station, (d3) The spacing among the bicycle rental stations is 3~5km, (d4) It is easy to pick up/drop off bikes at the parking meter, (e6) Equipped with a mobile APP with real-time rental information, (f2) Citizens show recognition towards the biking activity, (f6) Governmental policies show support towards the promotion of the public bicycle system.

(2) The second quadrant (low importance and high performance):

Seven items are in the second quadrant. There are (a7) Enclosed rear-wheel cover to protect the skirt from sucking, (a8) Dual-purpose and theft-proof bicycle lock, (b3) Mobile phone number can be used for renting, (b6) Free of charge for the first 30 minutes of use, (b8) The rental fee is charged cumulatively, (d2) The bicycle rental station is near to a tourist attraction, (d5) Equipped with an automated multi-functional service machine.

(3) The third quadrant (low importance and low performance):

Twelve items are in the third quadrant. There are (a1) Tough bicycle frame without top tube for easy riding, (b4) Credit card can be used for renting, (c1) Special bicycle path, (c2) Two-way special bicycle path, (c3) Pavement that is wide enough for biking, (c4) Sunlight shielding environment for riding, (c6) Flat and smooth road surfaces for biking, (d6) The rental stations are distributed in the city evenly, (e3) 24-hr bicycle dispatching,(e4) Bicycle is available in the rental station anytime, (f4) Citizens have high environmental awareness, (f7) The climate is favorable to biking.

(4) The forth quadrant (high importance and low performance):

Nine items are in the forth quadrant. There are (c5) Adequately lit environment for biking at night, (c7) Clear biking signs and directions, (e1) Official website with clear information, (e2) Periodical bicycle inspection, (e5) Parking space for returned bicycle is available in the rental station anytime, (e7) One can contact the service center anytime, (f1) Citizens are friendly to the bicycle riders, (f3) Citizens show care for the public bicycle facilities, (f5) Citizens consider the bicycle as a safe transport vehicle.

Then analysis data of all items are marked correspondingly in the diagram and ultimately creates a dot plot of importance-performance (Figure 4).

Figure-4. The dot plot of importance-performance

5. DISCUSSION

As shown by the results of Fuzzy Delphi, the experts show agreement on the critical factors for PBS promotion listed in the study. Therefore, the results can provide the construction standards for the cities which intend to promote PBS.

In the IPA study part, the study will explore the areas which are evaluated as important by the experts. The items under Quadrant I are important and satisfactory to the citizens, which are crucial to attaining efficient service performance. Moreover, 15 items located in Quadrant I take up over one-third of the 43 evaluation items in total, indicating that Taipei UBike is very successful. Among the 15 items, most belong to the two categories of A. Design of a tough and practical bicycle frame and B. Convenient rental regulations. It indicates that these two categories are the advantages of Taipei UBike in attaining efficient service performance.

The item with the highest level of importance and satisfaction is that bikes may be rented at one station and returned to another. As the basic characteristic of PBS (Curran, 2008; Beroud *et al.*, 2010; Hsieh and Chang, 2011) it is a matter of course to obtain the highest importance. The Taipei UBike system owns rental stations in other regions in Taiwan in addition to the operation in Taipei. The user is only required to pay a lower fee to return the bike to another county or city. Thus, it obtains the highest user satisfaction.

The Taipei UBike system is run by GIANT Company (Peng *et al.*, 2014). Taiwan's bicycle manufacturing industry is renowned and quite important globally, and GIANT Company is the largest bicycle manufacturer in the world. In order to run the PBS, GIANT Company makes so much effort to design the bicycle frame based on the idea of designing for the mass pubic rather than creating an advanced bicycle. Thus, the basket and the quickly-adjustable seat cushion are designed. Considering the safety of the users at night, it is equipped with a night lighting device at the front and rear sides, for which the power is supplied by the small generator driven by riding. It adopts puncture-proof tires to reduce the situation of a broken tire. Moreover, it incorporates the use of the internal speed shifting system. Even for the chain that might be overlooked by the user, GIANT Company cooperates with the largest chain supplier in the world, KMC Company for re-designing (Lu, 2014) so as to enhance the toughness and resist the humidity in Taiwan. All these are to design a tough and practical bicycle frame, so as to reduce the damage probability and lower the maintenance cost. In terms of the bicycle frame design, it takes full advantage of the complete supply chain in Taiwan's bicycle industry.

Currently, the transport network in Taipei is complete, including the MRT, bus, normal rail and high-speed rail. The rental stations of Taipei UBike are set up in all these places. At present, the number of stations throughout the area of 271.8 km^2 in Taipei reaches 196 with quite high density. Therefore, it is very convenient for the citizens to rent the public bikes. Besides, whether it is easy to pick up/drop off bikes at the parking meter is quite important as well. GIANT Company works with the manufacturer to develop a dual-purpose lock that can prevent it from being tampered. The lock combines the mechanical, electronic and RFID sensing functions to integrate the cylinder lock with the chain lock for temporary parking, so as to greatly reduce the loss rate to 0.38% (Lu, 2014) which is much lower than that of the cities in other countries. With the mobile phone user number reaching 126.36%and the penetration rate of the smart phone over 50% in Taiwan (MOEA, 2013) the operator specially developed the mobile APP that can update the real-time rental information and allow the user to inquire about the UBike rental situation any time conveniently.

Taipei PBS didn't achieve a good outcome during the initial operation. However, it modified some of the rental methods and implemented several convenient rental regulations, which greatly increased the number of users. Therefore, good rental regulations belong to the critical factors that promote PBS. For example, the low membership threshold and low rental make more people willing to try and use it regularly. The attitude of the administration towards the PBS promotion is very important. In spite of the poor performance of Taipei PBS during the initial operation, the Taipei Municipal Government thinks it is urgent to promote a pollution-free city through the use of bikes. Thus, it proposes the subsidiary policy to provide the free use of UBike for the first 30 minutes (Lu, 2014) which greatly increases user intention. That is because most bicycle journeys can be finished within 30 minutes (JZTIBC, 2010). Therefore, the powerful support of the policy and the recognition of most people are both critical factors.

In addition, renting with EasyCard is a convenient measure. EasyCard is a non-contact electronic ticket system of IC card issued by EasyCard Corporation in Taiwan. It is put into use in Taipei MRT since June 2002, which is expanded to the buses of the counties and cities throughout Taiwan and the highway transport in some regions (Wikipedia, 2014a). The population in Taiwan is 23 million, while the number of the issued EasyCard has reached 50 million currently, which is more than twice the overall population in Taiwan. With the functions from transport ticket to the small-amount consumption, EasyCard is with us everywhere any time (Easycard, 2014). Moreover, EasyCard can be used in more than 10,000 24-hour convenient stores throughout Taiwan (Wikipedia, 2014b) which is the most convenient payment tool for the citizens in Taiwan. Therefore, the PBS adopts this payment mechanism that is quite convenient to the users.

Below some items with high importance but low level of satisfaction will be explored, because they take the priority for improvements. Item e7. One can contact the service center anytime obtains the lowest satisfaction. Thus, it is suggested that the operator add customer service personnel and print the contact information on the bicycle body. When the user confronts some problem, s/he can contact the operation center any time. In terms of the periodical bicycle inspection and maintenance, the user satisfaction is slightly lower than the mean value. Currently the operator assigns a special group which is responsible for the daily inspection of the bikes in the rental stations. However, with the rapid increase in the number of bicycle users, there will be more problems related to the bicycle. Thus, the operator should increase the inspection manpower to keep all bikes in good condition. Aside from this, the parking meters of the rental stations in Taipei are fixed on the ground, with a fixed number. If many users intend to return bikes at a certain rental station simultaneously, some users may not find an available parking meter, which will cause trouble to the users. Although the operation center will monitor the situation of all bikes and dispatch the bikes flexibly, it should also carefully analyze the use situation at different periods everyday. By doing so, it can allocate the number of available bikes and parking meters in each rental station, so as to avoid the problem of the user not being able to return the bicycle after s/he arrives at the destination.

The number of automobiles and motorcycles in Taiwan are quite high, and most people don't value the right-of-way of the pedestrians and bikes. Therefore, some citizens are doubtful about the safety of the bicycle as a transport vehicle. Some bicycle fans have climbed Wuling with the height of 3275m by riding a bicycle, and considered it as a great achievement. Someone also climbed Wuling with UBike which created much controversy. Although it proves the stableness of the UBike frame, most people think this behavior is not good for the public bicycle. Therefore, the government has to carry out more advocacy actions to guide the mass public towards a positive view of the public bikes.

The night market in Taiwan is globally reputed, and the convenient stores in Taiwan provide 24-hour service. All these indicate the night activities of Taiwanese, so the public bikes are frequently used at night. Thus, adequately lit environment for biking at night is important. Furthermore, due to the short running time of the public bicycle system, the signboards on the road are still mainly for the automobiles and motorcycles, without clear signs for the bicycle riders. The government can think about the improvements on these items, with the expectation to create a more user-friendly environment for biking.

6. CONCLUSION

With the increased demand for low emission transport and sustainable development, the PBS is greatly valued, which are promoted in the important cities of many countries. Taipei City in Taiwan has also constructed the PBS. In spite of the poor operation performance during the initial period, it has made great improvements after the adjustment of the operation model. Aside from the high daily turnover rate, the low loss rate and the profitable revenue indicate efficient performance of the PBS in Taipei City. The subjective and objective conditions vary in each city, and the policies and operation model are not the same. However, the study findings can still provide important reference for the cities that intend to develop PBS in the future.

The study effectively finds out the critical factors and establishes a service performance evaluation model. In the study of Taipei UBike, many critical factors are involved, among which such dimensions as the design of the bicycle frame and the convenient rental regulations are quite important. In terms of the service performance, the service quality of the management and service center can be further enhanced, so as to increase user satisfaction. To sum up, the good service performance of Taipei PBS requires the attentive development and operation of various hardware and software by the operator, as well as the full support of the government through related policies. However, there are some variables that affect public bikes, so countries should make the appropriate changes based on actual conditions and learn from the successful experience of others, so as to maximize PBS performance. When PBS is comprehensively developed and used with the original mass transport system, it will result in a more efficient public transport service.

The major limitation of the study is its sole focus on PBS performance from a user's perspective. In terms of the follow-up research, it is suggested exploring the performance from the perspective of finance because the study doesn't explore it based on the financial aspect. Moreover, it is suggested that a full investigation of the situation of bicycle rental and return in all rental stations at different hours. In this way, the operation center will forecast the user demands and allocate the bicycle configuration more accurately, so as to further improve the user satisfaction and the performance of the operator.

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