□論 文□

An Application of Multinomial Logit Model to Jongro Corridor Travellers

鍾路軸 出勤通行에 對한「로-짓」模型의 適用

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要 約

複雜多岐해지는 都市交通問題를 效率的으로 對處하려면 諸都市交通政策에 依한 交通分擔率效果를 事前에 推定할 수 있어야 한다. 短期間의 交通分擔率效果를 推定하는데 美國 및 歐羅巴 等地에서 널리 利用되고 있는 模型이 個別交通模型(Disaggregate Travel Demand Model)이다.

本 硏究의 目的은 로짓模型(Multinomial Logit Model)을 서울시의 鍾路軸을 利用하는 出勤通行者를 對象으로 實施한 調査結果에 適用하여 媒介變數(Parameters)를 推定함에 있다.

調査는 1980年 7月 5日부터 7月 15日까지 10일간 鍾路軸을 이용하는 通行者 536名에게 實施되었다. 調査實施前 서울市의 交通體系의 特性과 通行者의 行態를 綿密히 分析하여 適合한 變數를 選定하였다.

여러가지로 變數와 標本의 變形을 試圖한 結果 交通費用을 所得으로 나눈 變數와 待機時間(OVTT)을 距離로 나눈 變數를 包含한 模型이 가장 論理的인 것으로 나타났다. 한편 標本은 高所得層과 低所得層으로 區分하여 推定한 模型이 比較的 滿足스러운 結果를 나타내었다. 이는 우리나라 大都市의 경우 所得階層에 따라 交通手段選擇範圍가 限定되기 때문이다.

마지막으로 高所得層과 低所得層의 時間價値를 各各 算定하였는바, 이는 交通時間의 媒介變數와 交通費用의 媒介變數를 나눔으로서 求해질 수 있다. 時間價値는 高所得層은 910 원 低所得層은 582원으로 各各 算出되었다.

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I. Introduction

In most developing countries, there have been a number of transportation studies for short and long range urban transportation planning purposes. These transportation studies have largely been conducted by either foreign consultants or local transportation planners. Most of these large scale urban transportation studies produced aggregate travel demand models that treated travel demand as a sequential process of trip generation, trip distribution, modal split, and trip assignment. This wide spread conventional method has been criticized in recent years as lacking the capability to explain the causes of various tripmaking behavior and failing to explain interrelationships among choice sets of decisions that trip makers are confronted with.[1,2]

In an effort to overcome these deficiencies, disaggregate travel demand model has been developed both in U.S. and West Europe over the past ten years. This model has been widely used for empirical analyses in North-American cities and some European countries. Very few, if any, applications have been attempted to the urban areas in developing countries.[3,4]

Disaggregate travel demand model appears to be equally significant to the analysis of travel behavior in urban areas in developing countries. Such a methodology is appropriate, because, in recent years, the range of transportation policy alternatives and the range of transportation policy questions have greatly expanded in these countries. Thus disaggregate travel demand model may provide a useful basis for tackling these policy questions.

This study was oriented toward the building of disaggregate mode choice models for work trips among Jongro corridor in Seoul, Korea. A number of alternative model formulations were attempted, and the results of these formulations were analyzed. In doing so, applicability of this methodology to developing countries was explored. The model formulation that was considered to be the most satisfactory overall is based on segmenting data by income group.

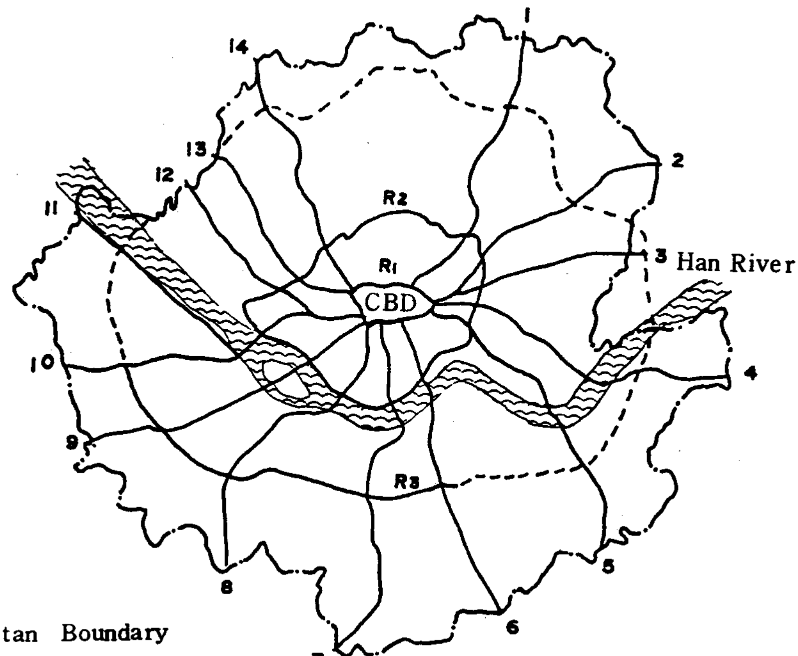
II. Characteristics of the Region's Transport System

Seoul is the capital city of Korea; it is located on both sides of Han River. Central business district (CBD)lies in the northern part of Han River with expansion to the North limited by the Bookak Mountain and to the South by the Namsan Mountain. Seoul metropolitan area has 6,249km of road, mostly all-purpose roadways used for through traffic, local traffic, freight, and public transport. The network is essentially radial, with 13 major corridors converging on the central area.

Since World War II, Seoul has rapidly grown in both size and population. The large population of the city and high rate of growth create a dense and centralized distribution of population. In fact, economic growth, technological progress, and social transformation have combined to significantly alter the structure of the urban environment and transportation patterns. Major new development has been occurring on the south of Han River and a policy of decentralizing both residential and employment opportunities has been followed.

Economic activity is heavily concentrated in the city center. Seoul city center is a strong regional and national center for government, banking, manufacturing, and education. In the metropolitan

Figure 1. Road System in Seoul



—·— Metropolitan Boundary
----- Ring Road Planned to be built
1—14 Radial Roads
R_1-R_3 Ring Roads

region of nearly 8.5 million people, city center is the principal urban area, serving as a regional center for a variety of services. Traditionally the CBD has served as center for five specific classes of activities; office employment (both government and private sectors), retail shopping, professional service, entertainment, and school.

The Central Business District of Seoul covers an area of 9.17km^2 and has a population density of 18,593 persons per km^2. While the central area of the city has a substantial network of wide streets, the conflict between the various road users combined with very high trip generation rate leads to considerable problems in terms of traffic congestion, accidents, and environment. These problems are growing rapidly due to the increase in vehicle ownership and usage. Conflict exists in most of the city center between pedestrians and vehicles, and between vehicles and vehicles.

The main radial routes provide access to the CBD from most areas of Seoul. The zones along these radial roads are the major trip attractors. In addition to the concentration of main commercial areas along these corriders, government offices and buildings are mostly located within CBD. Among these radial roads, Yulgokro, Jongro, Ulgiro, Thegero appear to be major east-west arteries entering into the CBD.

As shown in Table 1, major east-west arterials in CBD suffer from a serious congestion. Volume on these roads far exceeds the capacity except for Yulgokro. Therefore, traffic volumes approaching the core from all direction are exceeding capacity limitations.

Table 1 V/C Ratio on Five Major Arterials

Name of Road	Volume per hour	Capacity	V/C
Yulgokro	2,928 (pcu)	3,600	0.81
Jongro	3,649	3,600	1.01
Chunggero	6,227	6,000	1.04
Ulgiro	4,010	3,600	1.11
Thegero	4,945	3,600	1.37

The existing street network pattern in CBD reflects these major flows of movement. Circling the central business district is a ring road that has continued to function as an important circular road. This ring extends approximately 2.5km . Another ring is the outer ring road, bordering Han River which extends 5km from the center of Seoul. Because most trips are directed toward the city center, the downtown street network has become heavily congested. In addition, the Han River which is crossed by few major arterials create pockets of highly congested entrance to the CBD.

The current traffic situation is typified by dense traffic flows on the major corridors, low driving standards and driver behavior. Vehicles are illegally parked in most congested area in CBD. Car horns sound incessantly through frustration. Air becomes extremely polluted due the the heavy emission level generated by vehicles.

In an effort to improve present traffic congestion, a subway system was planned in Seoul connecting suburban areas to the city center. By 1980, subway line 1 has been in operation and subway line 2 is under construction. Subway lines 3 and 4 are to be completed by 1986. Ultimately, nine lines with a total length of 250km was envisaged to cater for the expected increase in urban population and to relieve severe traffic congestion occurring throughout the day. The subway system will then absorb most of existing bus riders. By 2001, Seoul will eventually be linked to most satellite cities by 9 subway lines. Hence subway will play the key role in urban transportation in Seoul and will be of paramount importance for work trips in Seoul.

Characteristics of Travel

The total number of trips made in Seoul is about 11 million per day. The significant portion of trips have their destination in CBD, north of Han River. The average person trips in Seoul in 1977 is 1.4 trip per person per day with 73% by public transit, 19% by taxi, 4% by auto and 4% by other modes.

The morning peak hours generally occur in the period between 6:30 A.M. and 9:30 A.M., representing 37.8% of total trips. The off-peak trips also appear to be significant which occur between noon and 5:00 P.M. This off-peak trips occupy 24.4% of total trips. Remaining trip which represents 21.7% of total trip is made in the evening peak hours between 5:00 P.M. and 8:00 P.M.[5]

Table 2 shows that role of bus in terms of modal share has reduced from 88.7 percent in 1970 to 67.7 percent in 1977. Taxi's share has rapidly increased during the same period. In 1977, taxi represents 18.9 percent of total modal shares. The information on walk trip is not available.

Table 2 Modal Shares in Seoul

Year / Modes (%)	1970	1973	1977
Bus	88.7	85.5	67.7
Taxi	3.3	4.6	18.9
Private car	3.2	4.2	4.0
Gov't or company Provided car	—	3.4	3.7
Subway	—	—	4.8
Other	4.8	2.3	1.9
Total (%)	100	100	100

Note: Walk-trip is not induded (no·data is available for walk-trip).

The growth in numbers of private cars and taxis in Seoul has been rapid in recent years. During the 1960's and early 1970's there was a relatively slow increase in the number of private cars and taxis registered in Seoul. Since 1975, there has been a growth of 27 percent per year. The number of private cars and taxis have increased from 47,881 in 1975 to 122,748 in 1979.

The private car ownership is 10.5 cars per 1,000 persons. However, with a forecast of annual increase in GRP of 8% and a situation where the demand for cars exceeds supply, it is expected that the

Characteristics of Modes and Income Groups

In Seoul, three transit modes are prevalent. They are bus, subway and microbus. As shown in Table 2, these modes typically provide for approximately 73 percent of all urban trips. Bus is used to a greater extent for all transportation through out metropolitan Seoul area than any other mode. Bus is a major means of mass transit in Korea. It's role is principally to provide services to the middle and low income residents. These groups represent a large captive market. Those in the middle-income and low-income brackets form a significant part of the bus riders. While the use of the bus by high income group is not as frequent among them as it is among the middle-income groups, the mode is still the one often used. In fact, the largest part of income groups ride the bus to work. In spite of high coverage and an average headway of around 4-6 minutes, the quality of service is very poor in terms of comfort, speed, and waiting time.

The subway has been limited to serving one major corridor and is largely an intra-city operation. In the region as a whole, the subway system plays an extremly small role as a commuting mode except for Jongro corridor. Income level of those who use subway for work trips appears to be similar to that of bus riders. The role of subway, as discussed earlier, will greatly be expanded in the future.

Microbus serves primarily intra-lines, with some extended services between CBD and the outlying areas. As compared to bus, microbus is less crowded and more direct to the final destination. The income level of riders using microbus appears much higher than those using bus and subway. The reason for this high income among microbus riders lies in the high level of fare structure, which is currently three times as high as the fare structure of bus and subway. Level of service of this mode is much better than the bus and subway in terms of comfort, and time delay.

Taxi is widely used for the shared ride mostly during the peak hours. Occupancy rate was estimated to be 2.5 to 3 persons during the peak hours. Taxis in particular are utilized to reach destinations not easily accessible by other forms of public transportation. The metered taxis in Seoul are providing two distinct kinds of service: exclusive service for which one or more passengers are carried directly from their origin to their destination without intermediate passenger pick-ups and drop-offs; and shared service for which driver picks up three or four passengers on the route. This service is particularly attractive to many who do not own the car and income level is relatively high (from upper middle to high income).

III. Calibration of Multinomial Logit Model

Disaggregate choice modal used in this analysis is a multinomial logit model. Its theoretical development and implications have been discussed extensively elsewhere in the literature.[7] The disaggregate choice travel demand models of multinomial logit mathematical form base their ability to predict the probability of a certain transportation-related choice on the theory of rational consumer choice behavior. This theory asserted that a decision-maker, such as a tripmaker, will rank all possible alternatives available to him from a set of alternatives, such as a set of mode choice alternatives.

Multinomial logit model is generally expressed as follows:

$$P(i|A_t) = \frac{e^{V_{it}}}{\sum_{j \in A} e^{V_{jt}}} \qquad \text{.......... (1)}$$

where $P(i|A_t)$: the probability of person t selecting alternative i from a set of alternative A_t

V_{it} : the systematic utility of alternative i to person t

$$V_{it} = \sum_{k=1}^{K} X_{kit}\theta_t \qquad \text{.......... (2)}$$

where X_{kit} : the k^{th} independent variable for alternative i and person t

θ_k : the coefficient of the k^{th} variable

k : number of coefficients

The coefficients are estimated by the maximum likelihood method:

$$L = \prod_{t=1}^{T} \prod_{i\,A_t} P(i|A_t)^{g_{it}} \qquad (3)$$

where T : number of observations

g_{it}: 1 if alternative i was chosen by person t, 0 otherwise

Taking the logarithm of both sides give us the log likelihood function:

$$\log L = L^* = \sum_{t=1}^{T} \sum_{i \in A_t} g_{it} \log P(i \mid A_t) \qquad (4)$$

By substituting equation (2) to (1) for V_{it}, and then to (4) for $P(i|A_t)$, we can find θ's (estimated coefficients) which maximize log L by solving:

$$\frac{\delta L^*}{\delta \theta_k} = 0 \quad \text{for } k = 1, 2, ..., K \qquad (5)$$

In ordinary regression analysis, the multiple correlation coefficient (R^2) measures the "goodness of fit" of a model to data. An analogous measure for models fitted by the maximum likelihood method is the likelihood ratio index, which varies between zero and one, with higher values reflecting better fits.

The likelihood ratio index is defined by the formula:

$$\rho = 1 - \frac{L^*(\theta)}{L^*(O)} \qquad (6)$$

where $L^*(O)$: the value of the log probability function when all of the parameters are zero (i.e. when every alternative has the same probability)

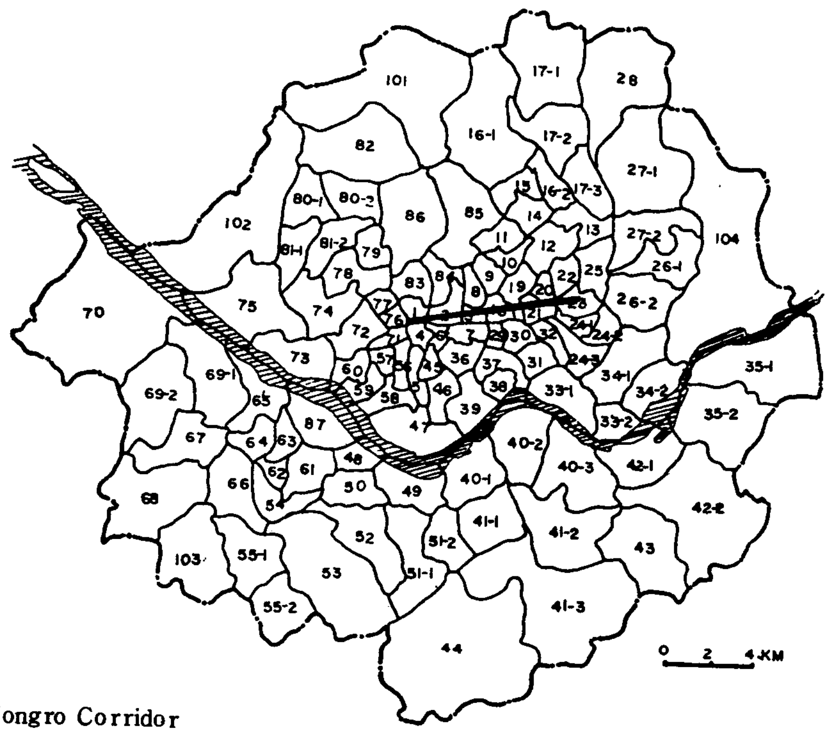
$L^*(\theta)$: the value of the log probability function at the maximum probability coefficient values

Data on Jongro Corridor

This analysis was based on data obtained in summer, 1980 from 536 people in Jongro-Chungrangri corridor which contains subway line in particular. The sample was designed to consist of workers who lived and worked in this corridor well served by bus and subway transit. Operationally, this meant people who lived in areas that were accessible to bus and subway service and who worked in either CBD or other areas in this corridor. Recognizing complex set of modes and operating with a limited amount of data, an attempt was made to only analyze work-trip.

As shown in Figure 2, Jongro corridor is located in the east side of central business district in metropolitan Seoul, running from Chongrangri, one of the major subcenters, for a distance of approximately 8 kilometers to the core of CBD. The corridor passes through some of the most densely developed commercial and residential areas of metropolitan Seoul. Most of the roadway configuration

Figure 2. Traffic zones in Seoul



Jongro Corridor

consists of a six-lane facility over the Jongro (1, 2, 3, 4, 5, Ka) 4 kilometers and a three-lane facility over the remainder of its length. Chungrangri is the last point at which inbound vehicles enter this corridor. This is also a focal point where outbound vehicles can be separated into collector roads connecting to suburban areas.

The areas surrounding this corridor was divided into zonal system. The specific classification system used was based on the KIST (Korean Institute and Science and Technology) traffic zone system.[6] Along the Jongro corridor from center to east, zones 1, 2, and 3 represent innermost area encompassing the part of central business district of the Seoul zone 18, 19, 20, 21, and 22 show the immediate areas in which most of dissaggregate data was collected. The outermost area represented by zones 25, 26, 27 covers suburban areas of metropolitan Seoul.

The data used to calibrate multinomial logit model was obtained from two sources. The first is a ten-day questionaire survey of travellers living along the Jongro corridor performed by author and several research assistants in August, 1980. 536 questionaires were collected from five zones in which Jongro corridor passes through. This survey provides information on travellers, level-of service components, origin-destination, and socioeconomic characteristics of travellers. The second data source was a 1978 survey conducted by the Korean Institute of Science and Technology which provides aggregate information on travellers using this particular corridor.

Ten-day survey was mostly used for calibrating multinomial logit model. Each observation had to be checked for consistency and completeness of data. Some of this screening was done on the entire data set. Out of the original 536 work trip observations, 116 were deleted tor the following reasons:

(1) 16 observations with an invalid mode were deleted
(2) 52 observations were incomplete
(3) 48 observations contained insufficient level-of-service data

This left 420 work trip observations for model estimation.

The Definition of Independent Variables

The independent variables can be divided into two broad categories: transportation system variables and socioeconomic variables. Selection of the variables to be considered for inclusion in the model was constrained by the availability of adequate data for these variables. Recognizing the complex and hetrogeneous nature of travellers and operating with a limited amount of data, it was not possible to incorporate such socioeconomic variables as the age, sex, breadwinner, education of travellers.

Essentially the transportation system variables considered for automobile travel were vehicle travel time, operating and parking cost. A similar break down was made for transit service: walking time (at both ends), waiting time, and transit fare. Socioeconomic variable considered included traveler's monthly income.

In 1980, the Jongro corridor provided a low level of service to the travellers using this corridor. The average travel speed for home-to-work travel during the peak-hours ranges from 15km to 25km. Three measures were utilized to characterize the service provided by the this corridor: in-vehicle-time, distance, and out-of-vehicle-time. Minimum travel distance were developed between every pair of zones, and the in-vehicle-time and out-of-vehicle-ti'mes were derived therefrom.

The inclusion of the time and monetary costs of travel is readily apparent and should require no explanation. However, of interest are the specifications of two of the level of service variables: travel cost divided by income and out-of vehicle travel time by distance.

Travel cost – for the private car mode, travel cost consisted of auto operating cost plus driver's wage and parking cost. Auto operating cost was based on a variable cost model relating the cost per kilometer to the average speed for the trip where average speed was calculated as trip distance divided by travel time. Driver's wage includes salary for the hired driver. With a few exception, most of the automobile owners observed have hired drivers who usually work as a primary worker in the household. Driver's wage was obtained from the survey data which provides for basis of determining operating cost per trip. Travel cost for taxi mode can be obtained by dividing taxi fare divided by the average size of passengers. Average 2.5 passengers was assumed to reflect the distribution of travel expeness among the shared passengers.

In-vehicle-travel-time (IVTT) – for the auto, taxi, this was given in the data set as corridor travel time between origin and destination. Ten minutes "penalty" was added to account for time required for waiting for taxi mode. For bus, subway and microbus, in-vehicle-time was the line haul time between origins and destinations. The time perceived by the user within the vehicle, will influence one's choice. The shorter this time, the higher will be the probability that he will choose that mode.

Out-of-vehicle-travel-time (OVTT) – out-of-vehicle-times for both car and taxi were given as average terminal time for each origin and destination. For transit, out-of-vehicle-time consisted of both wait time and walking time. Automobile terminal time represents (1) the walking time between parking location and the origin destination of trip, (2) the time required within the parking facilities. With a few exception, most of auto owners hire their own drivers and they are driven to the enterance of their work place. The time involved in terminal rarely exists and is not significant. Terminal time associated with taxi, however, appears to be important factors in terms of its proportion in overall out-of-vehicle time. Terminal times ranged from 5 to 10 minutes.

Income – This represents the monthly income of each traveller. Household income was not available in the data set.

Transit system characteristics – For bus and microbus, headways of 5 minutes or less generally occured on this corridor. Subway generally exhibits higher headway. Reported subway headway was approximately 7 minutes. The transit service characterized by two categories of travel time. – in-vehicle-time, waiting time, and access/egress time – and by the transit fare. Estimation of transit travel times were derived from origin-destination analyses.

The Fare Structures

Bus and microbus have operated on a single flat fare. When passenger boards a bus or microbus, the single fare permits a ride to any point along that bus route or to any station. Subway employed fare structure based on distance. No distinction in fare is made based on time of day, frequency of usage, and direction of service. Policies with regard to the fare have evolved along two major points: (1) to maintain a very low transit fare: (2) to maintain a single flat fare for travel between any two places within the city. Fare structures for bus and subway on Jongro corridor appears to be same while highest fare is charged on microbus riders. Average taxi fare was estimated by dividing total fare by average occupancy rate during the peak-hours.

Although a segment of population may perceive the existing fares for bus, subway, and microbus as a significant cost, the large proportion of transit trips are made by people for whom the fare is nominal. This is indicated by the large differential in cost between riding transit and owning an automobile, the next sustitute. Given this situation, a large population must currently exist which can afford more than the cost of bus transit,but which cannot afford the car. For these people, the costs of riding transit are probably dominated by the time involved in making the trips (waiting, transfer and travel time) and by the discomfort of the crowding on buses.

Calibration of Work Trip Mode Choice Model

Initial calibration efforts encountered several problems, despite many model structures for which calibrations were attempted. Most of these problems concerned with the sign, magnitude and significance of coefficient.

The first formulation, as shown in Table 3, reveals many interesting aspects about possible trends of mode choice behavior in the Jongro corridor, and at the same time some of the results are clearly nonsensical or insignificant, requiring that the model be formulated with the variables respecified. Parameter estimates presented in Table 2 are valid only for those travelers in the sample population who actually have a particular choice.

The first problem is that some of its coefficient estimators failed to converge after the maximum number of 8 iterations were performed. In-vehicle-travel-time had a positive sign. This is the opposite result often reached in other studies, since increase in travel time adversely affect the utility of any mode alternative. Out-of-vehicle-time had disturbingly small coefficients, indicating a lack of significance.

Table 3. Estimated Coefficients for Pooled Data

Independent Variables	Estimated Coefficient	T-statistics
Cost	−0.008	−1.478
IVTT	0.002	.782
OVTT	−0.005	−0.593
Constants 1	0.764	2.188
3	2.340	3.012
4	1.899	1.201
5	−0.550	−2.568
6	−0.774	−0.702
$L^*(0)$	566.754	
$L^*(\theta)$	379.540	
ρ^2	0.33	

Note: Alternatives: (1) Bus, (2) Subway, (3) Microbus, (4) Taxi, (5) Auto, (6) Walk. Number of people in sample who choose:

Bus	198
Subway	83
Microbus	38
Taxi	78
Auto	17
Walk	6
	420

For second formulation, market segmentation was employed for high and low income travelers to determine whether incomerelated hetrogeneity causes significant biases in parameter estimates.

Market segmentation by income group seems logical in that mode choice behavior of travelers in Seoul depends greatly on income group. Low income travellers appear to make different mode choices than high income travelers.

The strategy to divide by relevent income group was based on close examination of income groups with respect to their mode choice behaviors. It appears that income level of 22,500 ₩ was appropriate bordor line by which division can be made. 55 percent of the population are in the high income category. The income group below this level tends to have choice set such as walk, bus, subway, and microbus. The poorest travelers are generally limited to travelling by bus or walking as other modes are either too costly or unavailable. The income group above this level has a choice set such as subway, taxi, auto, and microbus.

Second model formulation, shown in table 4, contained 3 variables for both high and low income groups; they converged after 8 iterations. The coefficients for three variables had the expected negative sign, indicating that increases in travel time or costs adversely affect the utility of any mode alternative. The magnitude of these coefficients appears to be very small and the smallness of their corresponding "t" statistics shows that market-segmented models seems to have statistically improved compared to non-segmented model.

While coefficients were too small to make any judgement on travel behavior, high income travelers are more sensitive to the travel cost than low income travelers. This results seems somewhat counter intuitive since affluent group in developing countries tends to be less concerned about travel cost. Coefficients for IVTT and OVTT appears intuitively sensible as high income travelers would place a higher value on travel time.

Table 4. Estimated Coefficients for Low and High Income Split

Independent Variables		Coefficients for High Income	T-Stat.	Coefficient for Low Income	T-Stat.
Cost		−0.013	−1.253	−0.008	−2.936
IVTT		−0.003	−2.009	−0.002	−0.048
OVTT		−0.009	−0.378	−0.005	−1.252
Constants	1	0.826	0.208	0.926	1.211
	3	4.326	2.277	3.372	5.631
	4	2.963	0.428	*	*
	5	−1.236	−2.012	*	*
	6	*	*	−0.262	−1.083
$L^*(0)$		287.624		276.474	
$L^*(\theta)$		219.248		156.409	
ρ^2		0.238		0.434	

Number of people in sample who choose:

High Income	
Bus	86
Subway	53
Microbus	38
Taxi	43
Auto	12
	232

Low Income	
Bus	78
Subway	67
Microbus	36
Walk	7
	188

In third formulation, shown in Table 5, strategy to construct a satisfactory model focused on respecifying these variables to more realistically reflect the behavior of travelers. Transformations of cost and OVTT were attempted. As a first improvement to the model, travel cost variable was re-specified in order to better explain variations in tripmakers' perception of out-of-pocket costs due to their level of economic well-being. This variable was refined as "travel cost/monthly income" of traveller. The second transformation consisted of dividing out-of-vehicle-travel time by one-way distance (in kilometes). These transformations resulted in large coefficients and strong statistical significance. All coefficients were significantly different from zero at the 90% confidence interval. Looking at the likelihood ratio index, some improvement was made over first model with pooled data.

Table 6 shows the results of the market segmentation estimates with respecified cost and time variable. The three variables specified in the thirteenth model formulation consititute the best model developed in this analysis. The model coverged with all of the coefficient estimators being of reasonable magnitude and having the correct arithmetic sign. Comparison of the models in Tables 4 and 6 reveals that the transformations of travel cost and travel time change substantially the coefficient of cost and time.

Table 5. Estimated Coefficients for Pooled Data

Independent Variables		Estimated Coefficient	T-Statistics
Cost/Income		−0.042	−4.021
IVTT		−0.026	−3.726
OVTT/Distance		−0.057	−3.867
Constants	1	0.626	2.823
	3	18.368	9.476
	4	4.632	4.563
	5	.3738	1.302
	6	−2.863	−4.425
L* (0)		582.462	
L* (θ)		367.063	
ρ^2		0.37	

Note: Alternatives and sample size for each alternative are same as Table 2.

Table 6. Estimated Coefficients for Low and High Income Split

Independent Variables		Coefficients for High Income	T-Stat.	Coefficients for Low Income	T-Stat.
Cost/Income		−0.101	−4.625	−0.063	−5.326
IVTT		−0.044	−3.282	−0.036	−6.723
OVTT/Distance		−0.098	−2.256	−0.077	−4.023
Constants	1	4.65	8.280	2.859	3.893
	3	5.30	6.291	2.012	1.945
	4	5.66	6.632	*	*
	5	−2.52	−2.397	*	*
	6	*	*	−4.624	−1.682
L* (0)		315.263		265.469	
L* (θ)		199.276		149.506	
ρ^2		.37		.51	

Note: Alternatives are same as Table 2.

Number of people in sample who choose:

High Income	
Bus	86
Subway	53
Microbus	38
Taxi	43
Auto	12
	232

Low Income	
Bus	78
Subway	67
Microbus	36
Walk	7
	188

Likelihood ratio index show that market-segmented model with respecified variables is significantly different from the market-segmented model in Table 3. The high "t" statistics for the parameters that exceed the 99% confidence level indicate that they are truely the most significant ones for reflecting the mode choice of Jongro corridor tripmakers.

Looking at the IVTT and OVTT/Distance, high income workers appear to be slightly more sensitive to both IVTT and OVTT/Distance. This is consistent with the results often derived in urban areas in developed countries. Market segmentation shows OVTT to be considered more onerous for high income workers than for low income workers.

Low income workers appear to be "choice-captive" group who does not have a mode-choice alternatives. These workers are limited to travelling by bus or subway or walk due to economic constraints. High income workers have a extensive mode choices such as microbus, subway, taxi and bus as well. Automobile is only available for the workers with the highest income.

The cost coefficient of low income (−0.063) turned out to be considerbly smaller than that of high income (−0.101). This result is in some way different from a priori expectation – low income travelers are more cost-conscious than high income travelers. The following logic can be advanced for this reasoning. It is generally argued in developed countries that the character of transportation is an inferior good – one which people spend proportionately less as their income rises. Many commodities which are necessities at high income levels are normal goods or even luxuries for low income people. If such a pattern holds for transportation, then it is reasonable to hypothesize that low income travelers in developing countries tend to be more concerned about the travel cost than high income travelers.

IV. Value of Travel Time

In the multinomial logit model,the coefficients of time divided by the coefficient of cost normalized by wage can be interpreted as a measure of the value of time spent travelling, relative to the value of labor time.[8] Underlying assumption is that the trip maker is indifferent between the additional time savings gained and extra monetary cost incurred, and vice versa.

The value of time can be expressed as follows:

$$V = \alpha_1 \text{ (Cost/Income)} - \alpha_2 \text{ (Time)} \quad \cdots\cdots (7)$$

From equation (7), the following relationship can be established.

$$\frac{\partial V/\partial t}{\partial V/\partial C} = \frac{\alpha_1}{\alpha_2} \times \text{Income} \quad \cdots\cdots (8)$$

These value of time estimates are not specific to any mode due to the generic nature of the level of service variables. The estimates of value of time for the market segmentation, expressed in Won per hour, are shown below:

Table 7. Value of Time Estimated by Coefficients

Time \ Income	High Income			Low Income		
	Hourly Value (₩)	Wage/hr.	% of wage	Hourly Value (₩)	Wage/hr.	% of Wage
IVTT	910	2431	.37	582	1042	.56
OVTT	2352	2431	.98	1248	1042	1.20

Note: For calculation Procedure, see Appendix.

In examining the value of time estimates above, it can be seen that the value of IVTT is 37 percent of wage for high income traveler and 56 percent of wage for low income traveler. These estimation results are similar to the results drived for major American cities. The value of OVTT exceeds the value of IVTT by from 2 to 3 times. The results turned out to be same as a priori expectation-workers tend to value OVTT more highly than IVTT.

Low-income travelers value time more highly than high income travelers. This result is quite apposite to the similar studies in major cities in U.S. The trips made by low income workers seems to be highly valued. Keeping in mind that the home-based trip is usually considered the most essential means to make a living, these results do not seem to be too unreasonable.

As discussed earlier, the value of time estimated from multinomial logit model does not reflect the true value of time, the results of estimates, therefore, should be interpreted with caution.

V. Conclusion

This paper documents the estimation results of the disaggregate travel choice model to be used in calibrating of parameters for Jongro corridor work trip behavior in Seoul. The results of estimations reveal a good deal about the structure of mode-choice behavior among Jongro corridor workers. Specifications were made to improve the effects of level of service variables on mode choice. All the model coefficients are of the expected sign and appear to be reasonable. Variables investigated turn out to be important influences on travel mode choice.

While empirical estimations performed here was based on travelers in one corridor in Seoul, this analysis may provide a framework for testing the applicability of disaggregate travel model to the entire Seoul Metropolitan area. This implementation of the multinomial logit model has shown that modal choice model can possibly be applied to the context of developing countries.

The results of estimation suggest that further extensions of this effort are warrented. Research should be extended to include a more extensive set of explanatory variables, different trip purpose categories, a complete set of travel choices, extensive data sets, and aggregation.

In analyzing the results, one should certainly be cautioned by the imperfections of the analysis. As explained earlier, empirical research reported here is restrictive in a number of potentially important respects. The data on which model estimation was based, while in general adequate for the analysis, was deficient in some respects.

Overall, the results point out the validity of using the multinomial logit model as a planning tool for evaluating a number of transportation policies in developing countries.

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APPENDIX

Median monthly income in the sample:

High Income = 350,000 ₩
Low Income = 150,000 ₩

$$\frac{\text{Montly Income}}{36 \text{ hrs/week} \times 4 \text{ weeks/month}} = \frac{350{,}000}{144} = 2431/\text{hr.}$$

$$2431/\text{hr.} \times \frac{1}{60} = 40/\text{min.}$$

We use 40₩/min to be matched with time unit in multinomial logit model. To derive the value of IVTT for high income traveler, equation (8) can be used as follows:

$$\frac{0.044}{0.101/40} = 17.6/\text{min.}$$