

Research Article

An Empirical Analysis for Mode Choice in a Short-Distance Trip with Personal Rapid Transit

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Recently, there have been emerging demands for new transportation modes, such as personal rapid transit (PRT), to improve the connectivity of first and last mile travel. Advancement of ICT and growing concerns over environmental issues reinforce such demands through which specific transportation modes can satisfy the need of each individual for short-distance trips. Although PRT has received particular attention for short-distance trips, it is true that recent approaches have been developed to analyze the behavior of travelers for mid- to long-distance trips that are not relevant for short-distance trips. This study proposed a suitable approach using logistic regression models that could assist the understanding of features which determine mode choice in a short-distance trip. The mode choice for PRT in short-distance trips in this study was based on the data from the survey. After considering various factors, it was apparent that the purpose of the trip together with weather conditions impacted significantly on travelers' mode choices to PRT in short-distance trips. Additionally, it is expected that this study will play an important initial role in analyzing emerging transportation modes that can more easily respond to new demands for short-distance trips.

1. Introduction

In the four-step travel demand modeling process, mode choice models compute the proportion of trips that use a specific transportation mode between each origin and destination estimated from the trip distribution step. The capacity to explain the mode choice models following the introduction of a new mode or improvement of transportation service directly affects the accuracy of estimated trips by each mode, e.g., [1–3]. Mode choice models, consequently, play a critical role in decisions about investments in transportation [4].

Most current mode choice models target inter- or intra-regional travel of mid/long-distance trips. The assessment of investments or plans for transportation infrastructure, considering the movement of transportation modes separately and commonly, does not include the entire trip of travelers.

Consequently, travel distance and/or time of each transportation mode (e.g., automobile, rail, bus, subway, and taxi) have been employed as significant factors that are suggested to be implemented from previous studies, e.g., [2, 3, 5, 6].

The advent of a new user-oriented paradigm requires that traditional supply-oriented transportation services are changed to user-centered ones. Concurrently, road infrastructure for mid/long-distance trips in many metropolitan cities has already reached the maturity stage. A novel approach of smart mobility using small-sized modes for the short-distance trip has been gaining in popularity. Environmental issues arising from traffic problems linked to the Paris Agreement [7] have created a new social norm to deliver a convenient, healthy, and sustainable society, with interest in special transportation modes for short-distance trips. A short-distance trip requires analyzing new factors

including the level of service by public transportation, which have not been conducted due in part to the lack of suitable models or usable data [8].

The short-distance refers to a walkable distance on which walking, motorcycling, and bicycling currently comprise the major transportation modes. Travel of less than one km has often been ignored even in the short-distance trip. Recently, in tandem with the development of information and communication technologies, new transportation modes such as electric scooters, and autonomous and demand-responsive personal rapid transit (PRT) have also arisen as a means of a short-distance trip. These modes are key to connecting the terminal points of mid/long-distance trips by subways or buses, and to link the first and last miles to origins and destinations [9, 10]. Thus, transportation modes for short-distance trips enhance seamless services, user satisfaction, and popularity of mass transit systems.

Transportation modes for short-distance trips are increasing in importance. However, traditional travel demand models have difficulty in explaining the impact of such trips [8]. Because current transportation systems allow free transfers and easy alighting and boarding, this limitation hinders reliable analysis of contemporary transportation techniques and policies. As most mode choice models have been developed for mid/long-distance trips, e.g., [11, 12], factors other than travel time and cost have been rationally neglected that have minor impacts on mode choice. However, the impact of other factors is significant as the traveler's time and cost is trivial in a short-distance trip. Examples include accessibility to terminals, discomfort of using stairs, adverse weather conditions, requirements of children/the elderly, and carrying of baggage. As previously mentioned, traditional mode choice approaches based the disaggregated behavioral models used in the four-step travel demand process are limited to fundamentally reflect these factors [8].

2. Scope and Objectives

The main objectives of this study are to identify and quantify factors affecting mode choice and, to provide fundamentals for the analysis of emerging transportation modes for the new demands of a short-distance trip. As a primary approach, a survey was conducted for inputs to identify the likely PRT choice considering the trip purpose, weather condition, and if passengers were accompanied by children. Here, the concept of PRT, one of desirable transportation modes, was used in this study as a competitive means of walking in a short-distance trip. To ascertain the objectives of this study, a literature review was conducted to identify a suitable methodology for the assessment. An analysis was then performed resulting in an updated interpretation.

3. Literature Review

This study is among initial attempts to understand factors that determine transportation modes in a short-distance trip and three points are of major interest in the literature review which include

- (1) defining of the range of a short-distance trip;

- (2) alternative modes considered for a short-distance trip; and
- (3) explaining variables that determine the transportation modes for a particular short-distance trip.

3.1. Range Definition for the Short-Distance Trip. Travel distance is the most influential factor in determining a transportation mode. For example, the airplane is preferable for distances over 1,000 km, whereas walking, motorcycling, or cycling is a reasonable choice for distances less than 2 km. To develop mode choice models for a short-distance trip, the range of distance is therefore required to be defined for this study.

As shown in Table 1, although 5 km was frequently used as the maximum boundary for the short-distance trip [15, 16], various definitions of the short-distance trip have been suggested recently. That is, it is noted that a distance of less than 3 km was adopted in the most recent study [17] in order to respond to the need for the analysis of nonmotorized trips such as walking and bicycles.

3.2. Mode Alternatives for a Short-Distance Trip. Even for a short-distance trip, travelers frequently determine their travel from a specific set of available modes clustered by travel distance. For example, in Shanghai, China (see Figure 1), differences in average travel distance determined which mode was chosen for the short-distance trip. For example, walking was selected for an average travel distance of 1 km, while motorized modes (i.e., scooter and bus) were taken above an average travel distance of 2 km.

In addition to the preferred travel mode by distance, the average travel distance of all short-distance trip modes of 1.687 meters was used as a reference for the range of short-distance trips in this study.

To develop suitable mode choice models, possible alternative modes for a short-distance trip need to be explored which are shown in Table 2.

From the literature review, walking is the most prevalent mode for a short-distance trip (11 out of 11), followed by cycling (10 out of 11), individual vehicles (8 out of 11), and buses (7 out of 11). Interestingly, the competitor to nonmotorized modes (i.e., walking and cycling) is not public transportation such as bus, but rather, individual vehicles. This means that for a short-distance trip, the use of individual vehicles is common because of their superior access and comfort. In other words, travelers favor their personal vehicle as competitive for the first and last mile as it also satisfies their need for access and comfort.

Comparing the number of considered modes from the previous literature shows the range that is a maximum of 7, a minimum of 2, and an average of 4. Thus, in general, four separate mode choices were considered for the short-distance trip.

3.3. Explanatory Variables for Mode Choice in a Short-Distance Trip. Table 3 outlines the variables reviewed for mode choice models for a short-distance trip from the previous literature.

TABLE 1: A comparison of definitions used for a short-distance trip.

Authors	Used distance	Reasons
Kim and Ulfarsson [13]	Below 2.25 km	A short-distance was defined by the 95 th percentile of walking distances on the basis of 12,900 trip data sets
Tran et al. [14]	Below 1 km	A distance under 1 km was regarded as a short-distance because of its competitiveness for walking rather than other modes, such as motorcycles and bicycles
Li et al. [15]	Below 5 km	A distance under 5 km was considered as a short-distance because of the majority, being over 40% of all trips, caused traffic congestion
Pu et al. [16]	Below 5 km	A distance under 5 km accounted for 90% of all short-distance trips for the elderly
Ferrer and Ruiz [17]	Below 3 km	A short-distance was defined as the distance taking 45 minutes on foot or less

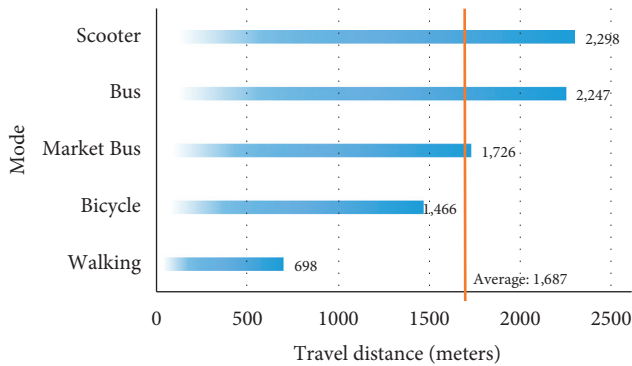


FIGURE 1: Average travel distances of each mode taken for the short-distance trip [16].

In total, 16 studies were reviewed, with 12 factors, which included socioeconomic factors such as gender, age, household income, and vehicle ownership that were mostly used as explanatory variables. Additionally, trip-related factors such as trip distance, walking comfort, travel time, trip purpose, traffic safety, and traffic condition/congestion were key factors applied in many studies. Some previous studies adopted weather (5 out of 16 studies) and crime (4 out of 16 studies) as explanatory variables. On average, 4.5 explanatory variables were used for 16 reviewed studies.

From this review, two features of the explanatory variables were identified:

- (1) Multiple factors were considered for mode choice models
- (2) Traditional factors (e.g., travel distance and time) were not always involved in mode choice studies

The mode choice for a short-distance trip may not follow the traditional approaches of mid/long-distance trips. Another reason is that in the short-distance trip, travel distance and time would likely have a minor impact on the choice of mode. Interestingly, these two reasons are correlated so that for short-distance trips other factors largely determine the mode. Travel distance and time are essentially non-determinants of the transportation mode.

3.4. Takeaways from the Literature Review. There are several key points from the literature review that can be extracted as inputs to analyze the mode choice of travelers for a short-distance trip:

- (1) Many studies have considered up to 5 km as a short-distance trip. With this, considering the average speed of walking (4 km/h) [29, 30] and the average speed of PRT (40 km/h) [31], this study adopted 4 km as a short-distance trip.
- (2) Among diverse transportation modes used in a short-distance trip, walking is the most common mode for a short-distance trip. Therefore, two modes being walking and PRT were selected as the alternatives for this study to develop the survey and mode choice models.
- (3) Various factors were reviewed as explanatory variables from previous studies. These trip features (e.g., travel time, travel distance, and trip purpose), environmental features (e.g., walking comfort and weather), and individual characteristics (e.g., gender and age) most affected the mode choice for a short-distance trip. In addition to these factors, the trip purpose, weather condition, PRT fare, travel time, and accompaniment were selected as determinants for the mode choice model in the study.

4. Methodology

It is useful to elucidate the overall procedure described in Figure 2. The proposed methodology in this study comprises four parts which consider these objectives:

- (1) Undertaking a pilot survey to test the predefined approach
- (2) Completing a directional setup with preliminary results for the main survey
- (3) Conducting the main survey
- (4) Modeling and calibrating the main survey results

The first step was to examine the factors (i.e., explanatory variables) through the pilot survey which were identified from the literature review. Two factors were selected in this step being a weather factor representing traffic environments, and an accompanying children factor which could affect the mode choice in a leisure trip. Note that the major objectives of the pilot survey were checking the applicability of selected factors in this study, and providing preliminary results to be used to set up the main survey.

In considering the weather factor, two different regions comprising large-sized residential areas with parks being

TABLE 2: Comparison of transportation modes considered regarding a short-distance trip.

Authors	Transportation modes							Number of considered modes
	Walking	Bicycle	Scooter	Taxi	Bus	Subway	Individual vehicle	
Mackett [18]	○	○	○	○	○	○	○	7
Olszewski and Wibowo [19]	○	○			○	○	○	5
Müller et al. [20]	○	○	○		○		○	5
Kim and Ulfarsson [13]	○	○			○		○	4
Walton and Sunseri [21]	○						○	2
Sidharthan et al. [22]	○	○						2
Halldórsdóttir et al. [23]	○	○			○		○	4
Tran et al. [14]	○	○	○					3
Li et al. [15]	○	○					○	3
Pu et al. [16]	○	○	○		○			4
Prato et al. [24]	○	○			○	○	○	5
Frequency	11	10	4	1	7	3	8	—

TABLE 3: Factors considered in previous studies of a short-distance trip.

	Gender	Age	Household income	Vehicle ownership	Trip distance	Walking comfort (slope/stairway)	Travel time	Trip purpose	Traffic safety	Traffic condition/congestion	Weather	Crime
Mackett [18]	○	○			○		○	○				
Olszewski and Wibowo [19]					○	○			○	○		
Müller et al. [20]				○	○						○	
Kim and Ulfarsson [13]	○	○			○		○					
Walton and Sunseri [21]	○				○	○	○				○	○
Sidharthan et al. [22]			○	○		○			○	○	○	
Halldórsdóttir et al. [23]	○			○		○	○	○			○	
Lee et al. [25]									○	○		
Marquet and Miralles-Guasch [26]	○	○	○					○				
Rybarczyk and Gallagher [27]					○				○	○		○
Tran et al. [14]	○	○	○	○				○	○	○		○
Li et al. [15]	○	○	○	○								
Pu et al. [16]		○	○	○			○	○				
Ferrer and Ruiz [17]						○						○
Guang and Reid [28]			○			○						
Prato et al. [24]	○	○	○			○	○	○			○	
Frequency	8	7	7	6	6	7	6	6	5	5	5	4

Gwanggyo and Ilsan in Gyeonggi Province, Republic of Korea, were selected. During the pilot survey, autonomous and demand-responsive PRT had been introduced as a new and more practical public transit mode to the respondents for the pilot survey. This PRT is an unmanned mode with a maximum of 6 passengers operating on a designated or virtually marked road where a user can access a ride anytime.

The second step to design the main survey was based on preliminary results from the pilot survey. Basically, two main purposes being mandatory and nonmandatory were

considered with two factors, which were tested in the pilot survey, using two different fare schemes. The type of scenarios was accordingly set up with factors that needed to be considered for the model calibration. The next step was to conduct the main survey comprising 60 questions, followed by model calibration and logistic regression. Despite the availability of emerging techniques, such as machine learning methods, the logistic regression model was selected as the tool to analyze the behavior of travelers for short-distance trips.

This decision has two significant reasons:

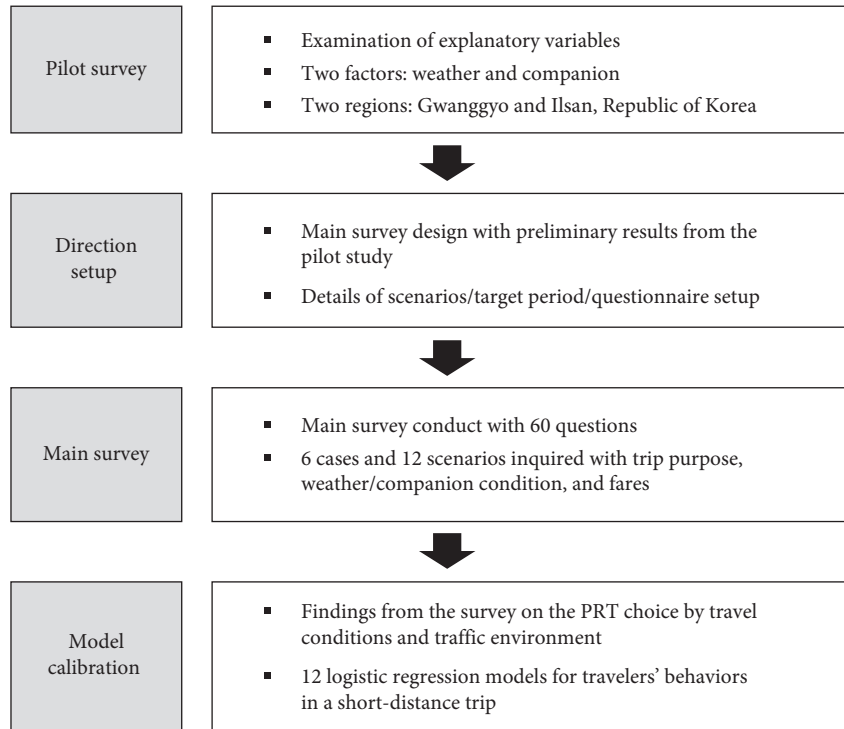


FIGURE 2: Overall procedure of the methodology.

- (1) The logistic regression models have been regarded as a standard method for describing the relationship between a response variable and explanatory variables over the last decade [32]
- (2) Machine learning techniques are gaining in popularity, but can become inefficient with a relatively small size datasets as it requires massive datasets to train the models [33]

5. Analysis and Results

5.1. Pilot Survey: Preliminary Findings for Travelers' Behaviors in Short-Distance Trips. From the pilot survey 1,030 responses were received by surveyors from the two regions (515 responses each). However, only 1,006 responses were valid (effectively 97.7%). The basic question had two choices being good versus bad weather (snow, rain, and/or cold temperatures). In cases where the travel time when walking was within 20 minutes, the intervals for the questionnaire were 5, 10, 15, and 20 minutes, with the mode choice being either walking or PRT. The flat fare for PRT was assumed as 500 Korean won (KRW) per person, regardless of the distance traveled. Figure 3(a) describes the result of the pilot survey for the weather condition.

Another location (Uiwang in Gyeonggi Province, Republic of Korea) being a lake park region where family leisure activities frequently occur was chosen to examine the effect of the travelers' companions. A total of 501 valid responses were obtained from nearby the Uiwang subway station and rail bike station. The PRT option was presented in terms of an increase in travel cost from 0 to 1,500 (KRW per person). In this pilot survey, only travel cost was given as a determinant in choosing PRT because the distance

between the Uiwang subway station and the rail bike station was fixed at 1 km, and the actual cost for accompanying children had not been confirmed. Figure 3(b) shows the results of this pilot survey.

The pilot survey revealed that travelers preferred PRT when the weather condition was not good, compared to when the weather was obviously good. The relationship between travel time and the weather condition was also observed. As travel time increased, the extent of impacts from the weather condition decreased. If travel time was relatively long, it became a key determinant of choosing PRT regardless of the weather condition. In contrast, when the travel time was relatively short, the weather condition became the crucial factor in selecting PRT. In terms of accompanying children, when the PRT fare was zero, most of the interviewees would choose PRT, but the probability of PRT choice decreased in two distinct cases. This was when the PRT fare increased, or when traveling without children. With a travel cost up to 500 KRW per person, the probabilities for PRT choice showed little difference, regardless of accompanying children.

5.2. Direction Setup for Main Survey: Case Development and Calibration Process. From the pilot survey, 6 cases (see Figure 4) were generated to develop main questionnaires in the survey and eventually to the development of mode choice models.

Six cases were originally generated, with each case having two different fare schemes: 500 and 1,000 KRW per person. Thus, in total, 12 scenarios were considered in this study. Because a mandatory trip rarely occurs with children, the

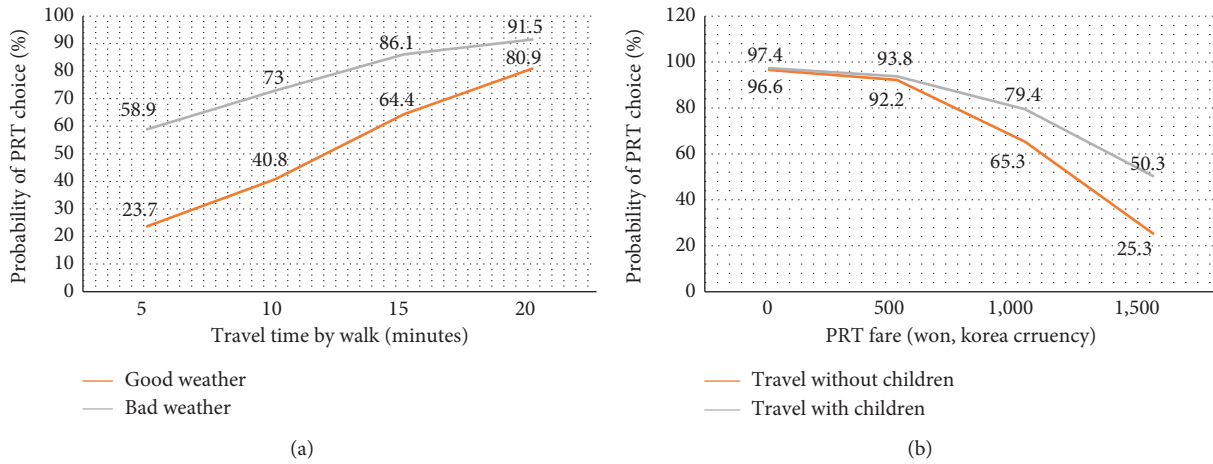


FIGURE 3: Pilot survey results of weather and companion conditions: (a) weather condition; (b) companion condition (travel with children).

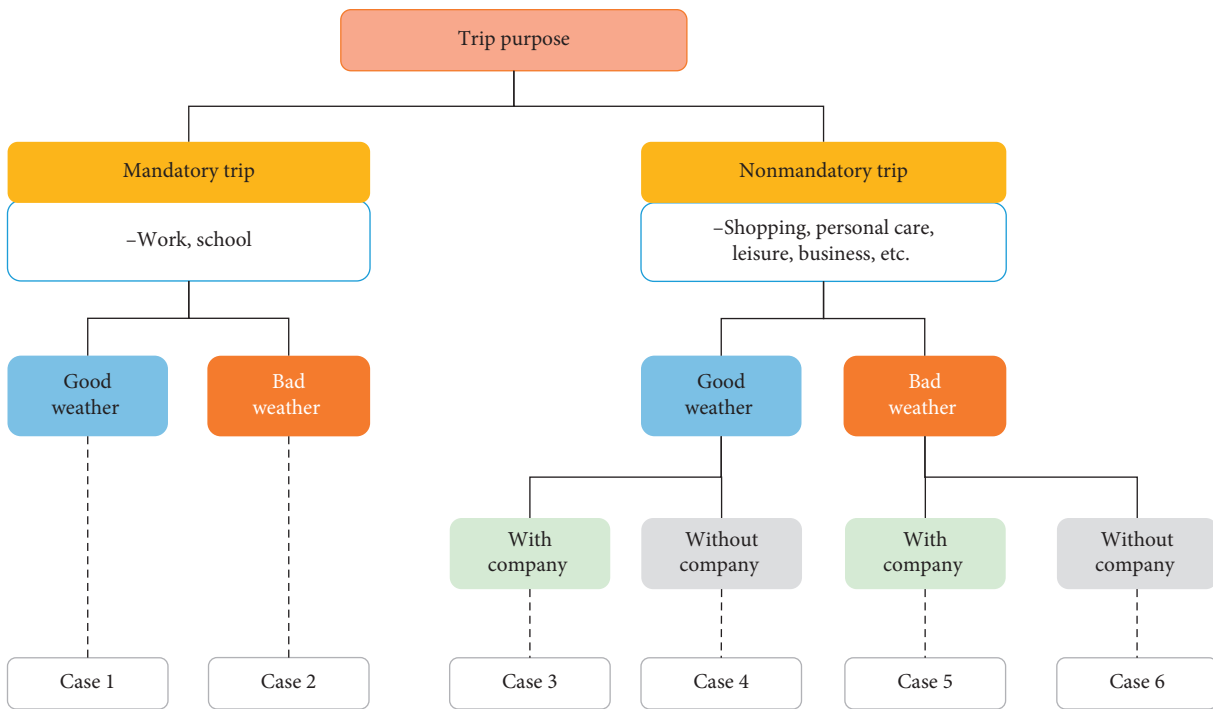


FIGURE 4: Case tree for mode choice models.

conditions for accompanying children were included only in a nonmandatory trip (see Table 4).

A four-step approach was taken (see Figure 5), of which questionnaires were developed from steps 1 to 3 and step 4 was about how to calibrate the mode choice models in this study:

- (1) A total distance of 4 km was divided into five intervals of 800 meters per each (defined as a short-distance trip in this study)
- (2) Travel distance was selected randomly from each interval

- (3) Travel times with walking and PRT, respectively, were estimated from each randomly selected travel distance

- (4) At every 100 meters, the probabilities of PRT choice were fitted into the diversion curve

As previously mentioned, 60 questions were posed to each interviewee in the main survey, consisting of six scenarios with two fare options (500 and 1,000 KRW), and five intervals separated by 800 meters (out of 4 km).

TABLE 4: List of selected cases for mode choice models.

Case number	Trip purpose	Weather condition	Companion condition
Case 1	Mandatory	Good	—
Case 2		Bad	—
Case 3	Nonmandatory	Good	No
Case 4		Bad	No
Case 5		Good	Yes
Case 6		Bad	Yes

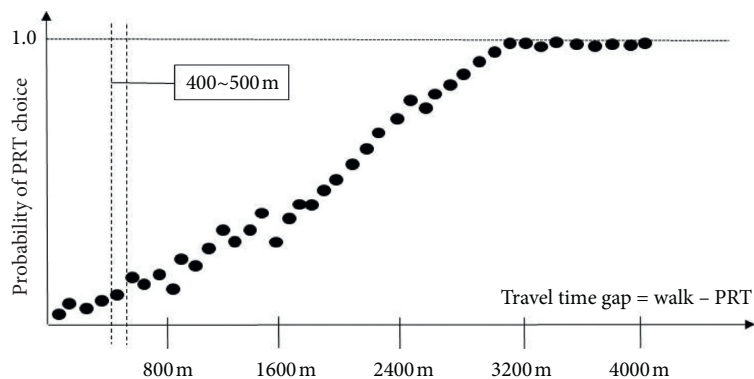
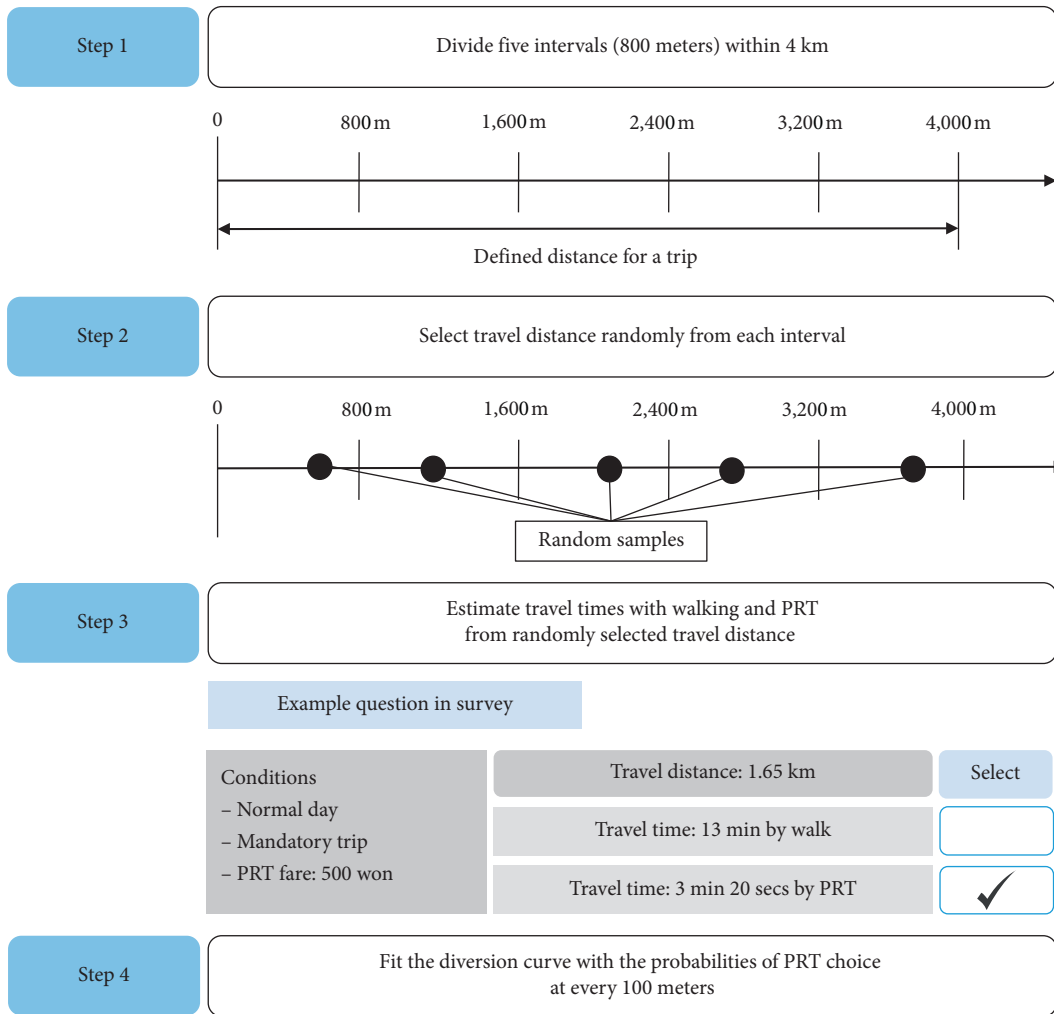


FIGURE 5: Process of developing mode choice models.

TABLE 5: Interviewees' characteristics.

Categories	Frequency (respondent, %)
Gender	
Male	609 (50.0)
Female	608 (50.0)
Age	
0–19	128 (10.5)
20–29	240 (19.7)
30–39	239 (19.6)
40–49	241 (19.8)
50–59	240 (19.7)
60+	129 (10.6)
Occupation	
Employee (full-time)	633 (52.1)
Self-employed individual	107 (8.8)
Sstudent	234 (19.2)
Housewife	157 (12.9)
Unemployed person	54 (4.4)
Others	32 (2.6)
Number of family members	
1	99 (8.1)
2	164 (13.5)
3	334 (27.4)
4	491 (40.3)
5	105 (8.6)
6+	24 (2.1)
Family income (unit: thousand KRW/month)	
0–999	61 (5.0)
1,000–1,999	117 (9.6)
2,000–2,999	205 (16.8)
3,000–3,999	236 (19.4)
4,000–4,999	200 (16.4)
5,000–5,999	186 (15.3)
6,000–6,999	85 (7.1)
7,000+	127 (10.4)

5.3. Main Survey: Results for Travelers' Behaviors in Short-Distance Trips

5.3.1. Description and Demographic Statistics. The main survey was conducted through the Internet to (1) obtain a significant number of responses for all types of traveler's groups and (2) have more balanced responses regardless of the locational features. 1,217 respondents were interviewed with gender parity for four days (from 30th of September to 3rd of October 2016). Table 5 presents the details of the interviewees' responses.

5.3.2. Description of Logistic Regression Models. On the basis of the main survey, there are preliminary observations regarding the impacts of travel conditions or the traffic environment on choosing PRT, in addition to the calibration of mode choice models, as follows:

- (1) In the mandatory trip, (i) PRT was preferred during inclement weather conditions regardless of PRT fares, and (ii) when the PRT fare was lower, travelers obviously preferred to use PRT even during good weather conditions (see Figure 6). To

be specific, both scenarios with travel costs of 500 KRW and 1,000 KRW during bad weather (in case 2) showed higher probabilities than case 1 (good weather conditions). However, in case 1 (good weather), a scenario with 500 KRW showed a higher probability than a scenario with 1,000 KRW (see a horizontal axis of 10-minute difference of travel time). If the weather was good, a cheaper PRT fare increased the probability of PRT choice by around 30% when the travel time was different by 10 minutes.

- (2) In the nonmandatory trip without company scenario, the same result was observed. That is, (i) PRT fares did not significantly impact the choice of PRT in bad weather and (ii) a lower fare affected PRT choice with good weather conditions (see Figure 7). In case 4, both scenarios with 500 KRW and 1,000 KRW with bad weather had higher probabilities than case 3 (good weather conditions), whereas with 500 KRW, a higher probability was observed in case 3 compared to the one with 1,000 KRW (being an approximate 15% gap in 18-minute difference of travel time between 500 KRW and 1,000 KRW).
- (3) When comparing a mandatory trip against a nonmandatory trip without company with a 500 KRW fare, the nonmandatory trip without company was more sensitive to weather conditions as shown in the left graphs in Figures 6 and 7. This sensitivity became similar with a 1,000 KRW fare (see the right graphs in Figures 6 and 7). That is, the decision for PRT was obviously affected by weather conditions in both a mandatory trip and nonmandatory trip without company.
- (4) In the nonmandatory trip with company, (i) the weather condition made a difference to the probability of a PRT choice regardless of fares and (ii) the impact of differing fares showed a minor difference under the same weather conditions both in cases 5 and 6 (see Figure 8). Specifically, with company, having bad weather conditions was a valid factor to determine the choice of PRT. As indicated in Figure 8, a gap of around 30% of 9-minute difference of travel time between bad and good weather conditions (in cases 5 and 6) was found in both fares. As shown in a horizontal axis of 15-minute difference of travel time with bad weather, similar probabilities were observed. This was regardless of the fare difference which led to the conclusion that trips with company were not affected by fares, but rather, by weather conditions.
- (5) Under good weather conditions, (i) differing fares influenced the choice of PRT regardless of trip purposes and (ii) the trip purpose affected PRT choice, particularly with a lower fare (see Figure 9). That is, with the same trip purpose, the probability of choosing PRT with 500 KRW was generally higher than the one with 1,000 KRW. Looking at the horizontal axis of 15-minute difference of travel

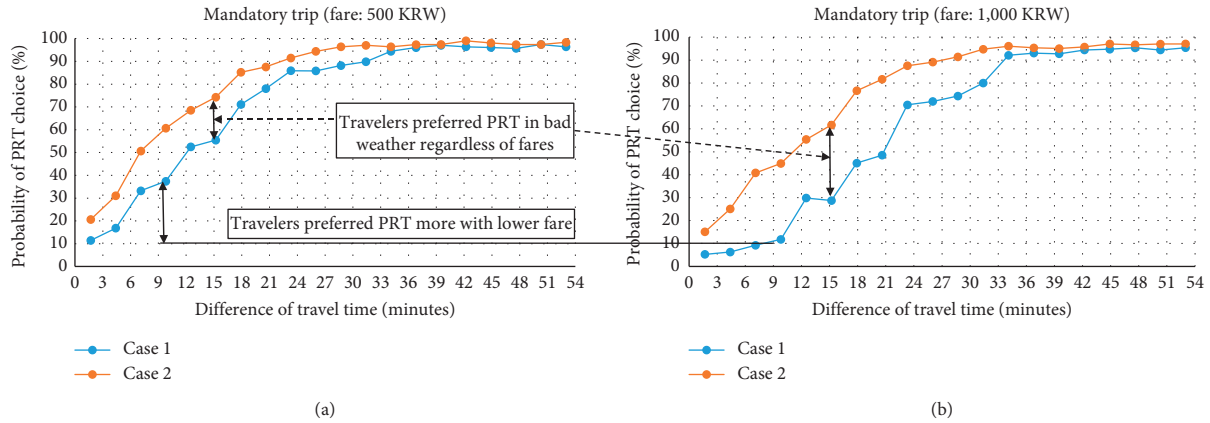


FIGURE 6: Impacts by weather and fare on PRT choice in the mandatory trip.

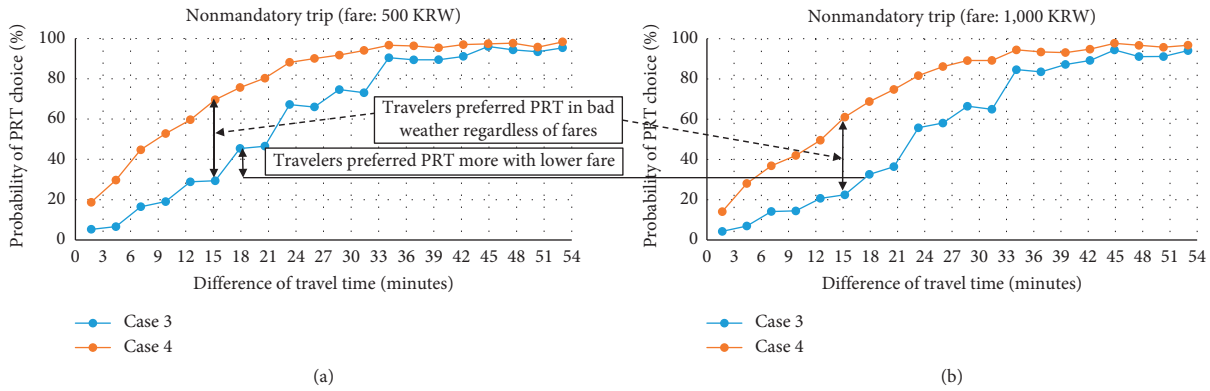


FIGURE 7: Impacts by weather and fare on PRT choice in the nonmandatory trip without company.

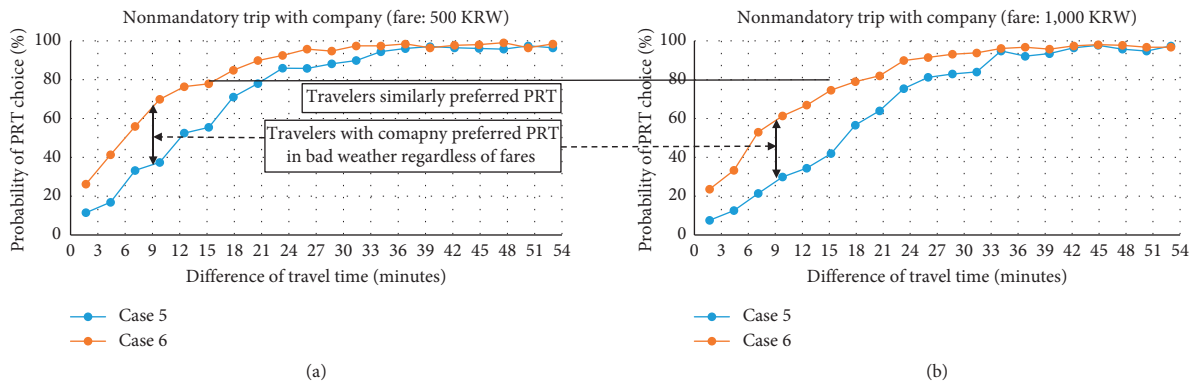


FIGURE 8: Impacts by weather and fare on PRT choice in the nonmandatory trip with company.

time, the probability of PRT choice in a mandatory trip with 500 KRW was higher by around 25% than the one with 1,000 KRW. Also, with different trip purpose, the probability of PRT choice for the mandatory trip was always higher than for nonmandatory trips owing to the higher value placed on time by those who need to travel obligatorily.

(6) Under bad weather conditions, (i) the fare difference was not a strong factor to determine the choice of PRT regardless of trip purposes and (ii) the trip purpose did not affect the choice of PRT strongly (see Figure 10). With the same trip purpose, a similarity was found in terms of the probabilities of choosing PRT from the two fares. Likewise, with the same fare condition, the probabilities of PRT choice became

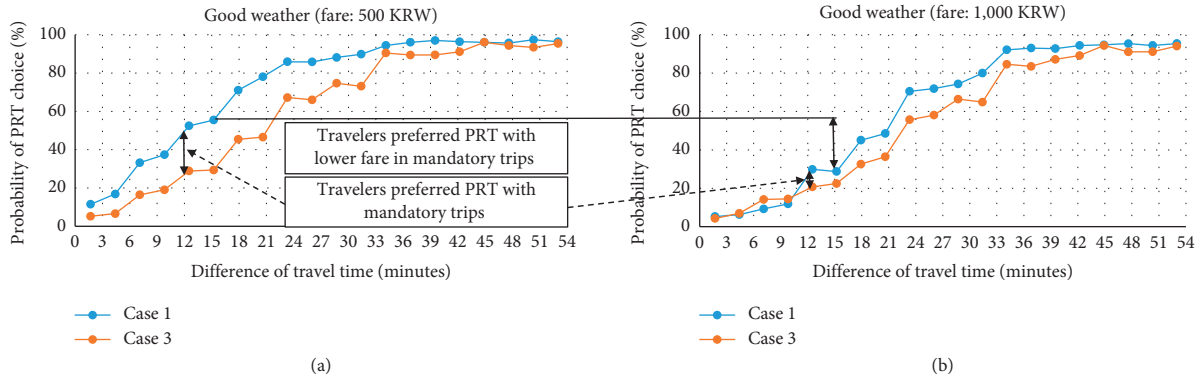


FIGURE 9: Impacts by fare and trip purpose on PRT choice under good weather conditions.

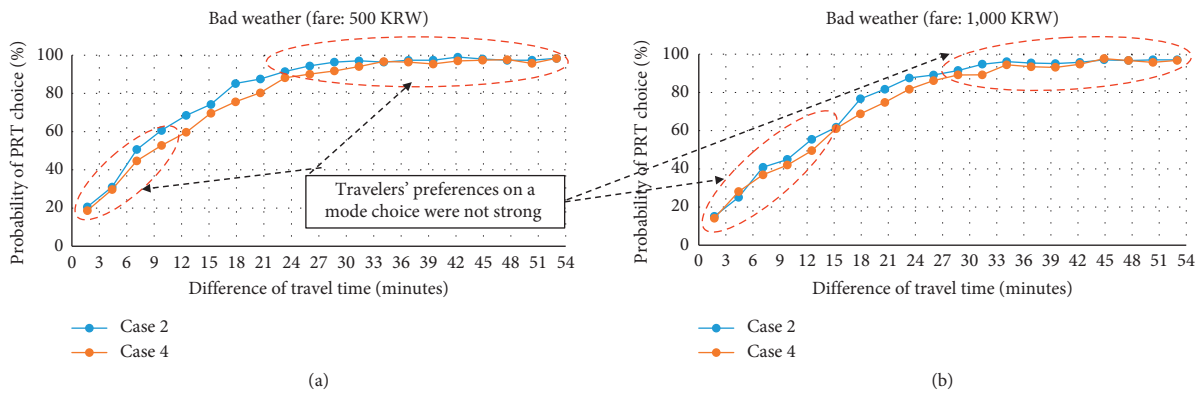


FIGURE 10: Impacts by fare and trip purpose on PRT choice under bad weather conditions.

TABLE 6: Logistic regression models for 12 scenarios.

Cases	Scenarios	Trip purpose	Weather condition	Companion condition	PRT fare (KRW)	Functions
Case 1	Scenario 1	Mandatory	Good	—	500	$P = \frac{\exp(-1.651+0.126 \times \text{difference of travel time})}{1+\exp(-1.651+0.126 \times \text{difference of travel time})}$
	Scenario 2				1,000	$P = \frac{\exp(-2.831+0.137 \times \text{difference of travel time})}{1+\exp(-2.831+0.137 \times \text{difference of travel time})}$
Case 2	Scenario 3	Nonmandatory	Bad	—	500	$P = \frac{\exp(-1.034+0.133 \times \text{difference of travel time})}{1+\exp(-1.034+0.133 \times \text{difference of travel time})}$
	Scenario 4				1,000	$P = \frac{\exp(-1.344+0.122 \times \text{difference of travel time})}{1+\exp(-1.344+0.122 \times \text{difference of travel time})}$
Case 3	Scenario 5	Nonmandatory	Good	No	500	$P = \frac{\exp(-2.548+0.122 \times \text{difference of travel time})}{1+\exp(-2.548+0.122 \times \text{difference of travel time})}$
	Scenario 6				1,000	$P = \frac{\exp(-2.825+0.117 \times \text{difference of travel time})}{1+\exp(-2.825+0.117 \times \text{difference of travel time})}$
Case 4	Scenario 7	Nonmandatory	Bad	No	500	$P = \frac{\exp(-1.139+0.119 \times \text{difference of travel time})}{1+\exp(-1.139+0.119 \times \text{difference of travel time})}$
	Scenario 8				1,000	$P = \frac{\exp(-1.365+0.111 \times \text{difference of travel time})}{1+\exp(-1.365+0.111 \times \text{difference of travel time})}$
Case 5	Scenario 9	Mandatory	Good	Yes	500	$P = \frac{\exp(-2.001+0.134 \times \text{difference of travel time})}{1+\exp(-2.001+0.134 \times \text{difference of travel time})}$
	Scenario 10				1,000	$P = \frac{\exp(-2.182+0.128 \times \text{difference of travel time})}{1+\exp(-2.182+0.128 \times \text{difference of travel time})}$
Case 6	Scenario 11	Nonmandatory	Bad	Yes	500	$P = \frac{\exp(-0.657+0.122 \times \text{difference of travel time})}{1+\exp(-0.657+0.122 \times \text{difference of travel time})}$
	Scenario 12				1,000	$P = \frac{\exp(-0.826+0.112 \times \text{difference of travel times})}{1+\exp(-0.826+0.112 \times \text{difference of travel time})}$

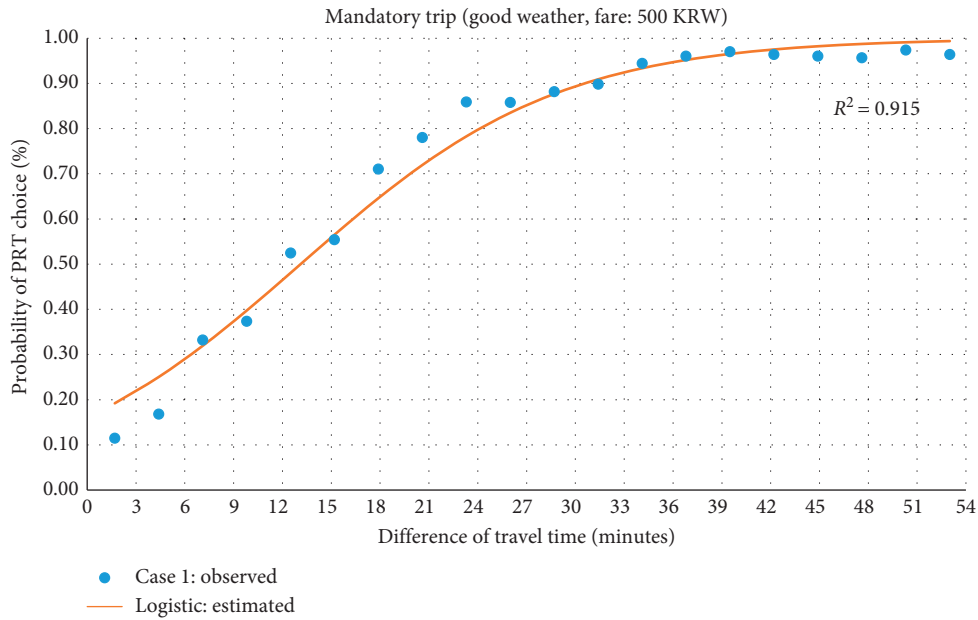


FIGURE 11: Logistic regression curve of the mandatory trip with 500 KRW under good weather (scenario 1).

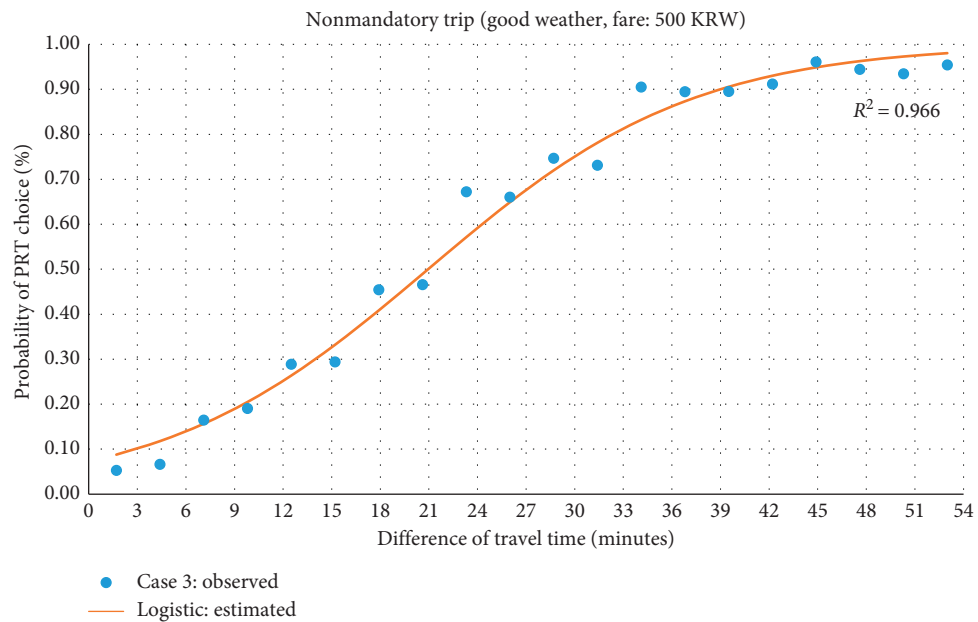


FIGURE 12: Logistic regression curve of the nonmandatory trip with 500 KRW under good weather (scenario 5).

similar on both mandatory and nonmandatory trips without company.

5.4. Model Calibration: Logistic Regression Models for Travelers' Behaviors in Short-Distance Trips. Based on the results from the main survey, the probability function for PRT choice was calibrated. After testing a variety of functions, a logistic regression curve was determined because of its high goodness-of-fit. In total, 12 logistic regression curves are presented in Table 6.

Among the 12 scenarios, two examples have been presented based on the observed data from the main survey and calculated values from logistic regression functions 1 and 5. The R-squared measures per each model showed high goodness-of-fits which were 0.915 (Figure 11) and 0.966 (Figure 12), respectively.

6. Conclusions

There are emerging demands for connectivity of the first and last mile of travel. According to the advancement of ICT and

growing interest in environmental issues, special transportation modes in short-distance trips that satisfy an individual's various needs for convenience and comfort have been identified. Previous studies have mostly dealt with mid/long-distance trips due in part to the lack of suitable models or usable data for the short-distance trip. Some studies that have focused on short-distance trips conducted a simple analysis and were limited in scope.

The main features of the current study are

- (1) to propose a suitable approach that can understand the features determining mode choice of transportation for a short-distance trip;
- (2) to quantify the impact of various factors, including the trip purpose, weather condition, fare, travel time, and accompanying children, which affect the mode choice for a short-distance trip;
- (3) to reaffirm the applicability of the logistic regression model for the analysis of traveler's behavior for a short-distance trip; and
- (4) to provide the groundwork for the analysis of active transportation modes, such as electric scooters, which are expected to grow in response to new demands (including Mobility-as-a-Service) for the short-distance trip.

In conclusion, the trip purpose and weather condition impacted as factors on the mode choice being consistent in part with Ashkrof et al. [34]. For a mandatory workplace or school trip under similar travel times, travelers preferred PRT. A preference for PRT was also observed in bad weather conditions, regardless of the type of trip purposes and PRT fares. When traveling with company, the weather condition became a key factor again in choosing PRT, while the variation of fares did not comparatively have an impact on mode choice. In summary, when the weather was not good, PRT fare difference and trip purposes were not a strong factor when deciding to choose PRT. However, during good weather, other factors contributed to the choice of PRT. These included differing fares regardless of trip purposes, and the trip purpose (i.e., mandatory trips) affected PRT choice, particularly with a lower fare. Given that fares become an effective factor under good weather conditions, this finding is also similar to the one from Liu et al. [35] who concluded that cost significantly influenced mode choice for short-distance trips.

The weather has a significant effect on our lives. For example, the average number of days with precipitation (including snowfall and rainfall) is 103.5 days per year in the Republic of Korea [36]. As such, the extent of the impact of weather conditions on PRT choice is noteworthy. This might require further careful and thorough investigation because of the recent spotlight on diverse environmental factors, such as global warming, climate change, yellow dust, and fine dust.

In comparison to previous disaggregated behavioral models (e.g., logit models), this study employed a logistic regression model to calibrate the outputs from the survey. Note that the short-distance trip is less affected by travel

deterrents such as travel time, distance, and fares, when compared with the long-distance trip. However, various other factors, such as weather, security, and slope, determine mode choice for the short-distance trip. Because a logit model requires many explanatory variables, the process of calibration becomes complicated, which in turn defines the model's explanatory significance as low.

To overcome this problem, an alternative model considering diverse variables for mode choice was developed by using a logistic regression model, which replicated actual mode choice from the survey. Nevertheless, as the logistic regression model has a limitation when expressing more than three multiple modes, alternative approaches need to be considered. These include machine learning techniques that can incorporate a number of factors and modes together. In this aspect, decision analysis techniques, such as the conjoint method, Naïve Bayes algorithm decision tree algorithm, or random forest algorithm, can be options used for mode choice modeling with various explanatory factors within future studies.

Data Availability

All data used in this study are available upon request to the author (Hyunmyung Kim, khchlsy@gmail.com).

Disclosure

Changju Lee is currently at Transport Division, United Nations Economic and Social Commission for Asia and the Pacific, Bangkok 10200, Thailand. The views expressed herein are those of the authors and do not necessarily reflect the views of the United Nations.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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