Evaluations of Convenience of Use and Image Preference of Bicycles to Develop Electric Bikes

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Abstract: This study was carried out to present design guidelines for developing electric bikes which could be used for more users regardless of gender and age. Through a survey with 336 male and female respondents in Seoul aged between 10s and 70 years or older, the convenience of bicycle use and image preference by gender and age were investigated. To evaluate convenience of bicycle use, the 7 principles of universal design made by Universal Design Center were customized to fit for accessing bicycles. The following are results of statistical analysis on 301 valid data: (1) of the 7 principles, conventional bicycles were identified to be the most inconvenient in principle 6(low physical effort), followed by in principle 5(tolerance for error) and 7(size and space for approach and use). Women appeared to feel more inconvenience than men in all evaluation criteria while using bicycles. The relation between the convenience of use and users' age was not identified. (2) Preferred images by bicycle users turned out to be those of "simple" and "light." By gender, male preferred more "technical" and "dynamic" images than female. By age, users in their 10s-20s preferred more "individual" image than 70 years or older.

Keywords: *Evaluation, Convenience of Use, Image Preference, Electric Bikes, Universal Design*

1. Introduction

Electric bike is a product to be moved forward with the aide of electric energy when it is necessary while people ride it by turning its pedals. With a reasonable amount of effort, a user can climb hills of 1 in 10 (10%) on an electric bike with ease[1]. It also has the advantage of not emitting pollution unlike scooter or motorcycle. But, although new electric bikes are being made to take advantage of these merits, most of them are pointed out to have problems in usability and appearance etc. People say that they can hardly find considerations for women or the elderly. Some people also point out that forms of most electric bikes don't give feelings of expensive products as they are not different from general bicycles except a battery pack is attached to them. With growing economic activities of women, products not appealing to them can not survive any more in the market. Also, companies neglecting needs of increasing number of old people can

[1] Why choose an electric bike?-Ten good reasons from A to B magazine, www.atob.org.uk/electricbikeadvantages.htm

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not expect their perennial growth. Korea is becoming the aging society at the fastest speed in the world and falls within the United Nations' forecast of becoming by 2026 a "super-aged society," where people 65 years or older account for more than 20 % of the population[2]. Accordingly, designers and manufactures are required to develop products to accommodate a variety of users including women as well as old people. Reflecting this, this study was pursued to present design guidelines needed for developing electric bikes for various users. Concrete objective of this study was as follows:

(1) To identify the problems of bicycles through evaluating their convenience level by gender and age.

(2) To find out the image preference of electric bike users by gender and age.

2. Methods

After a preliminary study, a survey was conducted with a total of 336 male and female respondents in Seoul who could ride bicycles. The respondents' ages were between in their 10s and 70 years of age or older. Survey questions consisted of 3 parts: "situations of using bicycles", "evaluation of convenience of use" and "image preference of electric bikes" Although the ultimate goal of this study was to draw design guidelines for electric bikes, this survey was taken with users of all kinds of bicycles including electric bikes since electric bike users were quite limited in Korea and it was assumed that the problems of general bicycles were basically the same as those of electric bikes. Before the survey, a brief education on evaluation criteria of the convenience of use for survey assistants was conducted. To analyze 301 valid data, frequency, cross tabulation, T-test and one way ANOVA were used.

3. Results

3.1. Respondents profile

The respondents consisted of 172(57%) males and 129(43%) females in their 10s to 70 years or over (Table 1). Among them, people in their 10s-20s occupied the most with 57%, followed by those in their 30s-40s with 19%, 50s-60s with 18% and people over 70 years old occupied 6%. People who were 160-170cm in height occupied the most with 35%, followed by 170-180cm with 30% and 150-160cm with 22%. By occupation, college students accounted for 32%, followed by office workers with 12%, engineer or technician and house wives with 10% respectively.

Table 1 Profile of the respondents (n=301)

Gender	Count	%
Male	172	57
female	129	43
Height	Count	%
Below 150cm	21	7
151-160cm	66	22
161-170cm	106	35
171-180cm	90	30
181-190cm	18	6
	301	100

Age	Count	%
10s-20s	171	57
30s-40s	59	19
50s-60s	53	18
70 years or older	17	6
Occupation	Count	%
College student	98	32
Office worker	36	12
Engineer or technician	31	10
House wife	30	10

[2] Population in old ages (2000-2050), Korea National Statistical Office, http://kosis.nso.go.kr.

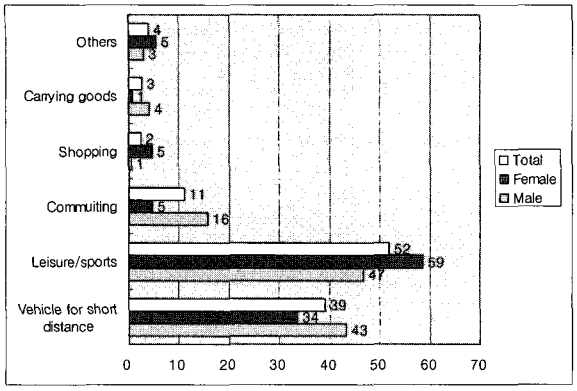


Fig. 1 Purpose of using bicycles (multiple answers)

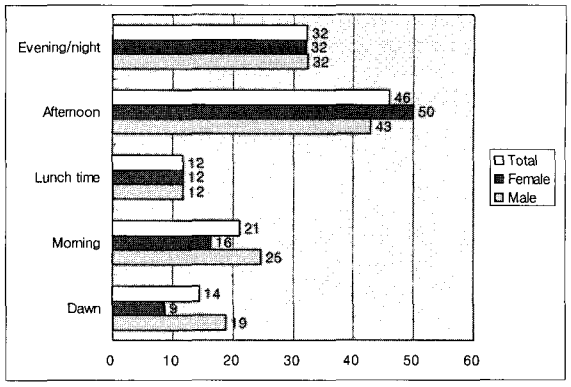


Fig. 2 Time for riding bicycles (multiple answers)

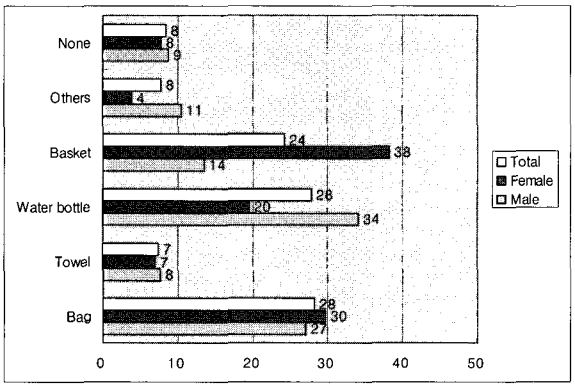


Fig. 3 Things loaded on bicycles (multiple answers)

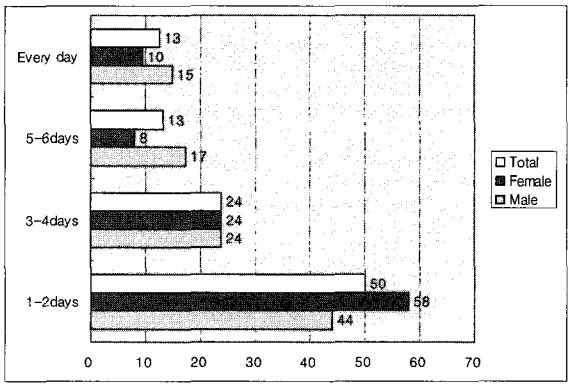


Fig. 4 Number of days for using bicycles

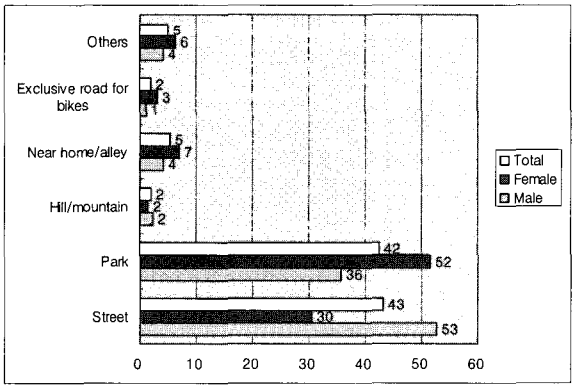


Fig. 5 Places for riding bicycles

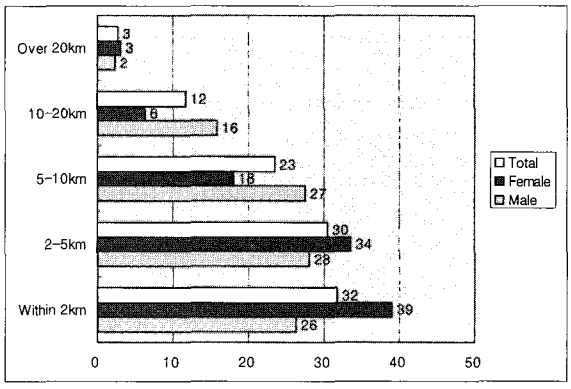


Fig. 6 Distance of riding bicycles

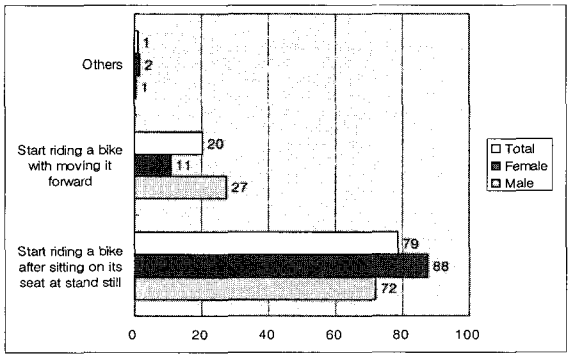


Fig. 7 Methods of riding bicycles

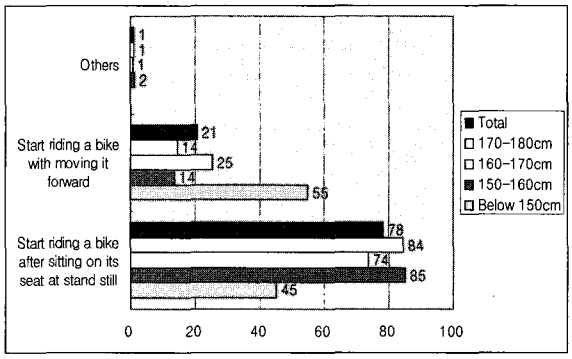


Fig. 8 Methods of riding bicycles(by height)

3.2 Situations of Using Bicycles

• Purpose of using bicycles

Of multiple answers to a question on the purpose of riding bicycles, "leisure and sports" occupied 52%, followed by "a vehicle for short distance trips" with 39% and "commuting" with 11%. By gender, as shown in Fig. 1, male appeared to use bicycles more for commuting etc. than female, while female more for leisure and sports.

•Time for riding bicycles

Of multiple answers to time for riding bicycles, "afternoon" occupied 46%, "evening/night" followed with 32%, "morning" with 21% and "dawn" with 14%. As shown in Fig. 2, female appeared not to use them as frequently as male in the morning and dawn (Fig. 2).

• Things loaded on or attached to bicycles

Of multiple answers to things loaded on or attached to bicycles, "bag" and "water bottle" occupied 28% respectively, followed by "basket" with 24%. This figure might have been caused since people in their 20s attending colleges comprised almost half of the respondents. By gender, the ratio of female carrying basket was much higher than that of male (Fig. 3).

• Number of days of using bicycles

Of the numbers of the days of riding bicycles per week, "1-2 days" accounted for 50%, followed by "3-4 days" with 24% ('5-6 days' 13%, 'every day' 13%). Fig. 4 shows that the ratio of male using "5-6 days" or "every day" was higher than that of female.

• Places for riding bicycles

Of places for riding bicycles, "street," "park" occupied 43% and 42% respectively. By gender, male turned out to use bicycles more often in street than female, while female more often in park (Fig. 5).

• Distance of using bicycles

As for the distance of using bicycles, "less than 2km" and "2-5km" accounted for 32% and 30% respectively, followed by "5-10km" with 23%. By gender, as shown in Fig.6, longer the distance, the ratio of male appeared to be higher than that of female.

• Methods of riding bicycles

Among methods of riding bicycles, "start riding a bicycle after sitting on its seat at stand still" and "start riding on a bicycle with moving it forward" were turned out to be 79% and 20% respectively (others 1%). Fig. 7 shows that male respondents had the higher tendency of riding bicycle with moving it forward than female ones. By height shorter respondents had a higher tendency to ride on a bicycle with moving it forward (Fig. 8). It indicates that short people may not easy start riding a bicycle while sitting on its seat at stand still since their feet can not easily reach pedals of a bicycle.

• Parts of the body being frequently injured

The most frequently injured parts of the body were "knees" with 42%, followed by "legs" with 30%. Following "legs" were "hands" with 23%, "arms" with 9% and "face" with 2%.

• Parts of bicycles being frequently broken

As for the most frequently broken parts of bicycles, 42% of respondents answered "chain," followed by

"tire" with 27% and "gear" with 17%. (Seat 6%, handle 5%, others 2% and brake 1%). This result shows the chain is one of major complaints to be addressed in bicycle design and supports the idea of adopting "chainless technology" to solve various problems related to the chain[3].

3.3 Intentions of Using Electric Bikes

As for a question whether they have intentions of using electric bike, 57% of respondents checked "yes," while 43% answered "no." For reasons why they would like to use it, 81% answered "because they can ride it with electric energy when they feel tired" and 10% answered "because it is environment friendly" (others 4%, economy of energy 3%, reasonable price 1%).

As for reasons of not intending to use electric bikes, 38% pointed out high price. Opinions that "movable distance with one battery charge is too short" and "using electric bike is not helpful for exercise" were both 16% respectively (it is too slow 6%, operation is too complex 5%, it is too noisy 5% and others 5%). By gender, as shown in Fig. 10, the ratio of male not intending to use electric bike for its expensive price was higher than female. This result shows that, in order to increase sales of electric bikes, above all, problems of the expensive price and the battery should be solved.

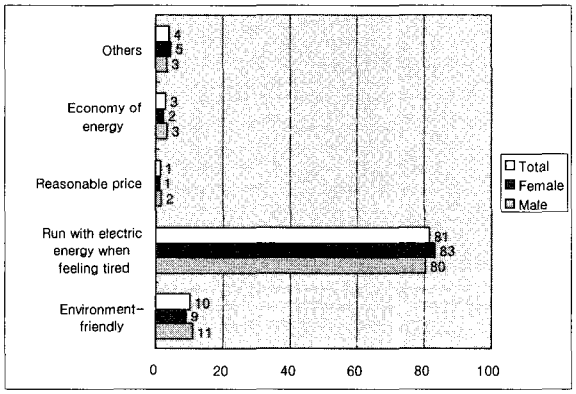


Fig. 9 Reasons of using electric bikes

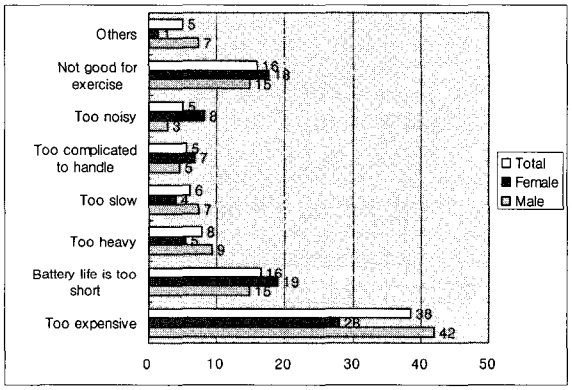


Fig. 10 Reasons of not intending to use electric bikes

3.4 Evaluation of Convenience of Use

The convenience of bicycle use was evaluated by the 7 principles of universal design[4], but as shown in Table 2, detailed criteria were customized to fit for the evaluation of bicycles and were changed to the form of questions. To make the criteria, the PPP evaluation checklist[5]developed to assess the level of universal design application to products and environments by Tripod Design[6], was also examined. Of the evaluation criteria, for example, the criterion of principle 7 "Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility" was customized to "Is it easy for users who have diverse physical abilities to ride or get off your bicycle?". (Table 2) It was assessed according to the following 5 grade scale; strongly positive (5), positive (4), average (3), negative (2), and

[3] Dynamic Bicycles, Chainless Technology, www.dynamicbicycles.com/chainless
[4] The Center for Universal Design, Universal Design Principles, www.design.ncsu.edu:8120
[5] Nikkei Design (2004) 100 Cases of Universal Design, Tokyo, Japan, 26-33.
[6] Tripod Design, www.tripoddesign.com

strongly negative (1).

As a result, the convenience of use for conventional bicycles was evaluated in the order of principle 3(simple and intuitive) (3.62), principle 4(perceptible information) (3.30), principle 1(equitable use) (3.27) and principle 2(flexibility in use) (3.20) (p-value <0.05) (Table 2, Fig. 11). It can be assumed that existing bicycles were assessed high in "simple and intuitive" since the survey was done with the respondents who could ride bicycles.

In remaining 3 principles, respondents' assessments were negative. Of all principles, in principle 6(low physical effort) respondents' evaluations of existing bicycles were especially negative (2.57), followed by in principle 5(tolerance for error) and in principle 7(size and space for approach and use) with 2.83 and 2.95 respectively (p-value <0.05). This result indicates that, to develop electric bikes above all, the problems caused by such as physical efforts, dangers resulted from possible errors and difficult approaches should be solved.

- **Evaluation results by gender**

In all principles, conventional bicycles were turned out to be more inconvenient for female than male (Table 2, Fig. 11) (p-value <0.05). Female respondents felt more inconvenience than male ones especially in principle 6(low physical effort) (the gap between genders: 0.29). This result indicates that, in order to expand the population of the users, designers should increase their efforts to alleviate physical difficulties of women.

Table 2 Evaluation results of conventional bicycles by gender (n=301)

Principles	Criteria	Male	Female	Total
1.Equitable use	Is your bicycle useful and appealing to all users?	3.30	3.22	3.27
2.Flexibility in use	Is it possible for users to adjust parts of your bicycle to accommodate their height or body size?	3.26	3.13	3.20
3.Simple and intuitive use	Is use of bicycle design easy to understand, regardless of user's knowledge, or current concentration level?	3.66	3.55	3.62
4.Perceptible information	Does your bicycle communicate necessary information (change of gear, bell sounds etc.) effectively to the user, regardless of ambient conditions or the user's sensory abilities?	3.39	3.18	3.30
5.Tolerance for error	Does your bicycle provide measures to minimize casualty of users while riding it?	2.88	2.76	2.83
6.Low physical effort	Is it possible for users to ride their bicycles comfortably with a minimum fatigue in the conditions of hill, rain and snow etc.?	2.70	2.41	2.57
7.Size and space for approach and use	Is it easy for users with diverse physical abilities to ride or get off their bicycle?	2.98	2.90	2.95

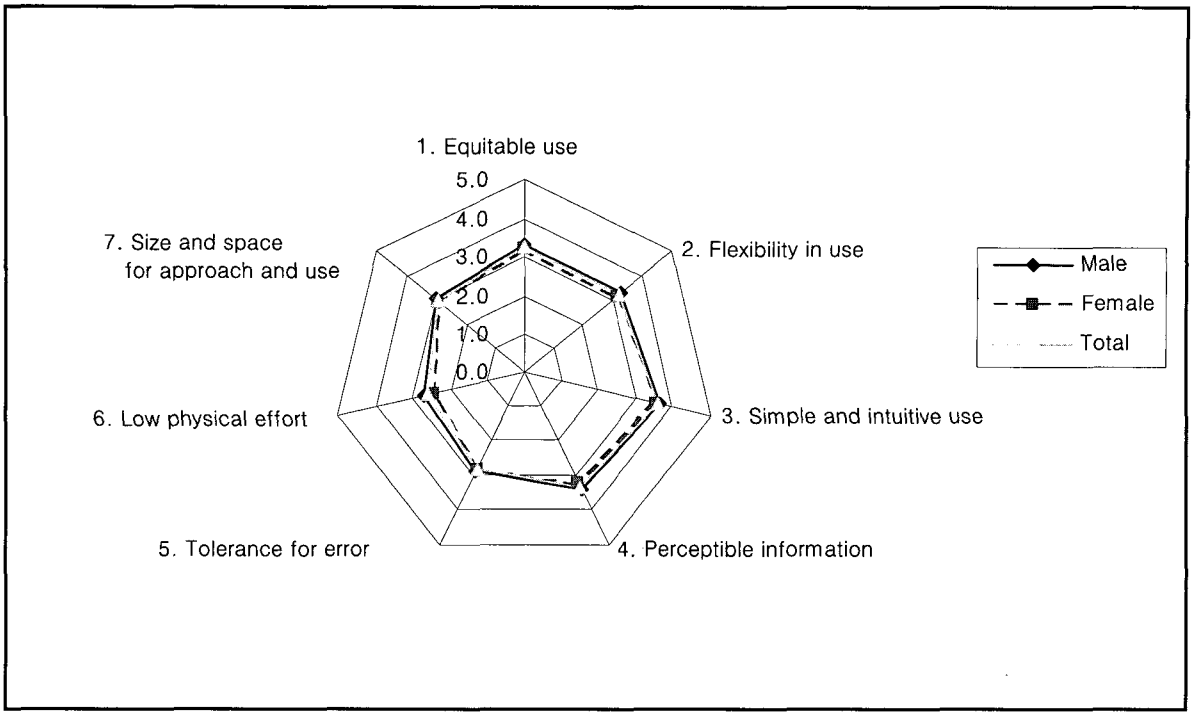


Fig. 11 Evaluation on convenience of bicycle use by gender (n=301)

• Evaluation results by age

As a result of multiple comparisons, in principle 1, 6, and 7, a tendency for respondents to feel more inconveniences with aging was apparent (Fig. 12). In other principles, however, increase in inconveniences accompanied by aging was not identified. It is assumed this might have been resulted since respondents in a certain age group had better bicycle riding skills with their longer experiences.

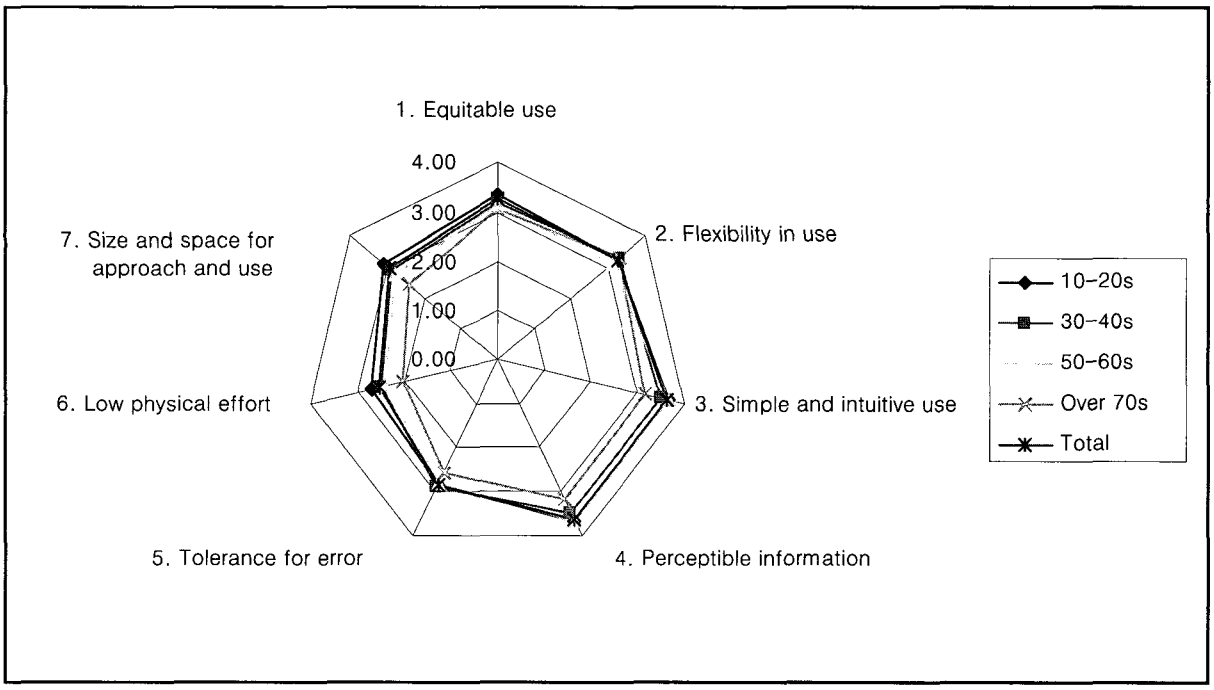


Fig. 12 Evaluation on convenience of bicycle use by age (n=301)

3.5 Evaluating Images of Electric Bikes

To identify preferred electric bike image, first, respondents were asked to appreciate two representative pictures of existing electric bikes respectively by using an evaluation scale. The scale consisted of 9 groups of opposite adjectives and the following 5 scale; "very," "somewhat," "middle," "somewhat," and "very." Then, they were asked to check their ideal electric bike images on the scale. Lastly, the ideal images were compared with those of two conventional electric bikes (Fig. 13, 14).

Table 3 Process of evaluating electric bike images

Step 1: to assess two existing electric bikes by using an evaluation scale
⇩
Step 2: to check ideal electric bike images according to the scale
⇩
Step 3: to compare the ideal images with those of the two existing electric bikes

(1) Evaluating Images of Electric Bike 1 and 2

According to the evaluation, respondents felt bike 1 to be "aggressive" (4.09) and "individual" (3.90), while bike 2 to be "traditional" (1.71), "realistic" (1.79), "general" (1.92), and "feminine"(1.95) (Table 4)

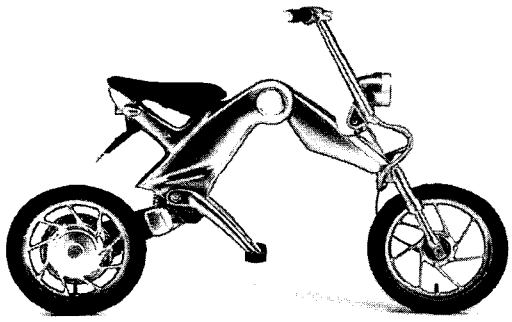


Fig. 13 Electric bike 1

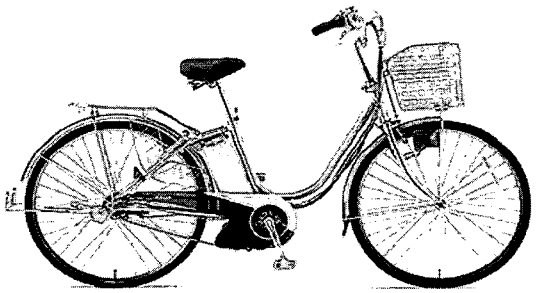
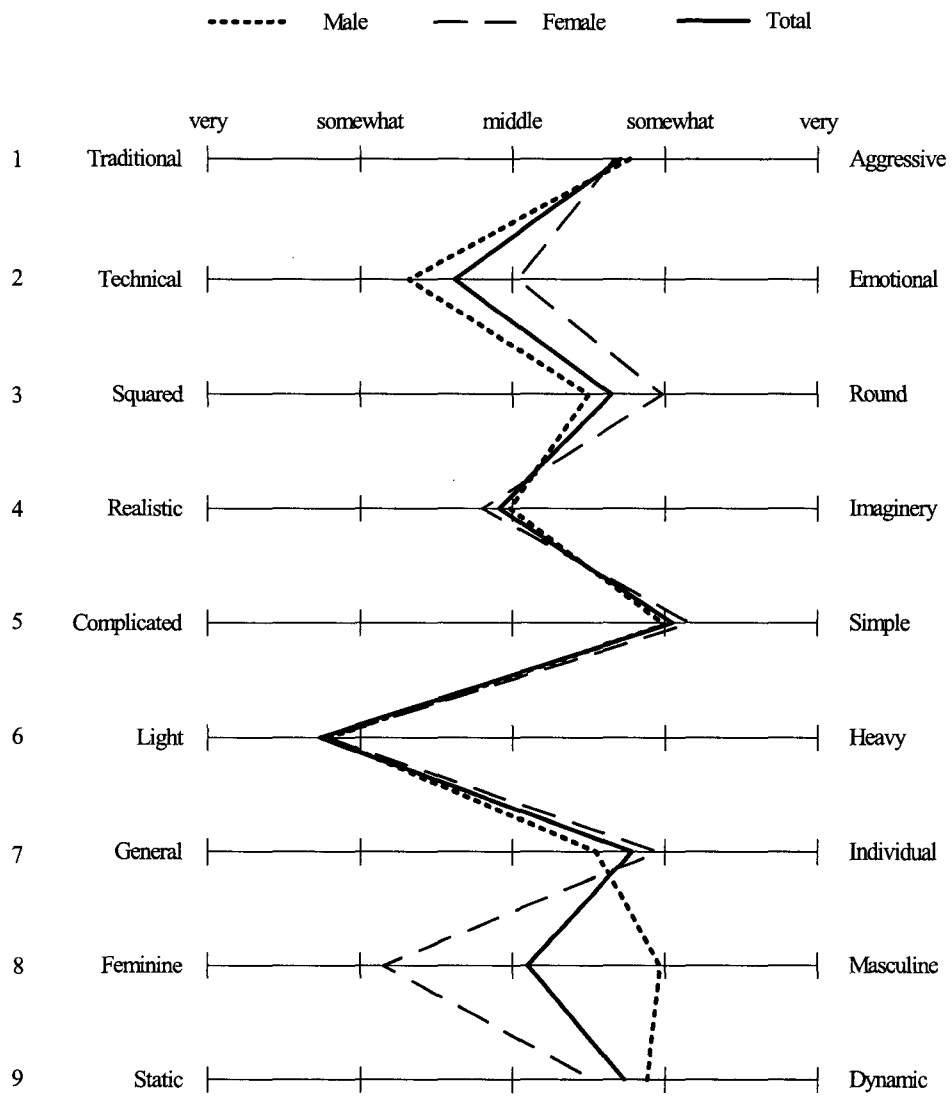


Fig. 14 Electric bike 2

(2) Checking Preferred Images

Preferred bicycle images were turned out to be those of "simple" and "light." They were also the images of somewhat "aggressive," "individual" and "dynamic." By gender, as shown in Table 4, male appeared to prefer more "technical", "square", "masculine" and "dynamic" image than female. Multiple comparisons by age group showed that, in the images of "complicated-simple" and "general-individual," image preference change by age was apparent. By age, respondents over 70s appeared to prefer much less "individual" image (2.94) than those in their 10s-20s (4.01). On the other hand, they preferred more "simple" image (4.59) than those in their 10s-20s (3.94) (p-value <0.05).

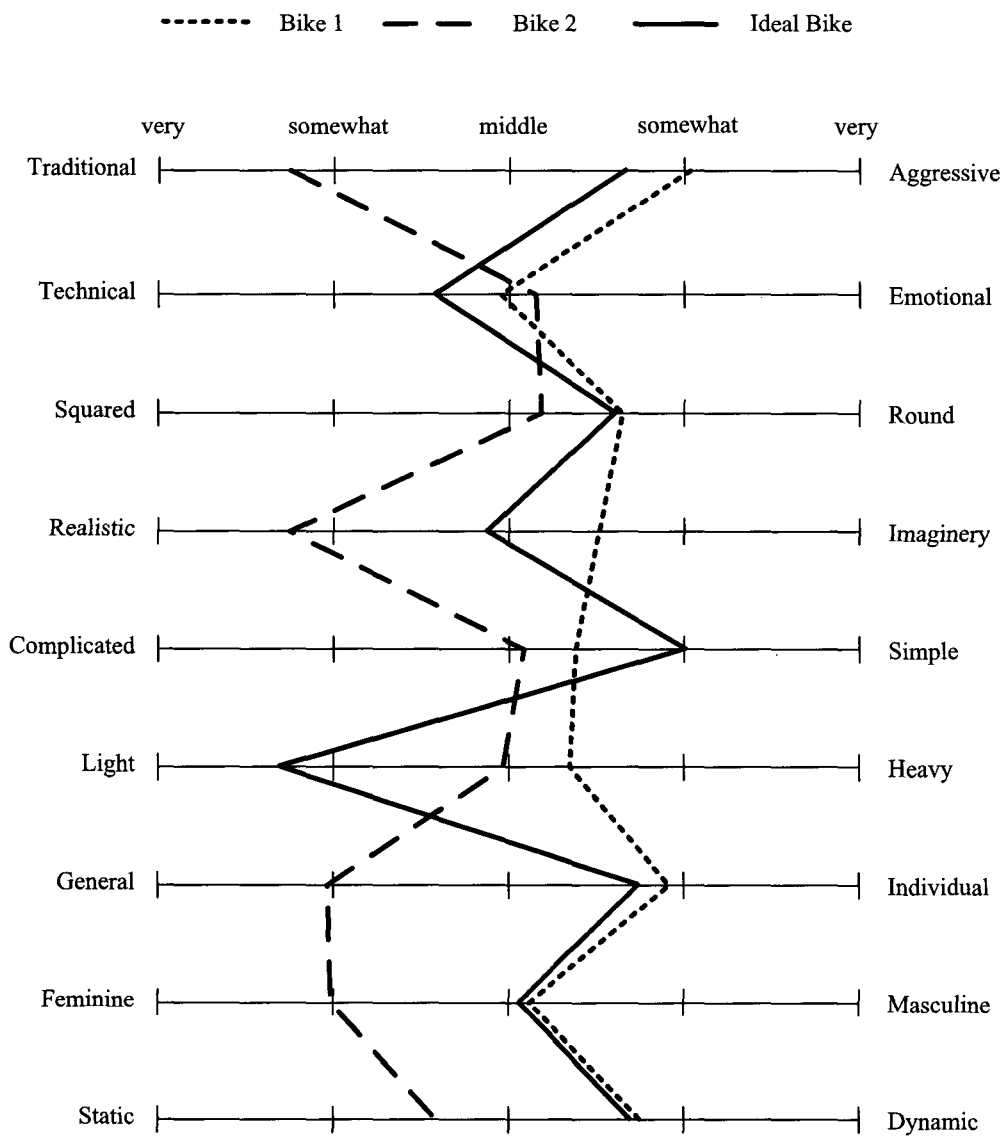
Table 4 Profile of preferred bicycle images by gender (n=301)



(3) Comparing Ideal Images with Images on Two Electric Bike

As shown in Table 5, as a whole, the ideal images of electric bikes appeared to be closer to those of electric bike 1 than electric bike 2. Especially in the group of adjectives such as "squared-round," "general-individual," "feminine-masculine" and "static-dynamic," the images of electric bike 1 were very close to those of the ideal one. However, in "realistic-imaginary," "complicated-simple" and "light-heavy," bike 1 turned out to be comparably different from the ideal one. Especially, in "light-heavy," the difference between the two was considerable. This result shows that the ideal electric bike has somewhat "aggressive," "round," "individual" and "dynamic" images like bike 1, yet it has more realistic, simple and lighter images than bike 1.

Table 5 Comparing ideal images with two existing electric bike images (n=301)



3.6 Problems and Ideas Related to Electric Bikes

As for an open-ended question asking about problems of conventional electric bikes and ideas to solve them, 26% of respondents pointed out problems related to battery such as "battery life" and "charging battery" (weight 13%, cost 12%, appearance 9%, chain 6%, seat 6%)(Table 6). This result shows that battery is one of major problems of conventional electric bikes. To extend movable distance with one battery charge, the idea of having the battery regenerate electricity on its own while being used was presented.

In relation to appearance, a problem that most electric bikes are not differentiated from general bicycles was pointed out. In order to improve the appearance, referring to forms of motor cycles or scooters was recommended.

Table 6 Problems and ideas related to electric bikes

	Major Problems	Ideas
1)	Movable distance with one battery charge is too short.	Make the battery to be regenerated on its own while being used.
2)	Charging battery is quite cumbersome.	Make people charge battery anywhere regardless of bike models by making charging function of all bikes the same.
3)	In many cases, battery case attached to an electric bike does not harmonize with its entire appearance.	To improve its appearance, incorporating a battery case into the frame of an electric bike can be considered.
4)	In appearance, most electric bikes are not differentiated from general bikes which are manually ridden.	It seems better to study forms of motor cycles or scooters than bicycles to make electric bikes to be regarded as high end products.
5)	Chain comes out easily.	Adopting chainless system can be considered.

4. Conclusions

This study was carried out to present design guidelines for designers and manufactures to develop electric bikes. As a result of a survey for bicycle users, the following were identified:

(1) Situations of using bicycles

Among the methods of getting on a bicycle, most people appeared to start riding a bicycle after sitting on its seat at stand still. But many short people below 150cm in height were found to start riding a bicycle with moving it forward since their feet could not easily reach pedals. This indicates that, to accommodate short people, accessibility of bicycles should be well considered.

(2) Convenience of using bicycles

In terms of the convenience of use, as a whole, conventional bicycles were identified to be inconvenient in the order of principle 6(low physical effort), principle 5(tolerance for error) and principle 7(size and space for approach and use). In all criteria customized from the 7 universal design principles, women appeared to feel more inconvenience than men while using a bicycle. Evaluation results by age showed a tendency that older people felt more inconvenience than younger ones in principle 6 and 7.
This result indicates that, in order to expand electric bicycle users to include women and senior citizens, designers should spare no efforts to lower physical efforts and to enhance tolerance for error and accessibility.

(3) Image preference for electric bikes

Preferred electric bike images turned out to be those of "simple" and "light." In addition, ideal images

were somewhat "aggressive," "round," "individual" and "dynamic." By gender, male had preferences for more "technical" and "dynamic" images than female. By age, respondents in their 10s-20s were identified to prefer more "individual" image than those over 70years or older while the latter to prefer simpler image than the former.

(4) Problems and ideas related to electric bikes

To improve existing electric bikes, problems related to the battery turned out to be solved the first. To differentiate the appearance of electric bikes from conventional ones, forms of motorcycles or scooters are needed to study. In order to enhance appearance of electric bikes, incorporating a battery case into the frame of an electric bike should be considered. Also, adopting chainless system instead of conventional chain can be considered.

As this study was conducted for bicycle users in which only small number of electric bike users was included, there were some limitations to find out problems specific to electric bikes such as instrument panel. These problems specific to electric bikes should be further studied to make the above design guidelines to be complete.

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