Analysis of Low-Floor Bus Passengers' Behavior Patterns Using Video Observation

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Abstract. Low floor buses have regarded as a transportation which is applied to the concept of universal design. However, studies on low-floor buses in terms of universal design were rarely conducted. Moreover, passengers using low-floor buses have felt that these buses are not convenient, satisfactory and safe enough. In this study, we conducted preliminary surveys to investigate the interior design factors which affect to passengers' convenience and satisfaction. Next, we draw passengers' behavior patterns based on context of use by conducting video observation and based on these, some design suggestions were drawn to investigate the way to ensure convenience, satisfaction and safety in using low-floor buses.

Keywords: Low-floor bus, Behavior Pattern, Video Observation, Context of use, Universal design.

1 Introduction

In recent years, as the numbers of people who have physical limitations (e.g. the elderly and disabled) increased, the needs for accessibility of public facilities for those people increased as well [2].Thus, Universal design has been spreading out in public facilities and applied even to buses. Low-floor buses provide easier access to the elderly, children, and physically disabled passengers [10]. Thus, these are regarded as an effective transportation to those people and introduced in many countries (Europe, America, Japan, etc.). Korea is also gradually expanding the introduction of low-floor buses.

Despite of the trend, studies on low-floor buses that consider universal design are rarely conducted. Also, low-floor buses are not satisfying mostly to passengers including elderly people, children, and physically impaired passengers [10].

In this paper, we will try to find common behavior of passengers using low-floor buses and extract the passengers' behavior patterns. Based on this, we will suggest how to design the interior design factors of low-floor bus to improve the convenience and satisfy all passengers.

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2 Related Work

2.1 Universal Design in Public Transportation System

Sandhu et. al. [3] defines universal design as "Universal design has a concept that extends to a broad diversity of users who have to interact with the built environment" (p.3.3). So, many designers and architectures have to consider the needs of diverse users by using UD (Universal design) [4].

In public transportation system's design, UD should be especially considered because of the characteristics of public transportation system which is used by diverse users. Schmocker et. al. [5] indicated that elderly people living in London use buses for shopping with the highest portion compared with other public transportation system. The main reason is the increase in low-floor buses since 2005[5]. In many countries like United Kingdom, accessibility of elderly and disabled people who has lower-mobility has been increased with the introduction of low-floor buses [11]. However, Audirac [12] indicated that "low-floor buses are not UD solutions to micro-level transit accessibility although they are a form of inclusive design" (p.10). Thus, this study focuses on the low-floor buses as a research target.

2.2 Context of Use

Dey [6] defines context as "any information that can be used to characterize the situation of an entity" (p.5). Dey refers to "entity as a person, place or objects that is considered relevant to the interaction between a user and an application, including the user and applications themselves" (p.5). Maguire [7] emphasizes context of use when designers and manufacturers are developing or assessing a product in terms of human factors (HF) and extracted the component of context of use. It composed of System report and stakeholder analysis (System or product report, Stakeholder report, User/stakeholder type), user (user name, experience, knowledge and skills, personal attributes), Task (Task list), Environment (Technical environment, Physical environment, Organizational environment).

3 Methods

This study conducted a user study using video observation as well as survey. The video observation as direct observation in the field has the advantage of understanding context of user activity [10]. Thus, in order to draw passengers' behavior patterns based on context of use on using low-floor buses, video observation method was used. Before the video observation, preliminary survey was conducted to investigate the interior design factors which affect to passengers' satisfaction and convenience.

3.1 Survey

The design of the questionnaire. Before the development of questionnaire, by FGI, a bus layout was divided into boarding/getting off/front/ rear space and space for disabled passenger in wheelchair and 10 issued interior design factors were selected. Table 1 indicates the selected interior design factors based on each space.

Table 1. Interior design factors

Space	Interior design factor
A boarding space	Stanchion pipe
	Bus LED display screen
A space of getting off	Anti slipping pad
A front space	Seat on wheel pan
	Stanchion pipe
	Passenger seat
	Seat handle
	Hand rail
	Hand rail Ring
	Route map
A rear space	Seat on wheel pan
	Passenger seat
	Stanchion pipe
	Seat handle
	Hand rail
	Hand rail ring
	Route map
A space for disabled passenger in wheelchair	Foldaway seat

The questionnaire was made up of 3 parts (a total of 27 items) that included respondent demographics (3 items), level of overall satisfaction and convenience of low-floor buses (2 items) and level of satisfaction and convenience of using of each interior design factor (22 items). All items were measured using a 7-point Likert scale ranging from 'disagree strongly' to 'agree strongly'.

Subjects and Procedure. A total of 208 people including 117 females (56.2%) and 91 males (43.8%) participated. The majority were 20-29 age group which composed 41% of the samples, 10% were 10-19 age group, 15% were 30-39 age group, 13% were 40-49 age group, 14% were 50-59 age group and 7% were above 60 age group. The average height of men and women were 173.3cm and 160.5cm. Both men and women showed an error of approximately 3cm considering the average height of Korean.

The preliminary survey was conducted for 6 days. It targeted the passengers who were waiting for the low-floor buses at a bus station to reflect earlier experiences and who were on the low-floor buses. The questionnaire data were analyzed with SPSS statistics version 18.0 and ANOVA (α=0.05) was used.

3.2 Video Observation

Data collection. In this study, data were collected by two low-floor buses which were manufactured by Hyundai motor company. We collected data during 14days including weekend, weekdays, and rainy days.

Helen et.al [9] indicate that researchers who use data gathering method with video have to be careful of Hawthorne effect and shouldn't miss the ongoing things out of the

Fig. 1. The examples of collected data

Table 2. Modified components of context of use

Category	Sub-Category	Component
User	User type	Passengers who do not have physical limitations
		Passengers who have physical limitations
	User characteristic	The level of personal belongings
		Sex
Task	Task list	Boarding
		Card tagging
		Movement in the inside
		Supporting passenger's body
		Sitting
		Standing
		Caring personal belongings
		Controlling the side widow or air conditioner
		Identifying the route map
		Pressing the call buzzer
		Getting off
		Unexpected incident
Environment	Technical	Card reader
		Door handle
		Seat handle
		Foldaway seat
		Wheelchair fixing device
		Seat on wheel pan
		Steps in rear aisle
		Hand rail
		Hand rail ring
		Stanchion pipe
		Call buzzer
		Side window
		Route map
		Air conditioner
	Physical	Rainy weather
	Organizational	The level of congestion

camera view. Thus, this study used a total of 8 cameras (4 cameras per bus) at various angle and which were set up at ceiling to avoid becoming aware of passengers.

Data Analysis. The collected data were analyzed by conducting 2 steps by three researchers. First step, the collected data were recorded on an event basis.

Fig. 1. were captured by viewer program and showed passengers' behavior in two low-floor buses. Four camera's data were showed all together and if necessary, one camera's data can be shown separately.

Second step, recorded events were shown repeatedly and finally analyzed based on modified components of context of use. By conducting FGI, we extracted the component of context of use in low-floor buses by borrowing and revising Maguire's concept [7] depending on characteristic of low-floor buses (Table 2). To gather well-reflected components under context of low-floor buses, a total of 5 participants (3 of HCI researchers, 2 of low-floor bus developers attended.

The object of this study is not concentreated on comparison of product of stakeholders. Thus, we emitted category of system report and stakeholders. Moreover, video observation focuses on the patterns of people by observing how people interact with one another and their physical environment [9]. Thus, User categories were divided into User type (Passengers who do not have physical limitations, Passengers who have physical limitations) and User characteristics (The level of personal belongings and sex). Regarding passengers' behavior in the low-floor buses, 12 tasks and 14 interior design factors were selected as a task and as technical environment. Rainy weather was considered as a physical environment because temperature change could not be reflected. The reason was that this study was conducted in summer. Finally, passengers' behavior can be changed according to the level of congestion [8]. Thus, the level of congestion was considered as an organizational environment.

4. Results

4.1 Survey Results

Comparison between groups, by sex, height and age, was conducted by ANOVA. ANOVA analysis showed that a total of 27 items were analyzed and 5 items were significant. There were significant differences among groups by sex and age. There were no significant differences of height. Table 3 indicates the specific relationship between significant items and passenger's sex, height and age.

The results demonstrate that passengers' sex and age are important factors to improve overall convenience of low-floor buses. Moreover, significant differences between male and female can be related to frequency of use of these interior design factors in the convenience of handrail and handrail ring. These assumptions were verified by observing passengers' behavior through video observation method.

Table 3. Summary of statistically significant results

Item	Passengers' characteristic		
	Sex	Height	Age
Overall convenience of using low-floor buses	F=6.351*	-	F=4.074**
Overall satisfaction of using low-floor buses	-	-	F=3.581**
Convenience of holding handrail	F=4.042*	-	-
Satisfaction of using handrail	F=6.313*	-	-
Convenience of holding handrail ring	F=4.793*	-	-

*Note: *: $p < 0.05$, **: $p < 0.01$, -: non-significant.

4.2 Video Observation Results

Events analysis. An analyzed total of 996 events contained 500 female events, 472 male events, and 24 were related to group events (Table 4). Group events means that the passengers in low-floor buses get all tangled up together because many passengers are in buses at the same time, so, more than 2 passengers were considered as same event. As passengers who have physical limitations, the elderly were mainly considered to draw passengers' behavior patterns. Because children and physically disabled passengers were rarely observed and pregnant women were not at all observed.

Table 4. The type of passengers

Passengers' type	Male	Female	Group	Total
Passengers who don't have physical limitations	373	369	22	764
The elderly	78	122	0	200
Physically disabled passengers	4	0	0	4
Children	17	9	2	28
Pregnant women	0	0	0	0
Total	472	500	24	996

Moreover, events were analyzed by the level of personal belongings (Table 5). The level of personal belongings was divided into 3 levels which were nothingness, light and heavy. Light personal belongings such as purse and hand bag indicated that it doesn't affect passengers' movements. Considering that the passenger's personal belongings affect his or her behavior, we classified as heavy personal belonging. Female passengers carried personal belongings with high frequency compared to male passengers and most of the passengers carried light personal belongings.

Passengers' Behavior Patterns. A total of 16 behavior patterns were drawn and Table 6 gives a summarized overview.

Table 5. The level of personal belongings

The level of personal belonging	Male	Female	Total
Nothingness	215	76	291
Light	236	375	611
Heavy	21	49	70
Total	472	500	972

Figure-2 indicates the behavior pattern of male passengers who are on board standing and do not have physical limitations.

Based on analyzed passengers' behavior patterns, we categorized passengers' behavior patterns according to passengers' sex, type and context.

First, in the case of male passengers who do not have physical limitations, they used support-purposed interior design factors such as seat handle when they sit and stand. However, in case there were not exist support-purposed interior design factors in their surrounding, they tended to grip head of seats, window frames and wheelchair fixing device et al. When male passengers who do not have physical limitations were standing, they tended to use handrail more frequently than female passengers. Moreover, they were able to use this interior design factor easily in the context of congestion.

Next, in the case of female passengers who do not have physical limitations, their needs for support-purposed interior design factors were similar to male passengers' needs. However, female passengers tended to use relatively low located interior design factors when they were standing. Thus, they showed unsteady behavior in the context of congestion because interior design factors to support female passengers were relatively not enough.

Table 6. Summary of passengers' behavior patterns

No	Type of behavior pattern
1	Sitting, Male passengers who do not have physical limitations
2	Standing, Male passengers who do not have physical limitations
3	Rainy weather, Male passengers who do not have physical limitations
4	Congestion, Male passengers who do not have physical limitations
5	Sitting, Female passengers who do not have physical limitations
6	Standing, Female passengers who do not have physical limitations
7	Female passengers who carry heavy personal belongings and do not have physical limitations
8	Congestion, Female passengers who do not have physical limitations
9	Sitting, Male passengers who have physical limitations
10	Standing, Male passengers who have physical limitations
11	Male passengers who carry heavy personal belongings and have physical limitations
12	Congestion, Male passengers who have physical limitations
13	Sitting, Female passengers who have physical limitation
14	Standing, Female passengers who have physical limitations
15	Female passengers who carry heavy personal belongings and have physical limitations
16	Congestion, Female passengers who have physical limitations

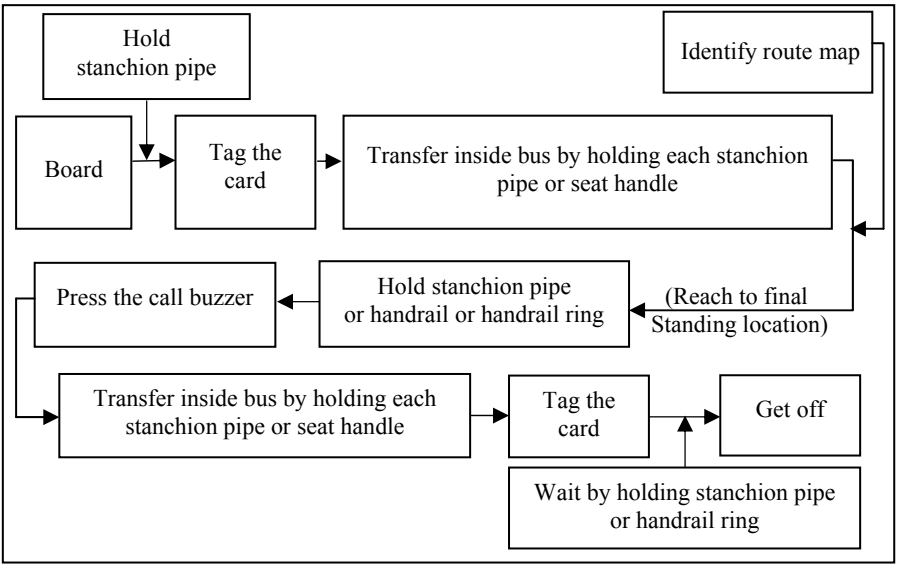

Fig. 2. One example of passengers' behavior patterns

Third, male passengers who have physical limitations showed similar behaviors using support-purposed interior design factors compared to those of male passengers who do not have physical limitations. However, they relied on support-purposed interior design factors from boarding to getting off and they tended to use seats in the front space rather than seats in the rear space.

Finally, In the case of female passengers who have physical limitations indicated high frequency for holding interior design factors and caring personal belongings. Moreover, they tended to use seats in the front space like male passengers who have physical limitations and support themselves with the door handle when they were boarding the buses. When female passengers who have physical limitations were standing, they showed similar behavior patterns compared to those of female passengers who do not have physical limitations. However, their mobility were reduced when they were moving to the rear space because of the steps in the rear aisle

In general, passengers showed low frequency of using rear aisle in the bus when it was crowded and there was a tendency to wait to get off in the getting off space. Furthermore, when sitting in the space for disabled passenger in wheelchair, passengers often held wheelchair fixing device on the wall. In the case of use of handrail ring, passengers supported themselves with an additional interior design factor like stanchion pipe and handrail because of swing.

5 Design Suggestion

The results of passengers' behavior patterns gave us insights on how to design low-floor buses. The results indicated that some interior design factors had to be improved

in universal designs. Because of the steps in the rear aisle, the passengers who have physical limitations used the rear space with less frequency and the front space was relatively crowded with passengers in the context of congestion. Thus, designers and manufacturers of low-floor buses can consider that they should get rid of steps in the rear aisle. However, they have to keep in mind that non-step in the rear aisle could lead to more difficulty in sitting on the seats on rear wheel pans. Moreover, the front space has to be designed to accommodate passengers who have physical limitations.

In the case of seats on wheel pan which were located in the front and rear spaces, many passengers had difficulty sitting because of the high height. In this case, additional support-purposed interior design factors can be added around the seats.

Finally, the heights of handrail and handrail rings also have to be considered when low-floor buses are designed.

6 Conclusions

In this study we point out the most interesting findings regarding behavior patterns of passengers based on context of use of low-floor buses. As a consequence of this study, there are some limitations. First, passengers' behavior patterns which were demonstrated in this study can be changed according to overall layout and characteristic of interior design factors in low-floor buses. Second, as passengers who have physical limitations, pregnant women could not be considered. This is because pregnant women were not observed in buses which were set up the cameras for the purpose of study in our study period. Given these limitations, user testing can be conducted with diverse users including pregnant women.

However, this study shows significance in the consideration of using video observation in dynamic circumstance and importance of context of use. Additionally, it can be applied to the passengers' behavior patterns based on various vehicles as a methodology, and we can anticipate that this study will be utilized as the guideline for next generation low-floor bus design.

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