

Prior Analysis of Effect of Introduction of Rental Two-Wheeled Vehicles in Tokushima City

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Abstract: The introduction of rental two-wheeled vehicles, specifically electric bicycles and electric motorcycles, is examined for improving mobility and increasing the level of vitality in the central area in the city of Tokushima. For this purpose, a questionnaire survey was distributed in Tokushima prefecture and then the effects of the introduction were analyzed. When rental two-wheeled vehicles are introduced, the effects on expansion of the movable field of people, the increase in the interaction opportunities with local residents, the increase in the availability of urban facilities, and the number of local residents to these facilities can be clarified. The results provide valuable information for examining the project of introduction of rental two-wheeled vehicles.

Keywords: Prior analysis, Rental two-wheeled vehicles, Tokushima city, Interaction, Movable field

1. INTRODUCTION

Ensuring the vitality of primary town centers is one of the significant issues for the city of Tokushima in Japan. The decrease of visitors to the city center of Tokushima is primarily due to an inadequate public transport network as well as a decreasing and aging population in Tokushima prefecture. To resolve such issues, Tokushima city government has considered introducing rental two-wheeled vehicles, specifically, electric bicycles and electric motorcycles, for improving the mobility and vitality of the city center.

Research into bicycles became popular in the late 1990s. Heinen *et al.* (2010) classified academic literature on bicycles into five different research fields: 1) built environment, 2) natural environment, 3) socio-economic factors, 4) psychological factors, and 5) cost, travel time, effort and safety. Yamashita *et al.* (2005) examined the uses of rental cycles and classified them into three types: leisure, commuting, and community. They concluded that the rental of two-wheeled vehicles as user-friendly public transportation would expand the level of activity in the leisure classification by providing travel information, and that the usage charge would influence the rentals for the commuting and the community classifications. Li *et al.* (2013) conducted market segmentation analysis for bicycle commuting to identify the potential markets of bicycle commuting. They identified six segments and concluded that the

needs of each segment have to be considered for policy implication. Martens (2007) examined several measures to promote the combined use of bicycle and public transport for one trip. The introduction of flexible rental bicycles at train stations in the Netherlands brought about the growth in both train trips and bicycle use for non-recurrent trips. Azuma *et al.* (2005) analyzed the differences of uses of rental cycles between railway users and non-railway users based on a questionnaire survey. Yamane and Inoue (1996) reported that public transportation and rental cycles become mutually beneficial by coordinating the operations between them. Cheng and Liu (2012) evaluated perceived intermodal inconvenience by using the Rasch model, and suggested customized marketing strategies for cyclists' needs. Lin and Yang (2011) addressed the public bicycle sharing system in terms of the location of bike stations. They examined service level by developing the mathematical model. However, few studies have conducted a prior analysis on the effects of the introduction of rental two-wheeled vehicles.

The purpose of this study is to provide useful information for examining the introduction of rental two-wheeled vehicles. "Two-wheeled vehicles" is defined here as both electric bicycles and electric motorcycles. This study analyzes the following effects: 1) to what extent the area of movement will expand, 2) to what extent opportunities to interact with local residents will increase, 3) to what extent the utilization of urban facilities will increase in terms of users, and 4) to what extent the benefits of the number of visitors to urban facilities will increase from the viewpoint of the managers of urban facilities. For a prior analysis of the overall effect, estimation models were proposed and calculated by using the results of the questionnaire survey given to local residents in Tokushima prefecture. The results provide valuable information for examining the introduction of rental two-wheeled vehicles.

2. QUESTIONNAIRE SURVEY ON THE EFFECTS OF THE INTRODUCTION OF RENTAL TWO-WHEELED VEHICLES

2.1 Methodology

A paper-based questionnaire of the attitude of local residents towards the introduction of rental two-wheeled vehicles was sent to a random sample of 3,000 households across Tokushima prefecture in September 2011. The questionnaire was sent with a pre-paid envelope in an attempt to increase the number of responses. In all, 630 households provided valid responses for a response rate of 21%.

The questionnaire asked the following questions: age, gender, attitudes towards the rental of two-wheeled vehicles around the Tokushima railway station, usage charge, and maximum travel distances that respondents would travel on foot, by motorbike, and by car.

2.2 Results of the questionnaire survey

Figure 1 shows the breakdown by gender of the respondents and Figure 2 shows the breakdown by age groups. By gender, 53% of the respondents were females, and 47% of them were males. By age group, 64% of the respondents were people of ages 50 and over, and only 5% were people of ages 12-29. Some reasons for the responses may be that the demographics of Tokushima prefecture tend toward an aging population, and that most respondents would be the responsible person of the household.

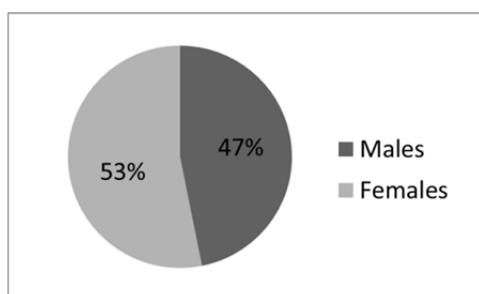


Figure 1. Respondents by gender

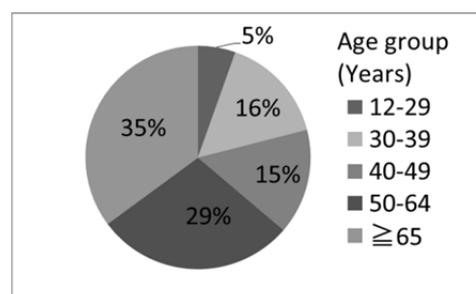


Figure 2. Respondents by age group

Figure 3 indicates the percentages of respondents who have traveled somewhere in Tokushima City by way of the Tokushima railway station. As shown, 45% of the respondents traveled by way of the Tokushima railway station.

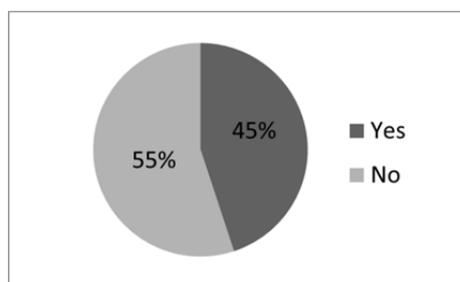


Figure 3. Experiences in traveling somewhere in Tokushima City by way of the Tokushima railway station

2.3 Attitudes towards the rental two-wheeled vehicles

Figure 4 shows the attitudes towards the use of electric bicycles. Figure 5 shows the attitudes towards the use of electric motorcycles. The predominant responses were “will not use” in both figures. In Figure 4, 32% of the males responded either “will use” or “will use with conditions” for electric bicycles. This percentage is 7% higher than that of the females. In Figure 5, 20% of the males responded “will use” or “will use with conditions” for electric motorcycles. This percentage is 12% higher than that of the females.

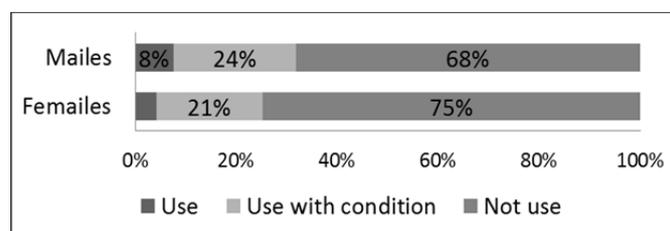


Figure 4. Attitudes towards the use of electric bicycles by gender

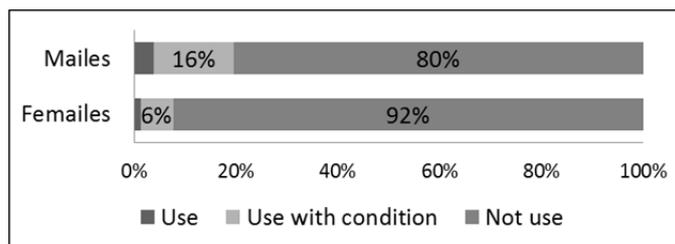


Figure 5. Attitudes towards the use of electric motorcycles by gender

Figure 6 describes the attitudes towards the use of the rental electric bicycles by age group. Approximately 40% of the respondents of ages 20-29, 30-39, and 40-49 responded either “will use” or “will use with conditions” for rental electric cycles; in contrast, approximately 25% of the respondents in the groups of people of ages 50-64, 65 and over responded either “will use” or “will use with conditions” for electric bicycles. Figure 7 describes the attitudes towards the use of electric motorcycles by age groups. In the people of ages 20-29, 37% of the respondents responded either “will use” or “will use with conditions” for electric motorcycles. The percentages of those in the older groups were much smaller than those in the group of ages 20-29. It is assumed that the demographics of Tokushima prefecture affect the project scale of the rental of two-wheeled vehicles.

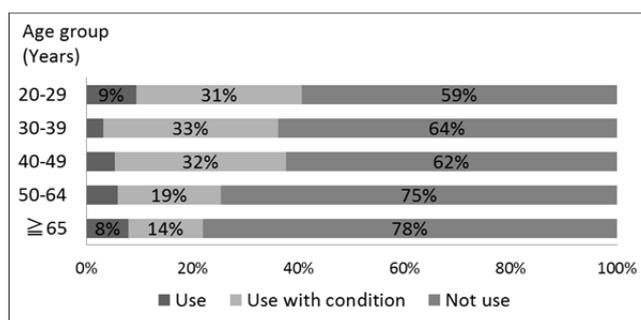


Figure 6. Attitudes towards the use of electric bicycles by age group

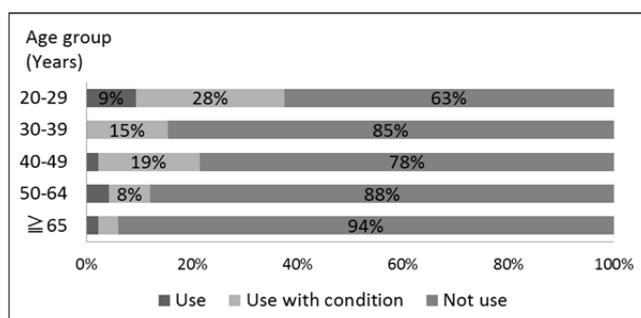


Figure 7. Attitudes towards the use of electric motorcycles by age group

This study calculated the “acceptance rate,” defined as the rate of respondents who would pay a usage charge for the rental two-wheeled vehicles. The respondents who answered “will use with conditions” gave the largest amount they would be willing to pay to use the rental two-wheeled vehicles per one hour. Figure 8 shows the acceptance rate for the electric bicycles. The acceptance rate sharply declines between 100 yen/hour and 200 yen/hour. Figure 9 shows the acceptance rate for the electric motorcycles. The acceptance rate sharply declines between 250 yen/hour and 500 yen/hour.

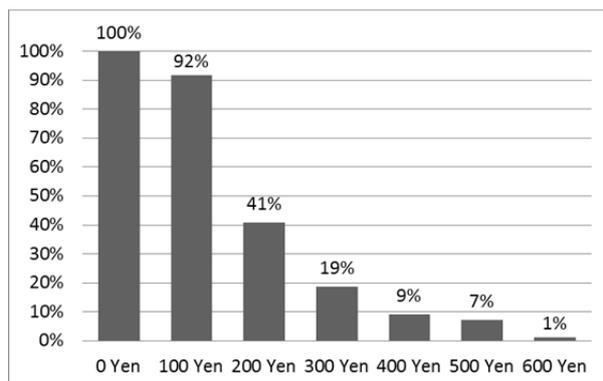


Figure 8. The acceptance rate towards usage charge for electric bicycles

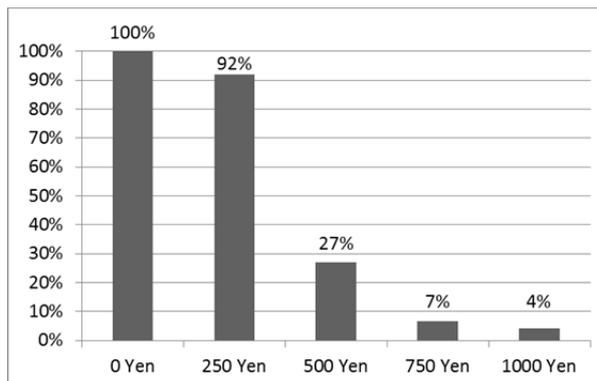


Figure 9. The acceptance rate towards usage charge for electric motorcycles

3. PRIOR ANALYSIS OF EFFECTS OF INTRODUCTION OF RENTAL TWO-WHEELED VEHICLES

This study analyzes the effects of the introduction of rental two-wheeled vehicles in terms of the following four aspects: 1) an expansion of the movable field of local people, 2) an increase in the interaction opportunities with local residents, 3) an increase in the availability of urban facilities, and 4) an increase in the number of visitors to urban facilities.

This study proposes the methodology to figure out the effects of the introduction of rental two-wheeled vehicles based on probability theory, and the effects are analyzed and calculated by using indicators. First, the basic concepts for explaining the users' behaviors of rental two-wheeled vehicles are developed and formulated. Second, the effects are calculated by using the indicators this study proposed. Lastly, the effects are discussed and compared.

The features of the methodology are as follows: 1) the effects of the introduction of rental two-wheeled vehicles are simply expressed and measured, and 2) the effects of the introduction of electric bicycles and electric motorcycles are easily compared.

3.1 EXPANSION OF MOVABLE FIELD OF LOCAL PEOPLE AND INCREASE IN THE INTERACTION OPPORTUNITIES WITH LOCAL RESIDENTS

3.1.1 Expansion of movable field of local people

From the questionnaire survey results, this study calculated the average maximum distance from the Tokushima railway station that residents would travel on foot, by electric bicycles, and by electric motorcycles. By using the average maximum distances of each means, this study calculated the areas of the movable fields of local residents. The effects of the introduction of the rental two-wheeled vehicles are defined by Formulas (1) and (2). The expansions of the introduction of the rental electric bicycles, S_{bw} , and those of the introduction of the rental electric motorcycles, S_{sw} , are described, respectively:

$$S_{bw} = S_b / S_w \tag{1}$$

$$S_{sw} = S_s / S_w \tag{2}$$

where,

- S_w : Areas of the average movable field on foot
- S_b : Areas of the average movable field by electric bicycles
- S_s : Areas of the average movable field by electric motorcycles

Figures 10, 11, and 12 show the average movable fields by each means. The average movable field on foot, S_w , was 3.2 km². The average movable field by electric bicycles, S_b , was 19.2 km². The average movable field by electric motorcycles, S_s , was 119.9 km². The expansion of the introduction of the rental electric bicycles, S_{bw} , was 6.0, and that of the rental electric motorcycles, S_{sw} , was 37.6. In terms of the expansion of the movable field, electric motorcycles were very beneficial.



Figure 10. The area of the average movable field on foot



Figure 11. The area of the average movable field by electric bicycles



Figure 12. The area of the average movable field by electric motorcycles

3.1.2 Increase in the interaction opportunities with local residents

In this study, the populations in movable fields were calculated based on the 2010 population census data, published by the Statistics Bureau, Ministry of Internal affairs and communication, Japan. The increases in the interaction opportunities with local residents by the introduction of the rental electric bicycles, N_{bw} , and those of the introduction of the rental

electric motorcycles, N_{sw} , are defined, respectively:

$$N_{bw} = N_b / N_w \tag{3}$$

$$N_{sw} = N_s / N_w \tag{4}$$

where,

- N_w : the interaction opportunity with local residents on foot
- N_b : the interaction opportunity with local residents by electric bicycles
- N_s : the interaction opportunity with local residents by electric motorcycles

Table 1 shows the interaction opportunities with local residents by each means. The interaction opportunity with local residents on foot, N_w , was 44,000. The interaction opportunity with local residents by electric bicycles, N_b , was 119,100. The interaction opportunity with local residents by electric motorcycles, N_s , was 241,400. The increase in the interaction opportunity with local residents by the introduction of rental electric bicycles, N_{bw} , was 2.7. The interaction opportunity with local residents by electric motorcycles, N_{sw} , was 5.5.

Table 1. Interaction opportunities with local residents by transportation

Transportations	Populations in movable fields
On foot	44,000
Electric bicycles	119,100
Electric motorcycles	241,400

3.2 INCREASE IN THE AVAILABILITY OF URBAN FACILITIES

3.2.1 Methodology

The introduction of the rental two-wheeled vehicles will affect the availability of urban facilities near the Tokushima railway station, where the main docking station will be located. The potential availability is defined as the availability of urban facilities for visitors. In this study, the increases of the potential availabilities by introducing rental two-wheeled vehicles, compared with those traveling on foot, are calculated as effects. The potential availability, P , is described as the summations of availability q_j of an urban facility j . The availability q_j of the urban facility j is described by the probability for distances between the Tokushima railway station and an urban facility, j .

$$P = \sum q_j \tag{5}$$

This study defined Formulas (6) and (7) as the increase of potential availability of urban facilities. The increase of potential availability of urban facilities by electric bicycles, P_{bw} , and the increase of the potential availability of urban facilities by electric motorcycles, P_{sw} , are shown, respectively:

$$P_{bw} = P_b / P_w \tag{6}$$

$$P_{sw} = P_s / P_w \tag{7}$$

where,

- P_{bw} : Increase of potential availability of urban facilities by electric bicycles
- P_{sw} : Increase of potential availability of urban facilities by electric motorcycles
- P_w : Potential availability of urban facilities on foot
- P_b : Potential availability of urban facilities by electric bicycles
- P_s : Potential availability of urban facilities by electric motorcycles

3.2.2 Function of potential availability of urban facilities

This study proposes the function of potential availability of urban facilities. If the maximum travel distance x is the distance that individuals can visit from the Tokushima railway station, x is seen as the probability density function, $f(x)$. If the distance, z , is the distance between the Tokushima railway station and an urban facility, the potential availability of the urban facility, q , is calculated by the integral of z with respect to z , as shown in Formula (8).

$$q = F(z) = \int_z^\infty f(x) dx \tag{8}$$

where,

$$\int_0^\infty f(x) dx = 1.0 \tag{9}$$

When the distribution of maximum distances x assumes a Weibull distribution based on previous studies, such as Ding *et al.* (2008), Aoyama and Kondo (1986), and Tsuchie *et al.* (2006), potential availability q can be derived as follows:

$$q = F(z) = \int_z^\infty \frac{2x}{\alpha} \exp(-x^2/\alpha) dx = \exp(-z^2/\alpha) \tag{10}$$

where,

α : parameter

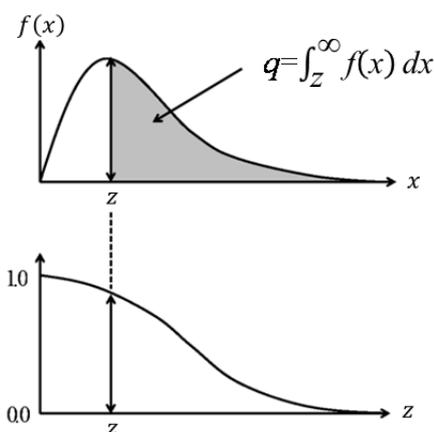


Figure 13. Function of the availability of urban facilities

Table 2. Model estimation results

Transportations	Parameter α	Coefficient of determination R^2	t Value
On foot	2.664	0.976	-12.86
Electric bicycles	16.05	0.993	-27.40
Electric motorcycles	152.3	0.991	-24.03

Both Formulas (8) and (10) are represented in Figure 13. This study defines Formula (10) as the function of potential availability of urban facilities. By using Formula (10), the relationships between the distances between the Tokushima railway station and urban facilities, z , and the potential availability of urban facilities, q , are described. The parameters are calculated from Formula (11) by taking the logarithm of both sides of Formula (10).

$$\ln F(z) = -z^2/\alpha \tag{11}$$

In Formula (11), the travel distances from the Tokushima railway station to urban facilities on foot, by electric bicycles, and by electric motorcycles are calculated by the distribution of the maximum travel distance based on the results of the questionnaire survey of local residents.

Distances z from the Tokushima railway station to urban facilities are divided into several ranks. Both the distance of each rank and the corresponding $F(z)$ are generated as data sets. These data sets are used as samples for the regression analysis for calculating α . Table 2 shows the result. Both coefficients of determination and t-values are high.

Figure 14 describes the function of the potential availability of urban facilities on foot, by electric bicycles, and by electric motorcycles based on the calculated α .

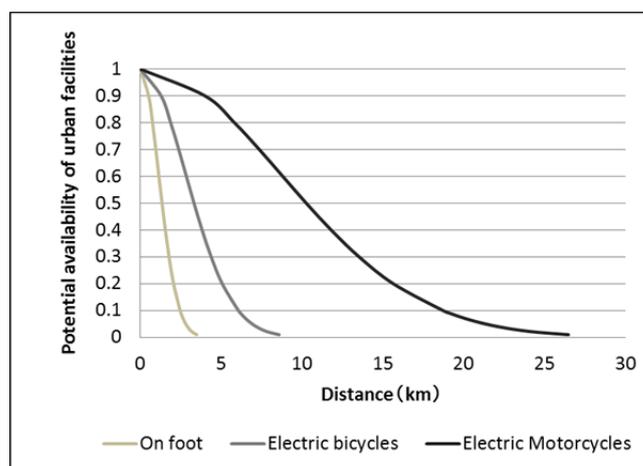


Figure 14. Function of the potential availability of urban facilities

3.2.3 Calculation results of the increases in the availabilities of urban facilities

Increases in the availabilities of urban facilities were calculated by Formula (6) for electric bicycles and by Formula (7) for electric motorcycles. Figure 15 shows the calculation results. Although some differences appear in the calculation results among urban facilities, the introduction of the rental two-wheeled vehicles increases the availability of urban facilities. Availabilities of “Schools” are highly increased by using both electric bicycles and electric

motorcycles; in contrast, availabilities of both “Restaurants” and “Post Offices” are slightly increased by both electric bicycles and electric motorcycles. The primary reason is the locations of urban facilities. “Schools” are located in most areas in Tokushima city, whereas “Restaurants” and “Post Offices” are mostly located near Tokushima station.

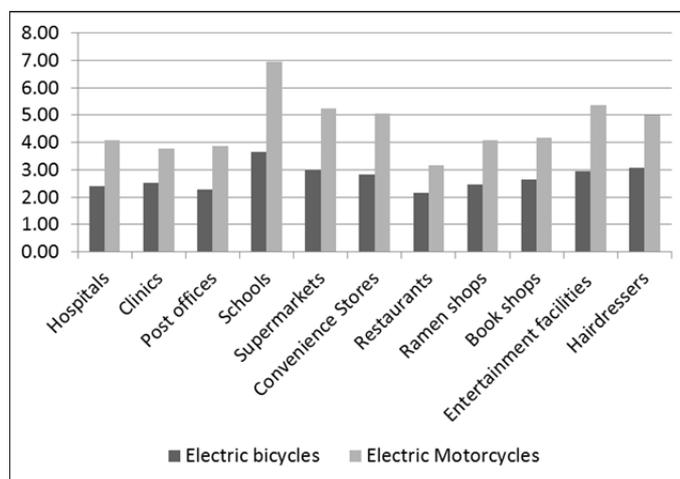


Figure 15. Calculation results of increases in the availabilities of urban facilities

3.3 INCREASE IN THE NUMBER OF VISITORS TO URBAN FACILITIES

3.3.1 Methodology

This study examined the increase in the number of visitors due to the introduction of the rental two-wheeled vehicles, because an increased number of visitors is one of the most important benefits for managers of urban facilities. The increase is described by the ratio R , which is the number of visitors who use the rental two-wheeled vehicle divided by the number of visitors who travel on foot.

First, the availability of any urban facility in the movable fields by traveling on foot from the Tokushima station, $F_w(z_j)$, needs to be calculated. The availability of all urban facilities in the movable fields for visitors traveling on foot from the Tokushima station, U_w , is described in Formula (12).

$$U_w = n \sum_j F_w(z_j) \quad (12)$$

where,

U_w : The availability of all urban facilities in the movable fields for visitors traveling on foot

n : The number of visitors who travel on foot

$F_w(z_j)$: The availability of urban facilities travelled on foot

Next, Formula (13) shows the availabilities of all urban facilities for visitors traveling by electric bicycles, U_b . Ratio R_b is the number of visitors who use the rental electric bicycles divided by the number of visitors who travel on foot. Formula (14) shows the availabilities of all urban facilities for visitors traveling by electric motorcycles, U_s . Ratio R_s is the number of visitors who use the rental electric motorcycles divided by the number of visitors who travel on foot.

$$U_b = n(1 - R_b) \sum_j F_w(z_j) + nR_b \sum_j F_b(z_j) \tag{13}$$

$$U_s = n(1 - R_s) \sum_j F_w(z_j) + nR_s \sum_j F_s(z_j) \tag{14}$$

where,

- U_b : The availability of all urban facilities in the movable fields for visitors traveling by electric bicycles
- U_s : The availability of all urban facilities in the movable fields for visitors traveling on foot from the Tokushima station
- R_b : The number of visitors who use the rental electric bicycles divided by the number of visitors who travel on foot
- R_s : The number of visitors who use the rental electric motorcycles divided by the number of visitors who travel on foot
- $F_b(z_j)$: Function of availabilities of urban facilities by electric bicycles
- $F_s(z_j)$: Function of availabilities of urban facilities by electric motorcycles

The effects of introducing the rental electric bicycles, U_{sw} , are estimated by using Formula (15). The effects of introducing the rental electric motorcycles, U_{sw} , are estimated by using Formula (16).

$$U_{bw} = U_b / U_w \tag{15}$$

$$U_{sw} = U_s / U_w \tag{16}$$

To calculate the effects, the ratio of utilization of the rental two-wheeled vehicles is set by the ratio of respondents who affirmatively answered on the questionnaire that they would “use” and “use with condition” the rental two-wheeled vehicles. Table 3 shows the ratio of utilization of the rental two-wheeled vehicles.

Table 3. Ratio of utilization of the rental two-wheeled vehicles

Transportations	Ratio of the utilization
Electric bicycles	0.29
Electric motorcycles	0.14

3.3.2 Calculation results of the increase in the number of visitors to urban facilities

Figure 16 shows the effects of the introduction of the rental two-wheeled vehicles from the viewpoint of managers of urban facilities. The result shows that the number of visitors increased by 1.3 to 1.8 times. The differences in the increase in the number of visitors among urban facilities between electric bicycles and electric motorcycles are seen.

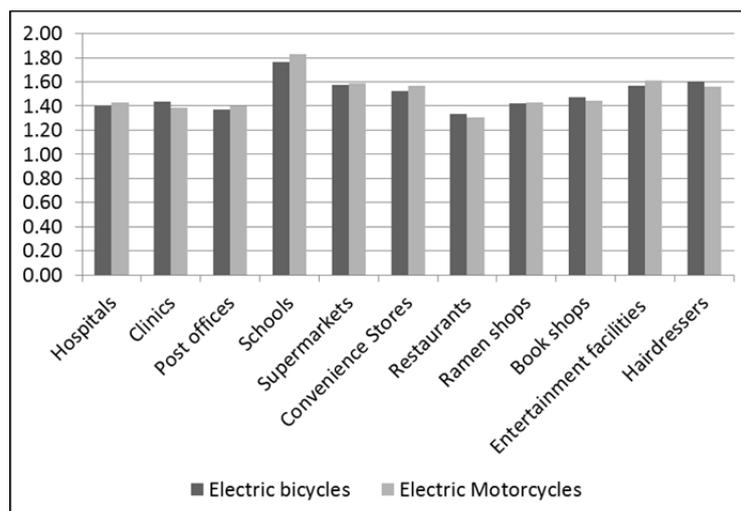


Figure 16. Effects of the introduction of two-wheeled vehicles on number of visitors to urban facilities

4. CONCLUSION

This study examined and estimated the effects of introducing rental two-wheeled vehicles in Tokushima city in terms of the users and the urban facilities. The main findings are as follows.

- 1) The introduction of two-wheeled vehicles expands the movable field of local people. The areas of the average movable field by electric bicycles are 6.0 times higher than those on foot; the areas of the average movable field by electric motorcycles are 37.6 times higher than those on foot. The interaction opportunities to local residents by using electric bicycles is 2.7 times higher than those on foot; the interaction opportunities to local residents by using electric motorcycles are 5.4 times higher than those on foot.
- 2) This study proposed and empirically verified the methodology for estimating the effect of the introduction of rental two-wheeled vehicles. The model for calculating the effect of introducing rental two-wheeled vehicles represents a high level of estimations. The calculation results show that the introduction of the rental two-wheeled vehicles brings positive effects on the availabilities of urban facilities. The availabilities of “Schools” have the most positive effects, and the availabilities of “Restaurants” have the least positive effects. These results are influenced by the locations of the urban facilities.
- 3) This study also proposed the methodology for estimating the increase of visitors to urban facilities. The results by using the estimated model, which this study proposed, show that the number of visitors increased by 1.3 to 1.8 times. The results do not show the difference in the increase in the number of visitors among urban facilities between electric bicycles and electric motorcycles.

Overall, the results show the expansion of movable fields, the increase in interaction opportunities with local residents, and the increase of availabilities of urban facilities in the case that rental two-wheeled vehicles are introduced.

Future research would be useful in the following areas. First, the methodology for the estimation of movable fields does not reflect individual behavior variation. It would be

helpful to develop the methodology by using individual data for a more accurate estimate. Second, although the results of this study show positive effects on rental two-wheeled vehicle projects, more development of the methodology is needed in order to examine the following rental details: the number of two-wheeled vehicles, store hours and location of docking stations.

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