Passenger Choice Models for Analysis of Impacts of Real-Time Bus Information on Crowdedness

Joon-Ki Kim, Backjin Lee, and Sungho Oh

This research explores the effect of bus occupancy information on transit users' choice of a bus by use of a binary logit model. The model predicts the probability of bus choice between the first arriving bus and the second arriving bus. The analysis is based on interview survey data obtained over 1 week (June 19 to June 25, 2008) in the Seoul metropolitan area in South Korea. The data reveal that the need for public transportation information varies by user group (white- or blue-collar workers, students, homemakers, self-employed workers, and older people) and the stage of the trip (before a trip, at a stop, on board, and at a transfer point). The results show that the availability of seats will increase the probability that a bus user will choose to board an arriving bus, with all other things being kept constant, whereas the travel time on board and the crowdedness on a bus decrease the probability that a public transit user will choose to board an arriving bus. The effects of bus occupancy information are also different among user groups (white- or blue-collar workers, students, homemakers, self-employed workers, and older people) and trip purpose (commute and noncommute).

Public transportation has recently gained added importance because of air pollution and increasing oil prices. As a result, more transit lines have been supplied, and they are becoming more complicated in South Korea, which means that users of public transportation have a wide range of choices for their trips. However, public transportation service has been recognized as an uncomfortable system in comparison with the comfort of traveling in a private car, and as the national income increases, the users of public transportation want to receive better service when they use public transportation systems. To meet people's desires, intelligent transportation systems (ITSs) have been applied; specifically, public transportation information systems have been provided. For example, Transport Advice on Going Anywhere provides real-time information for integrated public transportation systems such as trains, express buses, airplanes, and so on and was built and has been operating since 2005 to assist people with their intercity trips (*1*). Bus information service (BIS) systems operate in 22 cities in the national capital region and metropolitan regions in South Korea (*2*).

However, existing services cannot meet the various individual demands for public transportation information because they have been operating from the point of view of the operators. If the information that satisfies various users' needs can be provided, a mode shift from passenger cars to public transportation can be expected, along with improvement of the quality of service of public transportation.

It has been widely recognized that public transportation information plays an important role in increasing public transportation ridership because public transportation information has a strong relationship to the accessibility of the public transportation service and users' satisfaction (*3*). Therefore, it is important to provide a variety of types of public transportation information to the users of public transportation systems. The study described here investigated the importance of information about the crowdedness on a bus for bus users. In other words, the study analyzed whether bus users want to know bus occupancy information, such as seat availability. One way of investigating the importance of information on crowdedness on a bus is to ask users directly how much they would be willing to pay for the information. In this case, however, users often show a tendency to reply to the question without realistically considering the payment. Hence, in an indirect way, an attempt is made to evaluate the significance of information about crowdedness on a bus. This study evaluated a bus user's behavior when the user selects between taking the first arriving bus and taking the second arriving bus. If information on bus occupancy statistically affects a user's choice of which bus he or she will take, then it can be said that information on crowdedness is important; otherwise, it is not.

LITERATURE REVIEW

Adler and Blue showed that intelligent traveler information systems can play a role in assisting travelers with making pretrip and en route travel choice decisions (*4*). Golob and Regan explored the potential effects of information technology on both personal travel behavior and commercial vehicle operations (*5*). Lyons and Urry challenged that travel time was unproductive and wasted time, and they indicated that through the use of information and communication technologies, travel time could be used productively as activity time (*6*). Those studies explicitly showed the role that ITSs play in public transportation.

ITSs play a significant role in improving the quality of service and maintaining public transportation systems (*7–10*). Previous studies also showed that ITSs have noteworthy impacts on users' contentment. For example, Dziekan and Kottenhoff found that real-time information displays at bus stops reduced waiting times and uncertainty, increased the willingness to pay for the information and the efficiency of travel behavior, and resulted in higher customer satisfaction ratings

Korea Research Institute for Human Settlements, Transportation Research Division, 224 Simin-Ro, Dongan-gu, Anyang-si, Gyeonggi-do 431-712, South Korea. Corresponding author: B. Lee, bjlee@krihs.re.kr.

Transportation Research Record: Journal of the Transportation Research Board, No. 2112, Transportation Research Board of the National Academies, Washington, D.C., 2009, pp. 119–126.
DOI: 10.3141/2112-15

and a better image of public transportation by customers (*11*). Molin and Timmermans indicated that travelers were willing to pay for public transportation travel information, and they also showed the relative importance of a variety of types of information (*3*). Zografos et al. studied online passenger information systems that accommodate the provision of real-time travel information for interurban multimodal trips (*12*). The results of their study indicated that the online passenger information system was user-friendly and cost-effective and met travelers' requirements (*12*). Grotenhuis et al. pointed out that travelers' desired quality of integrated multimodal travel information could vary by the stage of their trip, such as before the trip, at a stop, and on board during a journey (*13*).

Lam and Xie pointed out that transit users choose their routes on the basis of not only travel time but also other factors, such as the number of transfers and walking distance (*14*). In an evaluation of the selection between the automobile and the transit modes, walking access to transit was also found to have more of an effect than was previously thought, whereas travel time has little effect among users who have an automobile available for their trips (*15*). These results indicate that public transportation information can make public transportation systems more convenient by providing consumers with the desired information. Although a significant amount of research has attempted to study the impacts of public transportation information, few studies have been conducted to investigate the effects of information about crowdedness on a bus on consumer choice. Therefore, it is worthwhile to study the impacts of a variety of types of public transportation information to meet public transportation users' needs. In addition, an attempt was made to identify the public transportation information that public transit users desire on the basis of their trip stages, such as before the trip, on board, and during a transfer.

DATA DESCRIPTION

About 31 million daily trips are made in Seoul, and trips by buses and subways accounted for 27.8% and 35.0% of the trips, respectively, in 2006. The bus share increased about 1.3% in 2005, after bus routes were updated on July 1, 2004. There are five types of buses in Seoul: metropolitan express buses (red buses), main-line buses (blue buses), feeder line buses (green buses), circle buses (yellow buses), and local minibuses. Metropolitan express buses are designed for those commuting between downtown Seoul and the metropolitan area. Main-line buses access the median bus lane connecting suburban areas to downtown Seoul. Feeder line buses connect to major subway stations or bus terminals. Circle buses encircle downtown Seoul and stop at the stations for main-line buses, major subway stations, and tourist areas. Local minibuses provide accessibility to subway stations and bus stops (*16*).

The Seoul metropolitan area has convenient and integrated transit systems. For example, it has four bus routes with no transfers and 22 bus routes with a single transfer (the travel times vary from 27 to 35 min; and the headways are 3 to 7, 4 to 8, 5 to 8, and 7 to 12 min on weekdays for the four direct bus routes, respectively) to go from the Seoul City Hall to Dongseon 2-dong at Seongbuk-gu (a typical residential area in Seoul).

A survey of public transit users was conducted in the Seoul metropolitan area, where BIS is the prevailing service over 1 week, from June 19 to June 25, 2008. The survey provided 800 valid samples available for analysis. The survey was divided into four parts. The first part asked about individual characteristics (e.g., gender, age, and income). The second part asked about the frequency that a customer used some medium to receive public transportation information by trip purpose. The third part was designed to investigate the use of travel information by type of public transportation user (white- or blue-collar workers, students, homemakers, self-employed workers, or people older than 60 years), trip purpose (commute, leisure, shopping, or hospital), and trip stage (before a trip, at a stop, on board, and at a transfer point). The last part included questions about possible new services, such as information on the crowdedness of a bus, the availability of Internet service at stops or on a bus, real-time information on unforeseen incidents, and so on.

Among the different media used to receive public transportation information, that is, the Internet, cellular phone, a public transportation information kiosk, and a bus information terminal (BIT), BIT was the most widely used medium. For leisure trips, the Internet was more frequently used than the other media (Figure 1).

The independence of the data was tested by the Pearson chi-square test. Travelers used information more frequently as the waiting times increased (Table 1).

The information that public transportation customers used was different by trip stage (Table 2). Before they made a trip (at the origin), public transportation users were more interested in the route and the schedule (35%); at a stop, they were more interested in the bus arrival time (51%).

There were no statistically significant differences concerning complaints about the media that provided information to public transportation users (p = .269) (Table 3). Public transportation users complained about the reliability of the information that they received from the Internet (27%) and through a cellular phone (36%), a BIT (36%), a public transportation information kiosk (31%), and an information board (43%). Note that although an information board contains static information (not real-time information), people still complained that it provided unreliable information. The second largest complaint was the lack of the desired information from the Internet (29%) and through a cellular phone (25%), a BIT (16%), and an information board (13%). This indicates that users need to be provided with more information.

The survey also asked the participants what information they wanted as public transportation users (Table 4). Regardless of the trip stage (before a trip, at a stop, on board, and at a transfer), travelers wanted know when a bus was due to arrive. Travelers wanted to know the routes and the schedule of public transportation before the trip (16%). The estimated arrival time and road traffic conditions were the most desired information when public transit users were on board (19% and 16%, respectively). These results confirmed that the information desired was different on the basis of the trip stage (p-value = .000 in Table 4). The survey also evaluated whether the information that users want was different by user group (white- or blue-collar workers, students, homemakers, self-employed workers, and older people) and trip purpose (commute, leisure, shopping, and hospital), and no statistically significant difference among the data in the data set was shown.

Weather information was the most wanted additional information by white- or blue-collar workers (23%), students (21%), homemakers (26%), self-employed workers (27%), and older people (32%) (Table 5). Older people were more concerned about health information (23%) than the other groups, and students commonly mentioned the need for information about movies (17%) and performances (13%).

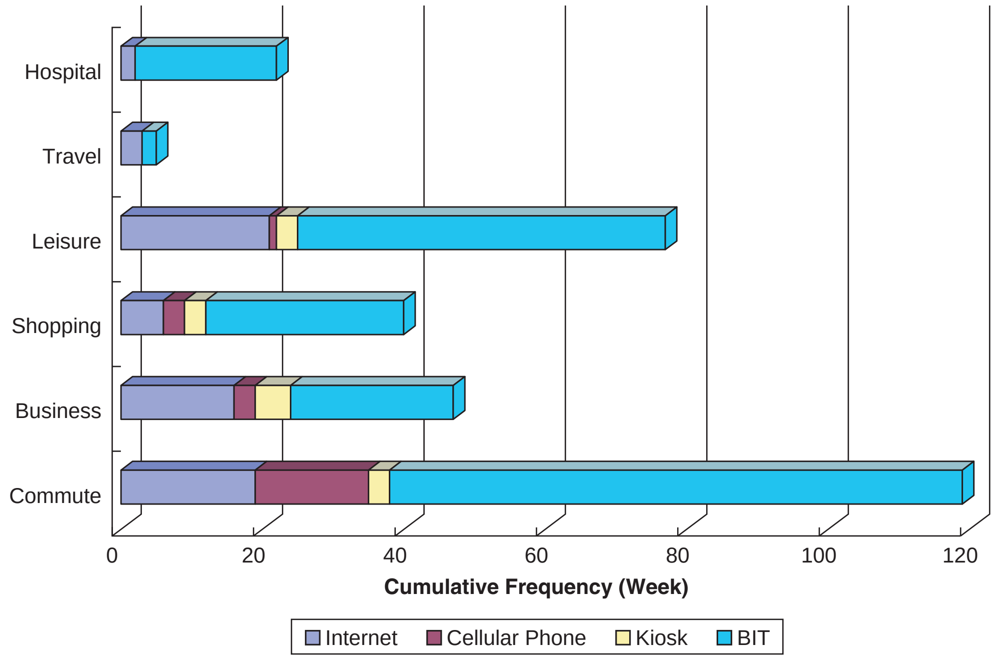

FIGURE 1 Medium of public transportation information by trip purpose.

METHODOLOGY

A stated preference survey was performed under the assumption that the importance of information on crowdedness on a bus was affected by waiting time, travel time on board a bus, and trip purpose. Four variables and two to four levels of values for the variables were used for the experimental design of the stated preference survey, as follows:

Variable	*Levels of Variables*
Waiting time (bus arrival time)	5 min, 10 min
Level of crowdedness on a bus	Available seat, normal, crowded
Travel time on board	30 min, 40 min, 50 min
Trip purpose	Commute, leisure, shopping, hospital

"Available seat" indicates that a traveler can have a seat on a bus. "Normal" means that a traveler must stand without a seat but that he or she has enough room to move. "Crowded" stands for no available seats and little room to move.

TABLE 1 Trends in Use of Public Transportation Information by Waiting Time

	At Stop		At Transfer	
Waiting Time	Yes	No	Yes	No
≤5 min	39 (15%)	223 (85%)	11 (7%)	138 (93%)
5–10 min	97 (24%)	314 (76%)	25 (20%)	98 (80%)
>10 min	46 (36%)	81 (64%)	3 (16%)	16 (84%)
Pearson chi-square test (2)	22.503		9.825	
P-value	.000		.007	

NOTE: Percentages in parentheses are row percentages. Number of degrees of freedom is given in parentheses after Pearson chi-square test.

In this study, a model of bus selection between selection of the first arriving bus and selection of the second arriving bus was built under the assumption that if information on crowdedness on a bus affects public transportation users' choice, then provision of the information is worthwhile.

A binary logit model was used to model public transportation users' selection of bus. The binary logit model was derived from random utility theory and assumes that a consumer makes a decision dependent on a utility function and chooses the alternative that maximizes the utility of the consumer. The probability that traveler n will select bus i between buses i and j [$P_n(i)$] is written as

$$P_n(i) = P\big(U_n(i) \geq U_n(j)\big) \tag{1}$$

where $U_n(i)$ and $U_n(j)$ are utility functions. If it is assumed that $U_n(i)$ has a linear-in-parameters form, then the utility function in Equation 1 is expressed as

$$U_{n(i)} = \boldsymbol{\beta}_i \mathbf{x}_{ni} + \epsilon_{ni} \tag{2}$$

where

$\boldsymbol{\beta}_i$ = vector of estimable coefficients for bus i,
$\mathbf{x}_{ni}$ = vector of exogenous variables for bus i and traveler n, and
ϵ_{ni} = error term that explains unobserved influences on bus selection, assumed to be identically and independently Gumbel distributed (*17*):

$$P_n(i) = \frac{1}{1 + e^{\beta(\mathbf{x}_{nj} - \mathbf{x}_{ni})}} \tag{3}$$

In binary choice, there are two alternatives, i and j (in this study, the first arriving bus and the second arriving bus, respectively).

TABLE 2 Public Transportation Information Used by Trip Stage

	Bus Arrival Time	Route and Schedule	Information on Transfers	Location of Public Transport Mode	Total Travel Time and Cost	Sum
Origin	19 (22%)	30 (35%)	15 (18%)	6 (7%)	15 (18%)	85
At stop	152 (51%)	54 (18%)	25 (8%)	41 (14%)	25 (8%)	297
On board	8 (32%)	6 (24%)	2 (8%)	6 (24%)	3 (12%)	25
At transfer	29 (45%)	8 (12%)	15 (23%)	11 (17%)	2 (3%)	65
Pearson chi-square test (12) = 52.102						
P-value = .000						

NOTE: Percentages in parentheses are row percentages. Number of degrees of freedom is given in parentheses after Pearson chi-square test.

TABLE 3 Complaints Against Medium of Public Transportation Information

Complaint	Internet	Cellular Phone	BIT	Kiosk	Information Board
Unreliable information	11 (27%)	10 (36%)	75 (36%)	4 (31%)	20 (43%)
Hard to see information	2 (5%)	2 (7%)	30 (14%)	3 (23%)	5 (11%)
Lack of desired information	12 (29%)	7 (25%)	33 (16%)	0 (0%)	6 (13%)
Hard to use a medium	3 (7%)	4 (14%)	27 (13%)	3 (23%)	3 (6%)
Takes a long time to see information	7 (17%)	5 (18%)	23 (11%)	1 (8%)	7 (15%)
Hard to understand information	6 (15%)	0 (0%)	22 (10%)	2 (15%)	6 (13%)
Pearson chi-square test (24) = 23.4139					
P-value = .269					

NOTE: Percentages in parentheses are column percentages. Number of degrees of freedom is given in parentheses after Pearson chi-square test.

TABLE 4 Public Transportation Information Needed by Trip Stage

Desired Information	Pretrip	At Stop	On Board	Transfer
Bus arrival time[a]	343 (24%)	288 (20%)	110 (8%)	65 (13%)
Route and schedule (starting time, ending time, interval)	224 (16%)	142 (10%)	83 (6%)	33 (7%)
Location of public transport mode[a]	199 (14%)	167 (12%)	111 (8%)	29 (6%)
Total travel time and cost[a]	126 (9%)	166 (12%)	152 (11%)	33 (7%)
Estimated arrival time[a]	103 (7%)	152 (11%)	262 (19%)	45 (9%)
Road traffic condition[a]	99 (7%)	197 (14%)	218 (16%)	31 (6%)
Information on transfers[a]	81 (6%)	51 (4%)	48 (3%)	76 (16%)
Unforeseen incidents (cancel, delay, accident, etc.)[a]	47 (3%)	80 (6%)	94 (7%)	11 (2%)
Alternative routes[a]	63 (4%)	46 (3%)	70 (5%)	35 (7%)
Others (congestion, pedestrian navigation, etc.)	132 (9%)	144 (10%)	246 (18%)	128 (26%)
Pearson chi-square test (24) = 651.9022				
P-value = .000				

NOTE: Percentages in parentheses are column percentages. Number of degrees of freedom is given in parentheses after Pearson chi-square test.
[a] Real-time information.

TABLE 5 Additional Information Needed by User Group

Additional Information	White- or Blue-Collar Worker	Student	Homemaker	Self-Employed Worker	Older People
Weather	477 (23%)	188 (21%)	268 (26%)	138 (27%)	231 (32%)
News flash	325 (15%)	82 (9%)	144 (14%)	78 (15%)	74 (10%)
Health	162 (8%)	41 (5%)	136 (13%)	61 (12%)	168 (23%)
Movie	225 (11%)	152 (17%)	55 (5%)	22 (4%)	13 (2%)
Performance and exhibition	161 (8%)	113 (13%)	67 (6%)	23 (5%)	38 (5%)
Others (events, sports, restaurant, etc.)	750 (36%)	306 (35%)	363 (35%)	189 (37%)	206 (28%)
Pearson chi-square test (24) = 405.2473					
P-value = .000					

NOTE: Percentages in parentheses are column percentages. Number of degrees of freedom is given in parentheses after Pearson chi-square test.

In Equation 3, a positive scale parameter is assumed to be 1. That is, the variance of ϵ_{ni} and ϵ_{nj} are both $\pi^2/6$, which means that the variance of $(\epsilon_{ni} - \epsilon_{nj})$ is $\pi^2/3$ (*18*).

Unlike a multinomial logit model, in a binary logit model a positive (negative) coefficient of a variable means that the variable necessarily increases (decreases) the probability (*19*).

A test needs to be performed to determine whether the characteristics of the distribution of the behaviors used to select a bus are the same among user groups (white- or blue-collar workers, students, homemakers, self-employed workers, and older people) and trip purpose (commute, leisure, shopping, and hospital). A process used by Ulfarsson and Mannering was followed to test for significant differences between the groups (*20*). Ulfarsson and Mannering demonstrated a method for segmenting various groups in a model (*20*). Once the separate models are developed, a joint model for all separate models is developed to enable performance of the Cox test (*21, 22*). The joint model is essentially a constrained model, since the coefficients on the variable for each separate group are now constrained to be equal. The Cox test likelihood ratio (LR) statistic is χ^2 distributed with degrees of freedom equal to the number of constraints and is represented by

$$\text{LR} = -2\left(L_j - \sum_S L_s \right) \tag{4}$$

where

L_j = log likelihood at convergence for the joint model,
L_s = log likelihood at convergence for the separate model, and
S = set of separate models.

RESULTS

When one notes the significance level of variables in the final models reported in the paper, only variables significant at the .1 level of significance or higher are included. This implies a fairly parsimonious structure.

The Cox test was performed to build a model. It can be stated that bus choice behavior has statistically significantly different distribution characteristics for commute trips and noncommute trips (the null hypothesis was rejected). For commute trips, the null hypothesis (the joint model restricts the user groups together) was accepted. That is, there is no statistical evidence of a need to build a model by user group for commute trips in the data. For noncommute trips, the Cox test suggested that it was better to make a separate and independent model by user group (the null hypothesis was rejected). Figure 2 describes the results of the Cox test.

A model in which a public transportation user chooses the first arriving bus is presented in Table 6, which shows the coefficient estimates and standard errors, as found by the method of maximum likelihood. The second arriving bus was set as a base case because one category should be selected as a base case, as shown in Equation 4. Therefore, the estimated coefficients in Table 6 show a difference (or log odds ratio) compared with the coefficients for the second arriving bus. When the coefficients on a variable were not found to be statistically significantly different at the .1 level of significance across user groups on the basis of the findings of the Cox test, those groups were combined together. In other words, those coefficients were constrained to have same effects on those groups. The adjusted ρ^2 value in Table 6 compares the log likelihood (LL) of a model with all parameters set equal to 0 [LL(0)] with the LL at convergence for the fully specified model [LL($\boldsymbol{\beta}$)] and accounts for the estimation of potentially insignificant variables, which is expressed as (*18*)

$$\text{adjusted } \rho^2 = 1 - \frac{\text{LL}(\boldsymbol{\beta}) - N}{\text{LL}(0)} \tag{5}$$

where N is the number of variables.

Commute Trips

The travel time on board decreases the probability that a public transportation user will choose the first arriving bus (–0.091 in Table 6), which is logical and as expected because people tend to go to work or school as quickly as possible during the busy commute.

Regarding the condition of crowdedness on a bus, public transportation users are more likely to choose the bus that has available seats (0.945 in Table 6), and a crowded condition on a bus decreases the probability that the bus will be chosen (–0.879 in Table 6). These results imply that information on the crowdedness on a bus is needed because people's choice of a bus is affected not only by the travel time but also by the crowdedness.

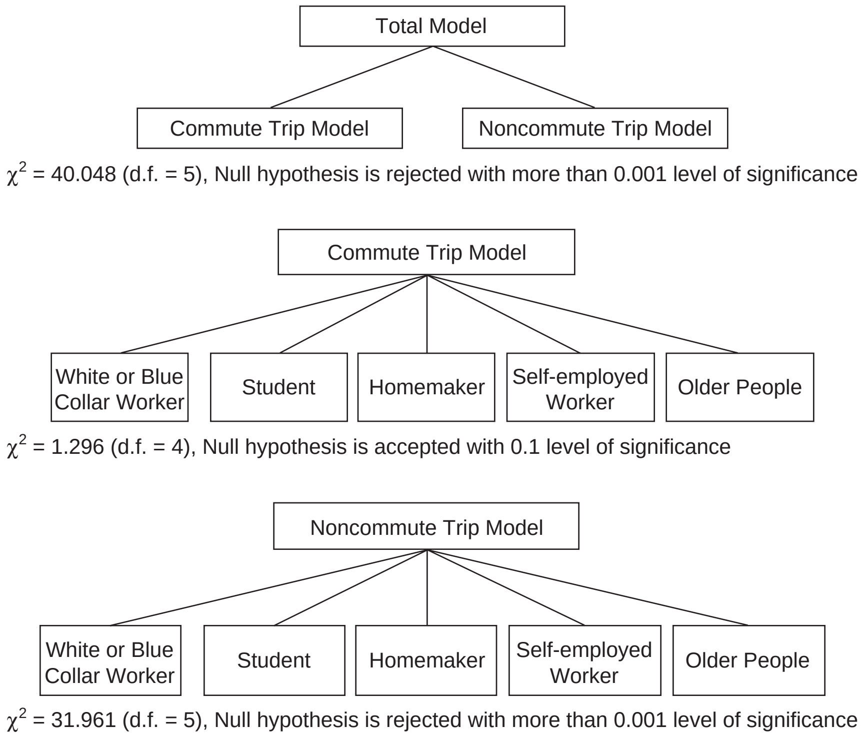

FIGURE 2 Results of the Cox test (d.f. = degrees of freedom).

Noncommute Trips

White- or Blue-Collar Workers

For noncommute trips such as leisure trips and shopping trips, the waiting time decreases the probability that white- or blue-collar workers will choose a bus (–0.141 in Table 6). The travel time on board, however, does not have a statistically significant impact on the selection of a bus (0 in Table 6). This result indicates that although people are not concerned about travel time in a bus for noncommute trips, waiting time still decreases the bus users' utility.

The availability of seats on a bus attracts more people, but the crowded condition on a bus is viewed negatively by white- or blue-collar worker bus users (2.462 and –0.806, respectively, in Table 6). Note that the estimated coefficient of available seats for a white- or blue-collar worker in noncommute trips is greater than the one for commute trips. This result can be reasoned by the fact that people are generally busier during commute trips than they are during noncommute trips.

Students and Self-Employed Workers

A student's behavior in selecting a bus is not statistically different from that of a self-employed worker. The model results for students and self-employed workers were compared by using the Cox test.

TABLE 6 Results of Choice of a Bus

		Noncommute Trip (shopping, leisure, hospital, etc.)			
	Commute	White- or Blue-Collar Worker	Student and Self-Employed Worker	Homemaker	Older People
Constants	4.670 (0.661)‡	1.196 (0.446)‡	0.989 (0.293)‡	1.900 (0.398)‡	–2.327 (0.928)†
Waiting time		–0.141 (0.071)†		–0.309 (0.055)‡	–0.272 (0.092)‡
Travel time on board	–0.091 (0.014)‡				0.110 (0.025)‡
Available seats	0.945 (0.381)†	2.462 (0.689)‡		2.092 (0.375)‡	2.501 (0.938)‡
Crowded	–0.879 (0.198)‡	–0.806 (0.345)†	–1.712 (0.362)‡		–0.788 (0.348)†
No. of observations	624	254	160	320	242
LL at initial	–432.524	–176.059	–110.904	–221.807	–167.742
LL at convergence	–364.8263	–150.0416	–98.298	–196.7228	–136.7925
Adjusted ρ^2	.151	.134	.102	.105	.167

NOTE: Standard errors are given in parentheses. Levels of significance for all comparisons were greater than .1; † > .05; ‡ > .01. Coefficients that were not significant at the .1 level were restricted to 0 and omitted from the table.

The LR statistic was calculated to be 1.484 with 3 degrees of freedom, which is less than the χ^2 table value, which is 6.25 at the .1 level of significance with 3 degrees of freedom. Therefore, the null hypothesis (the joint model restricts students and self-employed workers together) was accepted. This result of the Cox test suggests that there is not a need to assess the coefficients through separate and independent model estimations between students and self-employed workers.

The behaviors of students and self-employed workers when they choose a bus are statistically affected only by a crowded situation on a bus. Students and self-employed workers are less likely to choose a crowded bus (–1.712 in Table 6). In comparison with the other users, students and self-employed workers are the groups that are the most affected by crowdedness (for white- or blue-collar workers the value is –0.806, for students the value is –1.797, and for older people the value is –0.788 in Table 6).

Homemakers

The waiting time at a stop decreases the probability that homemakers will choose a bus for noncommute trips (–0.309 in Table 6). Among the different user groups, the effect of waiting time at a stop is the greatest for a homemaker (for homemakers the value is –0.309, for white- or blue-collar workers the value is –0.141, for students the value is 0, for self-employed workers the value is 0, and for older people the value is –0.272 in Table 6).

A homemaker is not statistically affected by the travel time on board or the crowdedness on a bus. The variable that affects homemakers' behavior the most is available seats (2.092 in Table 6). That is, a homemaker is more likely to choose the bus with available seats.

Older People

The waiting time at a stop for noncommute trips decreases the probability that older people will choose a bus (–0.272 in Table 6). An incomprehensible result is that older people are more likely to choose the bus that has a longer travel time (0.110 in Table 6). Older people are not sensitive to time, and although the surveyors were taught to kindly explain the questionnaire to older people, the older people might have had difficulty answering the questions. To scrutinize the effects of travel time on older people clearly, the characteristics of the trips that older people make need to be observed.

Among the different public transportation user groups, older people are the most affected by available seats (the values are 2.462 for white- or blue-collar workers, 2.092 for homemakers, and 2.501 for older people in Table 6). This result is reasonable because older people are more fragile because of their age and various medical conditions. However, in some sense this result is not expected because it was expected that the effect of crowdedness would be greater than the effect of available seats because most people in South Korea yield seats to older people when older people are standing in front of them (for older people, the values are 2.501 for available seats and –0.788 for crowded in Table 6).

CONCLUSION

The study described here examined the effect of bus occupancy information on transit users' choice of a bus on the basis of user groups (white- or blue-collar workers, students, homemakers, self-employed workers, and older people) and trip purpose (commute and noncommute). A binary logit model was used to build a model of transit users' choice of a bus. That model predicted the probability that the first arriving bus and the second arriving bus would be chosen. The analysis was based on interview survey data collected over 1 week (from June 19 to June 25, 2008) in the Seoul metropolitan area in South Korea.

The estimation results showed that travel time on board and crowded condition on a bus decreased the probability that the bus would be chosen (–0.091 and –0.879, respectively, in Table 6), and that the availability of seats increases the probability that a transit user will choose an arriving bus (0.945 in Table 6) for commute trips.

For noncommute trips, the effects of bus information are different among the transit user groups, on the basis of the results of the Cox test (Figure 2). The waiting time at stops decreases the probability that a bus will be chosen for white- or blue-collar workers (–0.141), homemakers (–0.309), and older people (–0.272 in Table 6). Travel time on board is significant only for older people. Older people are more likely to choose the bus that has a longer travel time (0.110 in Table 6). This result is incomprehensible and requires further study to examine the characteristics of older people's trips. White- or blue-collar workers (2.462), homemakers (2.092), and older people (2.501) are more likely to choose a bus with available seats (Table 6). White- or blue-collar worker (–0.806), student and self-employed workers (–1.712), and older people (–0.788 in Table 6) are less likely to chose crowded buses.

ACKNOWLEDGMENTS

The authors thank the anonymous reviewers, whose constructive suggestions helped improve the paper. This research was supported by a grant from Transport System Innovation Program, which is funded by the Ministry of Land, Transport and Maritime Affairs of the South Korean government.

REFERENCES

1. Ministry of Land Transport and Maritime Affairs, Gwacheoun-shi, South Korea. www.tago.go.kr/. Accessed July 21, 2008.
2. *A Study on the TAGO Plan and Maintenance.* Korea Institute of Construction Technology, Goyang-shi, South Korea, 2007.
3. Molin, E. J. E., and H. J. P. Timmermans. Traveler Expectations and Willingness-to-Pay for Web-Enabled Public Transport Information Services. *Transportation Research C,* Vol. 14, 2006, pp. 57–67.
4. Adler, J. L., and V. J. Blue. Toward the Design of Intelligent Traveler Information Systems. *Transportation Research C,* Vol. 6, 1998, pp. 157–172.
5. Golob, T. F., and A. C. Regan. Impacts of Information Technology on Personal Travel and Commercial Vehicle Operations: Research Challenges and Opportunities. *Transportation Research C,* Vol. 9, 2001, pp. 87–121.
6. Lyons, G., and J. Urry. Travel Time Use in the Information Age. *Transportation Research A,* Vol. 39, 2005, pp. 257–276.
7. Hounsell, N., and G. Wall. New Intelligent Transport Systems Applications in Europe to Improve Bus Services. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1791,* Transportation Research Board of the National Academies, Washington, D.C., 2002, pp. 85–91.
8. Maclean, S. D., and D. J. Dailey. Wireless Internet Access to Real-Time Transit Information. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1791,* Transportation Research Board of the National Academies, Washington, D.C., 2002, pp. 92–98.
9. Shelton, D., D. Haufschild, J. Pedley, and R. Spillar. Using Geographic Information Systems to Inform Bus Maintenance Base Location

Decisions. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1887,* Transportation Research Board of the National Academies, Washington, D.C., 2004, pp. 92–98.

10. Jeong, R., and L. R. Rilett. Prediction Model of Bus Arrival Time for Real-Time Applications. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1927,* Transportation Research Board of the National Academies, Washington, D.C., 2005, pp. 195–204.
11. Dziekan, K., and K. Kottenhoff. Dynamic at-Stop Real-Time Information Displays for Public Transport: Effects on Customers. *Transportation Research A,* Vol. 41, 2007, pp. 489–501.
12. Zografos, K. B., V. Spitadakis, and K. N. Androutsopoulos. Integrated Passenger Information System for Multimodal Trip Planning. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2072,* Transportation Research Board of the National Academies, Washington, D.C., 2008, pp. 20–29.
13. Grotenhuis, J., B. W. Wiegmans, and P. Rietveld. The Desired Quality of Integrated Multimodal Travel Information in Public Transport: Customer Needs for Time and Effort Savings. *Transport Policy,* Vol. 14, No. 1, 2007, pp. 27–38.
14. Lam, S.-H., and F. Xie. Transit Path-Choice Models That Use Revealed Preference and Stated Preference Data. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1799,* Transportation Research Board of the National Academies, Washington, D.C., 2002, pp. 58–65.
15. Beimborn, E. A., M. J. Greenwald, and X. Jin. Accessibility, Connectivity, and Captivity: Impacts on Transit Choice. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1835,* Transportation Research Board of the National Academies, Washington, D.C., 2003, pp. 1–9.
16. Seoul Metropolitan Government, Seoul, South Korea. www.seoul.go.kr. Accessed Nov. 10, 2008.
17. McFadden, D. Econometric Models of Probabilistic Choice. In *Structural Analysis of Discrete Data with Econometric Applications* (C. Manski and D. McFadden, eds.), MIT Press, Cambridge, Mass., 1981.
18. Ben-Akiva, M., and S. R. Lerman. *Discrete Choice Analysis.* MIT Press, Cambridge, Mass., 1985.
19. Greene, W. *Econometric Analysis,* 5th ed. Prentice-Hall, Englewood Cliffs, N.J., 2003.
20. Ulfarsson, G. F., and F. L. Mannering. Differences in Male and Female Injury Severities in Sport-Utility Vehicle, Minivan, Pickup and Passenger Car Accidents. *Accident Analysis and Prevention,* Vol. 36, 2004, pp. 135–147.
21. Cox, D. R. Tests of Separate Families of Hypotheses. *Proc., Fourth Berkeley Symposium on Mathematical Statistics and Probability.* University of California Press, Berkeley, Calif., 1961.
22. Cox, D. R. Further Results on Tests of Separate Families of Hypotheses. *Journal of the Royal Statistical Society,* Vol. 24, 1962, pp. 406–424.

The Transit Capacity and Quality of Service Committee sponsored publication of this paper.