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EVALUATION OF ELDERLY MOBILITY BASED ON TRANSIT CARD DATA IN SEOUL

ABSTRACT

The travel patterns of senior citizens in Seoul were analyzed using Automatic Fare Collection (AFC) data. The focus was specifically on mode choices and transfer patterns. The results showed that 99% of trips made by senior citizens (individuals over 65 years old), who were given free subway transit passes, consisted of single-mode trips. The average travel time was 31 minutes, and subway travel times were longer than bus travel times. Individuals made fewer transfers, took longer metro trips, and paid smaller fares when using their free subway transit cards. They were more negatively sensitive to bus travel time than metro travel time. Encouraging older adult travellers to use transfers that increase costs to a modest extent might help improve travel quality among a group of individuals who find it difficult to enter the metro system or who are uncomfortable making inter-metro transfers. Additionally, as older adults have more time, yet are economically disadvantaged and take more leisure trips, travel improvements could include adopting a time-flexible fare discount. These improvements are discussed in terms of the individual and social benefits afforded to transit passengers in South Korea.

KEY WORDS

elderly transit; Smart card data; evaluation of service

1. INTRODUCTION

The UN classifies countries with over 7% of their population aged 65 or older as “aging societies” [1]. Recently, the developments in medical technologies and low birth rates have led to increase in aging populations. Related to this trend, as quality of life issues for the elderly are starting to gain more attention, the governments in these countries are concerned with advancing elderly individuals’ welfare, considering both social and economic aspects. The rise in aging populations involves not merely population growth and lifetime extension but also changes in life patterns. As travel is a significant part of our daily lives, mobility has a large impact on one’s quality of life. Accordingly, this requires enhancements to various travel convenience policies to build a system for advancing older adults’ travel range. Thus, older individuals, who are classified as “transportation vulnerable,” have been a population of interest in transportation research.

Rosenbloom performed a comparative analysis on travel modes, travel volume, and total travel distances among people over the age of 65 in a variety of advanced countries as a way to assess travel policy implications [2]. Golob and Hensher analyzed older adults’ travel patterns in Sydney, Australia, as a way to examine potential differences with normal travellers and determine what sort of interventions might be necessary [3].

Trip distance among elderly travellers was an important indicator of sustainable transportation. Morency analyzed elderly, low-income adults and members of single-parent households using a spatial expansion model. The data were compiled from the Toronto Transportation Tomorrow survey and a travel survey conducted in Montreal. The results from a series of regression models predicting distance travelled suggested that individuals in these three at-risk groups seemed to travel shorter distances, but not in every case or in the same magnitude [4]. Mercado and Paez investigated determinants of mean trip distance travelled among different mode types with a focus on elderly adults in Toronto [5].

Schmocker examined demographic and disability variables as they related to patterns of trip generation among elderly and disabled individuals using an interim version of the London Area Travel Survey. The trip generation model used by Paez was included in this study. Results showed that increasing age, and disability independent of age, had an impact on trip frequency. Additionally, individuals experiencing difficulty with walking made fewer trips and travelled shorter distances [6, 7].

Other studies have analyzed the mobility of age-specific older adult groups in the Netherlands from various angles, including travel modes, periods, distances, etc., for purposes of policy implications [8]. Furthermore, some studies have focused on mobility as an important factor related to quality of life among the retired individuals over the age of 65 using structural equation modelling. Data used for this analysis included household activity survey data from the Puget Sound Regional Council in Washington State. One factor related to mobility that predicted the quality of life was older adults who were "transportation disadvantaged" [9, 10].

The aforementioned studies focused on general travel patterns based mainly on questionnaire surveys; however, current transportation systems and assessments of policies dealing with transportation card data have been given little consideration. In the Republic of Korea, a legal precedent has been set to systematically enhance travel conveniences among the transportation vulnerable [11]. However, insufficient systematic analyses and studies on travel patterns among older adults are available.

Several studies have focused on transportation mode choice modelling among elderly individuals. Van den Berg estimated the relationship between travel demands for purposes of social activities using data from social interaction diaries and questionnaires in Eindhoven, the Netherlands. A negative binomial model, random effects model, and mixed logit model were used for the estimation [12]. Schmocker attempted to understand mode choice decisions among older and disabled individuals in London, with the objective of determining what policies could best meet these individuals' mobility and activity needs. An interim version of the London Area Travel Survey that included information on both trip distance and journey travel time were used for the estimation. Models were estimated using six mode choices specific to variable travel costs [13].

The current study has great significance in that it attempted to discover travel patterns among older adults using travel data collected from transportation cards. Additionally, the current study focused on analyzing the factors influential to travellers by assessing multiple modes of public transportation through transit mode choice pattern data. This was done in order to assess the implications for improving mobility convenience facilities for the transportation vulnerable.

The current study collected data on "passengers over the age of 65" (traveller type) from Seoul transportation card data, as well as from travel records and free ride cost status data obtained through the metro operator of the Seoul metropolitan region, Republic of Korea. Analyses were performed to identify travel patterns. This included a multinomial logit model with principle explanatory variables influential to transit mode choice to determine relevant choice patterns.

2. ANALYSIS OF ELDERLY TRAVEL PATTERNS

The demand for public transportation has continued to increase as the population has been shifting from rural to more urban areas throughout the Republic of Korea. Starting with the launch of Korea's first subway, the Seoul subway Line 1 in 1974, the era of subways was inaugurated, and all sections of Seoul subway lines 1, 2, 3 and 4, and the Busan subway, opened in the 1990s.

The Seoul subway lines 5, 6, 7, and 8, as well as subway lines in In-Cheon, Dae-Gu, Gwang-Ju, and Dae-Jeon, opened in the 2000s. Thus, the Republic of Korea operates one of the most extensive metropolitan subway systems in the world, with a total of 768 stations along 31 lines that span almost 1,118.6 km. Although intended to assist the older adults, the free ride program for senior citizens, combined with the rapidly aging Korean population, has resulted in several complications, including financial difficulties experienced by several subway operators.

Although Korean subway operators are government-owned corporations catering both to public interests and profitability, the disparate emphasis on public interest and considerations for consumer prices have served to curb fare increases, resulting in fares being far less than their actual cost.

The main purpose of the present study was to investigate the travel patterns among elderly adults using transit smart card data over a one-week period. The paper presents older adults' travel patterns, with respect to time and frequencies of boarding and

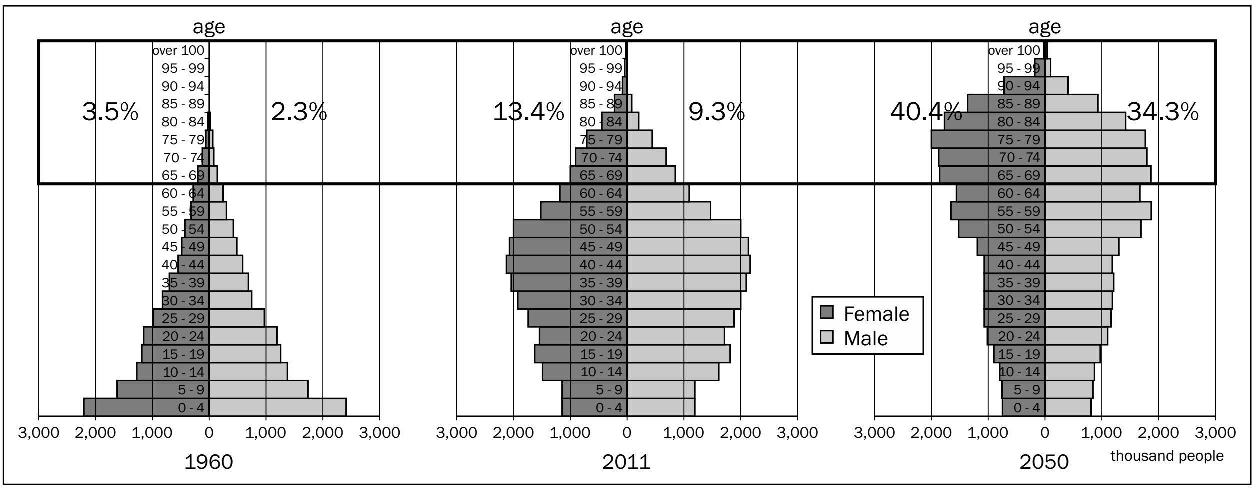

Figure 1 - Older adult population growth

Source: Korea National Statistical Office [14]

alighting, transfer chains and times, and the cost of free rides. Older adults' travel patterns based on transit smart card data are valuable to transit agencies for planning and scheduling routes for customers with special needs. Furthermore, they provide an opportunity to review and improve the operators' financial standing.

2.1 Aging society

Our world has been facing recent issues related to the increased aging populations. Population aging is a shift in the distribution of a country's population towards older ages. The number of older individuals is expected to greatly increase in some countries. The Republic of Korea officially became an "aging society" in 2000. In comparison with other countries, there has been a dramatic rise in the number of older adults in Korea. *Figure 1* shows the composition of the national population since the 1960s in Korea. According to the Korean national statistics, the distribution ratio among men and women in the over-65 age group was only 3.5% and 2.3%, respectively, in 1960. This increased to 13.4% and 9.3%, respectively, in 2011. Furthermore, this ratio is expected to sharply increase towards 40.4% and 34.3%, respectively, in 2050 [14]. Thus, travel patterns and transportation policies developed for the enhancement of elderly mobility need to reflect this ever-increasing population.

In order to subsidize the elderly mobility, metro operators have been providing discounts for elderly passengers over the age of 65 since the 1980s. Since about 45% of people over the age of 65 live in poverty, the government decided to subsidize metro operators for providing older adults with discounted tickets. From 1980 to 1984, the 1st metro system in Korea provided 50% discounts for elderly passengers. Since 1984, the metro system has been providing free passes. All new subway operators have been required to provide free passes from their 1st day of operation. Until 2008, one-use paper tickets were provided, which were replaced by smart cards. As the number of transportation studies assessing elderly adults has increased, the introduction of transit smart card data has provided an excellent opportunity to study older adult travel patterns and develop transportation policies to aid the elderly mobility.

2.2 Operation analysis using elderly travel patterns

Below, the data related to providing free passes are discussed. The percentage of free riders in the whole

Table 1 - Free ride metro costs in the Seoul metropolitan area

	Number of free rides (thou.)	Transit income (mill. KWN)	Cost of free rides (mill. KWN)	Ratio of free ride cost
2008	3,199,728	3,371,241	351,721	10.43%
2009	3,205,628	3,255,501	358,318	11.01%
2010	3,298,222	3,421,817	366,471	10.71%
2011	3,405,449	3,973,812	384,864	9.69%

Source: Annual transit plan, Seoul metropolitan rapid transit, 2013 [15], Statistical year book of Railroad, Korail, 2008-2013 [16], Annual transit plan, Seoul metro, 2012 [17]
** Current rate of exchange: 1USD = 1,057KRW, Nov. 18, 2013*

transit system is shown in *Table 1*. The number of free riders has continued to increase with the increasing population of older adults over 65. The costs of providing free rides are about 10% of all transit income and results in higher expenditures. Free ride costs substantially increase the financial burden placed on the operators.

Figure 2 shows the ratio of free riders relative to the total number of subway passengers within the five mega cities — Seoul, Busan, Gwang-Ju, Dae-Gu, and Dae-Jeon — of Korea. These cities had subsidization policies until 2004, but these policies no longer exist. As shown in *Figure 2*, the four mega cities other than Seoul had more than 20% of passengers that were free riders. This was primarily due to differences in metro services related to the number of lines and headways operating in each city.

Headway time for the four mega city (excepting Seoul) metro systems is about 8–15 minutes, longer than in Seoul (anywhere from 3–8 minutes). These

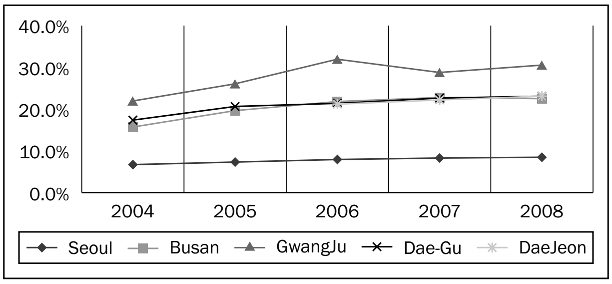

Figure 2 - Comparisons of the ratio of free riders relative to the total number of passengers from 2004 to 2008

other cities also have lower demands for public transportation than in Seoul. Thus, metro operators appropriately set their headway to be about 8–15 in order to meet their transportation needs. However, this inhibits performance for an economically active population, whose highly valued time is being spent using the subway. Of course, this extra time might not be as detrimental to elderly and disabled individuals, who might not experience the same time pressures as other passengers.

Figure 3 shows a comparison of mode shares between the five mega cities. In Seoul, even though there was a higher ratio of older adults in the population, the results revealed the lowest ratio of free subway rides. This difference is presented in the modal distribution of internal trips within the cities. Seoul and Busan subways used 36% and 17%, respectively, while the other cities held only about 2–7%.

Free fares provide a good opportunity for riding the subway. To differentiate transit times and increase metro ridership, work must be done to help increase the operation of express trains. To improve the availability of lines that pass the major landmarks, bus systems and metros should be more integrated. One study revealed generally negative opinions regarding the abolishment of free passes [20]. Older adults in Korea have few choices other than the metro or buses for vehicular travel; thus, if these individuals will incur restrictions on using the metro, such restraints are likely to have a more negative effect on elderly adults as compared to any other travel group.

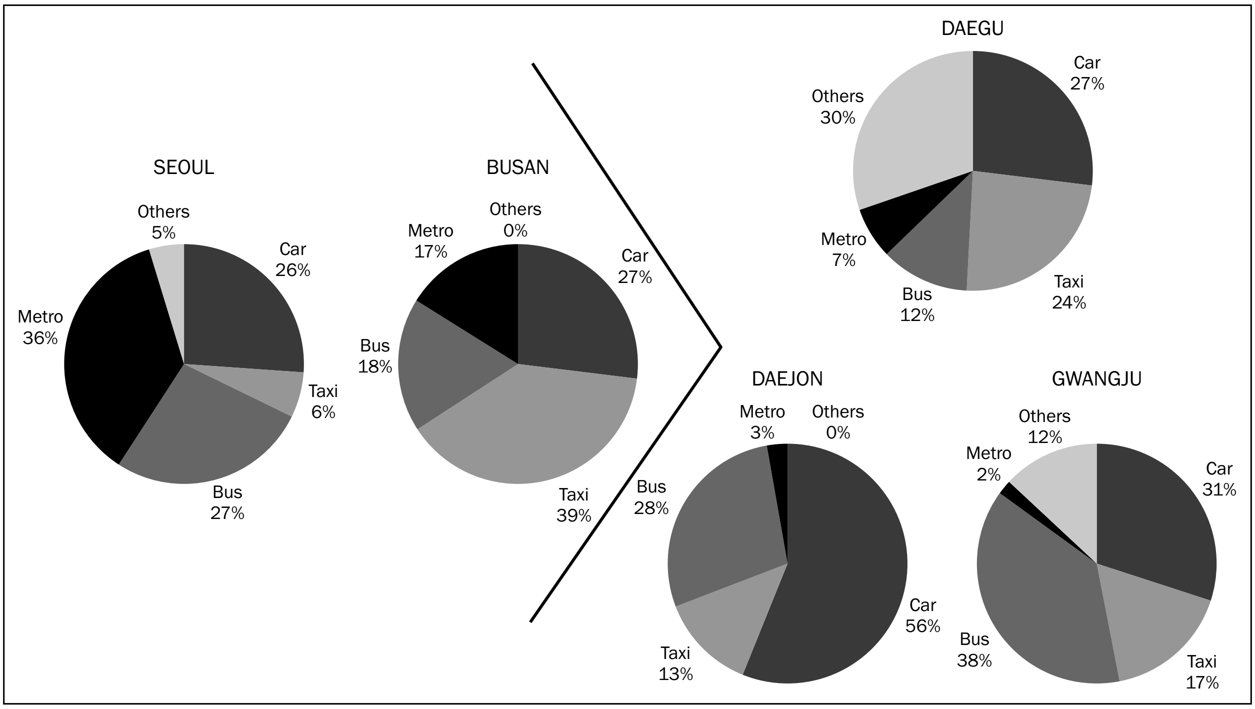

Figure 3 - Comparison of public transportation mode shares

2.3 Transit smart card data analysis

With the exception of elderly and disabled individuals, all transit systems follow a model of distance-based transit fares. Elderly adults are provided with a free ride, but only for the metro; elderly adults are charged bus fare according to the distance-based transit fare system. In this system, passengers pay a basic fare when boarding, and an additional fare is automatically calculated based on travel distance upon disembarkation. The additional fare will be charged within a maximum of four transfers. Elderly adults using the buses and metro with transit cards are charged the basic fare for the bus and additional fares calculated according to the distance travelled. Data collected from transit smart cards and operators provide an opportunity to investigate travel patterns and analyze the effectiveness of this transportation policy.

Table 2 shows content of recorded information from smart cards used in the current study. The actual number of recorded fields was more than 30, but only 17 fields (those listed in the table) were used for the analysis. Similar to other transit smart card systems, this includes individual ID cards, boarding and alighting times, transit mode, type of user, location of boarding and alighting, etc. In 2012 the transit smart card system collected data associated with metro stations and bus stops in Seoul.

The dataset used in the current study was obtained from the Korea Smart Card Corporation (KSCC), the operator of the Seoul AFC system. The dataset covered March 22 (Thursday) to 24 (Saturday), 2012. The number of transactions on a typical weekday in Seoul is more than 35 million. Each leg of a trip constitutes two transactions (boarding and alighting), so the total number of trip legs is about 18–19 million per day.

The average percent error in the card data was about 4% for each weekday, and records containing errors were eliminated from the analysis. Four types of errors were observed: (1) incorrectly recorded transfers, (2) partial or missing data, (3) identical boarding and alighting stations, and (4) the in-vehicle time was recorded as less than 30 s and the total travel time was greater than 5 h.

As shown in *Table 3*, most errors included missing data. This occurred when passengers did not tag their cards twice when both boarding and alighting. In this case, the tag time data for either boarding or alighting was missing. Additionally, the number of transfers providing trip chain information was not properly recorded. Data with excessively long or short transfer times were regarded as errors that could obstruct explanations related to transit travel behaviour. A few errors were also reported by faulty card tag systems, with station and route information missing.

Table 2 - Transit smart card data in Seoul

Information	Description
Card ID	Card number for each smart card
Departure time	Bus departure time
Transaction ID	Distinguished ID for Transfer
Mode of transport	Bus (local/main/feeder/metropolitan/circle bus), Metro
Number of transfers	Number of transfers (from 0 to 4)
ID of bus route	Given number of every bus route
ID of bus company	Given number of every bus company
ID of vehicle	Given number of every operated bus
Type of user	Adult, Student, Children, or Elderly
Boarding time	Boarding time (year/month/day/hour/minute/second)
ID of boarding location	Given number of boarding bus/metro stop
Alighting time	Alighting time (year/month/day/hour/minute/second)
ID of alighting location	Given number of alighting bus/metro stop
Number of passengers	Number of passengers
Basic fare	Starting (base) fare
Additional fare	Additional fare with distance
Travel distance	Distance from origin stop to destination stop

Table 3 - Filtering transit smart card data

Number of card data	Number of trips	1st filtering	2nd filtering	3rd filtering	4th filtering	Number of valid data
19,471,791	14,119,987	975	555,218	159,446	759	13,403,589

After the fourth filtering process, we finalized data in which about 19 million legs were recorded, corresponding to approximately 13 million trips on a weekday. Of these 13 million trips, approximately 1 million (or about 8%) were taken by people using free passes.

2.4 Comparisons of transit travel characteristics

It was expected that free riders, such as elderly and disabled individuals, would take fewer trips and make fewer transfers compared to general riders. As shown in *Table 4*, the observed average in-vehicle travel time for general riders was about 32 minutes, which was similar to older adults' travel times. However, the observed average fare per trip for elderly adults was only 151 (KRW*/trip), and the average number of transfers per trip was 0.04 (transfer/trip), which was much less than the average for general commuters. The average fare per trip for elderly passengers was only 15% of the fare obtained from general passengers. This means that elderly adults most likely used the metro instead of riding a bus in order to reduce their transportation costs. Furthermore, it is likely that elderly adults would not transfer between modes because they did not want to pay a bus fare nor did they want to make an inconvenient transfer trip.

One major benefit of using transit smart card data in Seoul is that we were able to analyze transfer patterns between modes. The transfer patterns obtained from cards were used to analyze and compare the different traveller types in *Table 5*. Approximately 90% of the total trips made by elderly adults were single-mode trips, and these individuals greatly preferred taking the metro rather than a bus. This can be explained by the fact that older adults and disabled individuals try to use their free pass metro cards and complete their trip using only one transportation mode. In contrast to transfer patterns among elderly and disabled individuals, general passengers used single and one-transfer modes, which account for approximately 64% and 30% of the total trips, respectively. This suggests that general passengers also like to minimize the number of transfers, even though some will still make numerous transfers.

Figure 4 shows the time of day travel patterns among general and elderly passengers on weekends and weekdays. As most elderly individuals are not employed, they travel frequently between 10 a.m. and 4 p.m. while general passengers mainly travel during both morning-peak and afternoon-peak hours (7–9 a.m. and 6–8 p.m.). Transit use patterns among elderly adults on weekdays and weekends are similar, although most older adult trips sharply decrease after 4 p.m. This could be because older adults engage in fewer evening outdoor activities, and have shorter activity durations, compared to general passengers.

Based on travel patterns by the time of day, we can provide a time-differentiated service for older adults in order to ease transportation burden on operators during morning-peak hours.

Table 4 - Comparisons of transit travel characteristics

User Class	Population (A)	Number of trips (B)	Trips/person (B/A)	Transfer frequency	Fare (KRW*)	In-vehicle transit time (min.)
General	6,711,986	10,585,348	1.58	0.43	1,043	31.8
Elementary school students	535,948	111,113	0.21	0.17	531	14.0
Middle, High School students	1,180,987	1,750,985	1.48	0.37	852	27.0
Senior citizens	928,956	797,458	0.86	0.04	151	31.4
Disabled	403,000	260,870	0.65	0.05	163	31.2
Citizens of national benefit	147,402	23,242	0.16	0.00	36	27.7

** Current rate of exchange: 1USD = 1,057KRW, Nov. 18, 2013*

Table 5 - Comparisons of transfer characteristics

User class	General		Senior citizen		Disabled	
Number of transits via public transportation	10,585,348		797,458		260,870	
Transfer frequency 0	6,749,913	63.8%	766,196	96.1%	249,256	95.6%
Transfer frequency 1	3,190,780	30.1%	26,618	3.3%	9,935	3.8%
Transfer frequency 2	560,214	5.3%	3,648	0.5%	1,333	0.5%
Transfer frequency 3	66,198	0.6%	700	0.1%	254	0.1%
Transfer frequency 4	18,243	0.2%	296	0.0%	92	0.0%

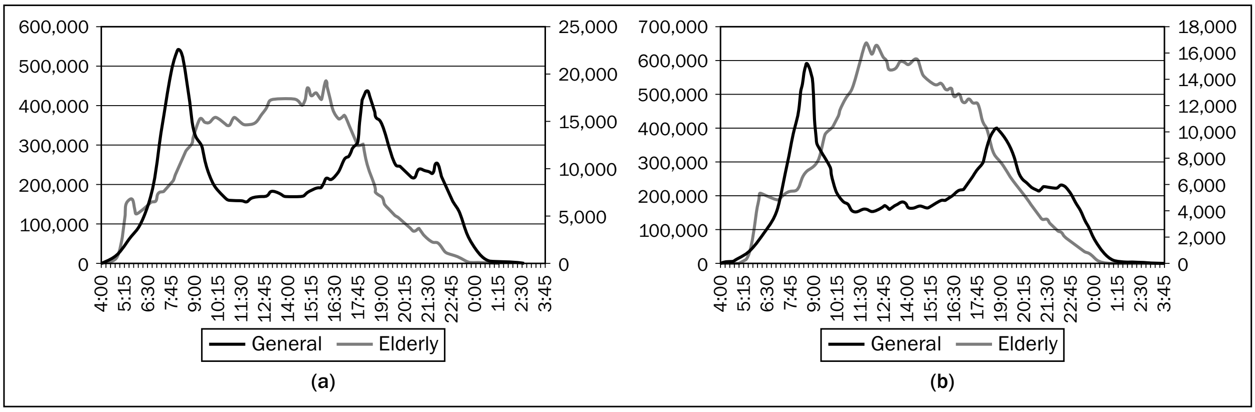

Figure 4 - The boarding and alighting time distributions of both free riders and other passengers for every fifteen minutes during weekdays (a) and weekends (b)

3. ELDERLY TRANSIT MODE CHOICE CHARACTERISTICS

Below, the factors related to transit mode choice behaviour among the elderly passengers within trip chain information observed from the card data are discussed. The trip chain data include data where all transit modes were recorded with in-vehicle travel time, transfer time from origin to destination and cumulative fares until one trip was complete. Overall, older adults seem to pay lower fares and make fewer transfer trips. Thus, we investigated the magnitude of the effectiveness of variables, such as transfer time and transfer modes, in determining the transit mode choice among elderly passengers.

3.1 Model structure

The model for analyzing individual choice patterns was constructed according to the following three conditions. First, this model assumes that individuals are rational decision-makers and always reasonably make the most desirable choice. Second, the usefulness of each choice is identified by its characteristics and the chooser's personal attributes, but some choice characteristics might not be evaluated by the observer and do not correspond to the chooser's judgment of usefulness. Therefore, even in groups where choosers' personal attributes are observed to match choice characteristics, the choices are not always the same. Although choices are made according to their usefulness, the choosing is still a probability calculation based on the unobserved chooser attributes and choice characteristics. Choosers that face mutually exclusive choice combinations are assumed to choose a combination with the highest probabilistic usefulness. Third, this model assumes that individuals' specific situations and personal attributes have a strong influence on their choice of transit modes. Thus, this model uses a microscopic approach that discovers travel patterns based on individual behaviour principles.

The basic theory of random utility models (RUMs) is well known, and several different contributions of discrete choice models for transportation studies have emerged [21-27]. As for the particular case related to the fare scheme in Seoul, the transfer data between metro trips was not fully obtained since only one private line recorded transfer information. In addition, data for more than three transfers was insufficient to construct a discrete choice model structure because not all observations were available for every transfer type. Therefore, the targeted alternatives consisted of single modes and modes with two transfers, which covered 99% of all transit trips (as shown in *Table 5*). By excluding transfers connected to the metro after riding a bus or other lines, transit mode choice, including transfer choice set, consists of the five types listed below.

Metro
Bus
Bus – bus
Bus – metro
Bus – bus – bus

The explanatory variables are shown in *Table 5* and include travel time for transfers, in-vehicle time, travel distance by mode, and distance-based fare. These variables were tested and used to develop a multinomial logit (MNL) transit mode choice model by transfer type. After testing the various combinations of utility functions, we set up the model listed below.

Model: $U_j = \alpha_j + \beta_1 IVTT + \beta_2 TFT + \beta_3 FARE$ (1)

where:

U_j – deterministic utility of alternative j;
α_j – constant parameter for alternative j;
β_n – parameters for attribute n;
IVTT – In-vehicle transit time;
TFT – Transfer time per origin-to-destination trip;
FARE – Fare per origin-to-destination trip.

The choice model (Eq. 1) consists of a combination of transit characteristics. The utility function is composed of in-vehicle transit time (IVTT), fare (FARE), and transfer time (TFT) with mode- and transfer-specific constants. The variables of in-vehicle time and fare are generally considered in the mode choice model without considering trip chain data. Generally, passengers tend to evade out-vehicle time more than in-vehicle time. This is because out-vehicle time contains psychological elements, including uncertainty, anxiety, etc. Transfer time (TFT) is applied to the choice model as out-vehicle time when transfer trips occurred.

3.2 Model estimation results

Table 6 shows results of the model estimation. This model was reliable, and all estimated parameters were significant with respect to t-values at the 95% significance level. In assessing the model's explanatory power, the rho-square value of the model was between 0.7 and 0.8. The signs of all parameters are shown to be negative, which makes sense because the explanatory variables such as travel time, time for transfer, and fare should negatively affect the mode choice model.

Results showed that time for transfers had a greater effect on transit mode choice than did travel time or fare. This helps explain why passengers might be more likely to choose the transit mode with the fewest transfers. The fare variable had a small effect on transit mode choice because most elderly passengers in Seoul pay only a small fare (about $1.00 for each trip). Furthermore, the parameter value for bus in-vehicle travel time was greater than the value of metro in-vehicle travel time, which suggests that passengers have more negative feelings regarding bus travel times. The likelihood ratio value expressing suitability of the whole model was more than 0.7. Generally, this value is known to be desirable when it is in a range from 0.2 to 0.4. Thus, this model can be argued to be good at explaining transit mode choice patterns among elderly passengers.

From these results, it is interesting to note that the travel time for transfers was highly affected by older adult transit mode choice as compared to just regular travel time and fare. This suggests that elderly passengers were more likely to choose the transit mode with the fewest transfers. The fare variable was observed to have a small effect on transit mode choice because most elderly passengers in Seoul use the metro for free and pay only a small fare for the bus (about $1.00 for each trip); overall, fares between modes are similar. Hence, fare does not seem to be a crucial factor for transit mode choice. Interestingly, the parameter value for bus in-vehicle time was greater than the value for metro in-vehicle time. This indicates that passengers could be more (negatively) sensitive to bus travel time than metro travel time.

From a trip chain perspective, elderly adults are likely not to choose multi-transit modes for their journey since alternative specific variables were negatively predictive compared to the bus only mode. Although parameter values were large compared to general variables, we can infer that older adults most likely choose

Table 6 - Estimation results of transit choice model

Variables	MODEL		
	Parameter	SE	t
Metro	-3.7300	0.1871	-19.9344
Bus-Bus	-0.4788	0.0971	-4.9298
Metro-Bus	-1.8214	0.2035	-8.9491
Bus-Bus-Bus	-3.7300	0.1871	-19.9344
IVTT	-9.24E-05	0.0003	-0.28812
TFT	-0.0570	0.0135	-4.20914
FARE	-0.0071	0.0002	-32.8076
No. of observations	31,897		
Restricted log likelihood $LL(0)$	-51,336.24		
Final log likelihood $LL(\beta)$	-13,372.98		
Rho-square ρ^2	0.74987		
Adj Rho-square $\bar{\rho}^2_{adj}$	0.74986		
Rho-square constant $\rho^2(C)$	0.03981		
Adj Rho-square constant $\bar{\rho}^2_{adj}(C)$	0.03975		
χ^2 statistics[b]	1,064.6(>21.03)[c]		

a Restricted log likelihood is fixed at the estimated value, and the other parameters are fixed at 0.

b χ^2 statistics = -2 (Restricted log likelihood - Log likelihood function)

c Critical value of χ^2 statistics with degrees of freedom = 7 (number of parameters) at the 95% significance level.

a convenient mode with regard to transfers such as a bus-to-bus transfer, rather than a metro-to-bus transfer. The mode-specific variable for the metro had a large negative effect on mode choice since the metro includes all transfers between metros. This indicates that it is likely that the elderly passengers would not choose the metro if a free pass card was not provided, on account of inconvenient accessibility.

4. CONCLUSION

Operation agencies of urban railways in the Republic of Korea offer a 100% discount to people over the age of 65. Since the Korean government does not properly support these discounted fares, the agencies maintain a system by which fare-paying passengers subsidize the costs for elderly passengers. Thus, flexible implementation of fares at SOC facilities is impossible; the burden on fare-paying passengers continues to increase. According to recent studies, the difficulties incurred by fare-paying passengers are annually rising, particularly in larger cities, including Seoul. However, fare discounts for older adults are reduced due to operation burdens and attendant social responsibilities. Consequently, the present study was conducted as a way to suggest possible solutions in consideration of both operators and travellers.

The current study collected data on "passengers over the age of 65" (traveller type) from Seoul transportation card data as well as travel records and free ride cost status data from a metro operator of the Seoul metropolitan region, the Republic of Korea. A statistical analysis was performed to assess travel patterns, and a multinomial logit model with principle explanatory variables influential to transit mode choice was assumed in order to analyze older adults' choice patterns.

Since the smart card data provides high quality and valuable information regarding travel patterns among transit users compared to traditional travel surveys, the smart card system can be used for many purposes related to transit planning above and beyond revenue collection. The large amount of data collected by a transit smart card system provides a better understanding of the travel behaviour since several observations are available as compared to the basic survey methods.

The analysis was focused on transit behaviour by considering transfer patterns for the distance-based fare system in Seoul. We found that about 99% of trips consisted of single mode trips and multimode trips with two transfers. The average travel time for older adult passengers was 31 minutes. Travel time when using the metro was longer than when using the bus. The average number of transfers was 0.04 per origin to destination, and each transfer took about 31.4 minutes. The average fare charged was about $0.14 (151 KNW). Interestingly, older adults made fewer transfers and longer metro trips with smaller fares by using their metro free pass cards.

In synthesizing this information, the most apparent problem appears to be the difficulty with transfer facilities and transfer costs. Thus, it is important to address the current discount policy offered to older adults, which is overburdening urban railway agencies. This can include creating an organic management system with bus transportation operators. Encouragement should also be given to elderly travellers to use transfers that might cost a little bit more than they currently pay in order to help improve the overall travel quality, as these individuals might find it difficult to enter the metro system or are uncomfortable making inter-metro transfers. Additionally, as older adults have more time available (but fewer financial resources), these individuals could be encouraged to travel during off-peak times. This could be accomplished by adopting time-flexible fare discounts. Hopefully, improvements in transportation services will not only be beneficial for alleviating transportation burdens on operators but also help improve travel comfort and safety for elderly individuals, which in turn could be beneficial to their overall quality of life.

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초록

서울시 교통카드데이터를 이용한 노인 이동성 평가

본 연구는 AFC 자료를 이용하여 수단선택과 환승패턴에 초점을 맞추어 서울시 노약자의 통행패턴을 분석하였다. 분석결과 지하철 무임 통행의99%는 65세 이상의 노인들에 의해 만들어졌으며, 평균 통행시간은 31분으로 그 중 지하철 통행시간이 버스통행시간보다 더 길었다. 환승횟수가 적은 통행자일수록 지하철을 이용한 통행시간이 더 길었으며, 노약자 운임할인카드를 이용하여 일반인에 비해 적은 요금을 지불하는 것으로 나타났다. 또

한 수단선택 모형의 분석 결과 노인들은 지하철 통행시간보다 버스 통행시간의 통행 만족도가 낮은 것으로 나타났다. 통행 자들에게 환승을 장려하여 환승 비용을 증가시키는 것은 지하철 시스템을 이용하기 힘든 이용자들이나 지하철간의 환승이 불편한 이용자들의 통행의 질을 향상시킬 수 있다. 노인들은 시간이 많은 반면 경제적인 어려움을 가지고 더 많은 통행을 하기 때문에, 통행의 질을 개선하기 위해 첨두, 비첨두에 따라 유연하게 요금 할인을 적용하는 것을 고려할 필요가 있다. 본 논문에서는 한국의 대중교통 이용자 편의 개선을 위한 다양한 정책에 대해 논하고자 한다.

키워드

노인통행, 스마트카드데이터, 서비스평가

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