Exploring Relationships between Information and Communications Technology (ICT) Use and Travel

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Abstract: The purpose of this study is to explore relationships between actual amount of information and communications technology (ICT) use and travel by developing trip generation models. The data for this study come from an ICT use and activity diary survey of 269 households of Seoul Metropolitan Area in 2006. We first conducted pair-wise correlation tests between ICT (Internet, mobile phone, and land-line phone) use and travel (number of trips). The test results show that ICT use and travel are positively correlated. We also developed regression models of number of trips considering socio-demographic variables as well as ICT use variables. It turned out that ICT use variables have statistically significant positive effects on travel. Furthermore, assuming that interrelations between ICT and travel exist, structural equation models were developed taking them as endogenous variables. The model results strongly suggest that ICT use positively affects travel (indicating complementary effects).

Key Words: *ICT, travel behavior, structural equation modeling, telecommunications*

1. INTRODUCTION

Today we are living in the information age of the 21st century and the unlimited sharing of information through Internet is bringing about enormous change over the society, economy and culture beyond the restrictions of time, space and distance. In addition, based on the rapid propagation of high-speed communications networks, called information superhighway, there were 33 million Internet users and 38 million users of mobile telecommunications as of the end of 2005 so that more than 70% of the total population of Korea is using information and communications technologies (ICTs). In case of the U.S. 204 million persons accessed Internet and 208 million persons used mobile phone as of the end of 2005. It means that more than 69% of the total population of the U.S. is using ICTs.

Such development of ICTs and increase in ICT use are creating new travel behavior. For example, without commuting to work or going to department stores, we can take care of our job at home or shopping on-line. Also, in case of a company, a meeting can be held through visual teleconference between head and local offices without physically meeting at a place. These kinds of activities using various ICTs can substitute existing commuting or shopping trips. On the other hand, a new trip may be generated through allocation of time saved by ICTs to personal leisure or recreational activities. Numerous studies (e.g., Mokhtarian, 1990; Salomon, 1985) have already identified the conceptual relationships between telecommunications and travel: substitution, complementarity, modification, and neutrality. Therefore, there is increasing necessity to develop new types of trip generation models that consider ICT use. This study explores the relationships between actual amount of ICT use and travel by developing trip generation models such as regression and structural equation models that take into account of ICT use variables.

In the next section we discuss key literature related to ICT and travel at the disaggregate level. Section 3 describes the characteristics of the data including ICT use and travel. Section 4 discusses types of trip generation models considering ICT variables and Section 5 presents model results. Finally, conclusions are discussed.

2. LITERATURE REVIEW

Most disaggregate empirical studies of relationships between telecommunications and travel have focused on specific telecommunications applications: for example, telecommuting, teleconferencing, and teleshopping.

Only a few studies among them are related to travel and telecommunications models. Mokhtarian and Meenakshisundaram (1999) explored the relationships among three types of communication (electronic communications, information objects transferred, and personal meeting) and travel (number of trips). They estimated a structural equation model with lagged endogenous variables and exogenous variables (such as elapsed time, seasonal dummies, and socioeconomic variables), using 1994-95 panel data (with two waves occurring about six months apart) from 91 respondents in the city of Davis, California. The study found that there were cross-mode complementary effects among communications modes and self-generation effects of each mode over time, whereas there were no significant relationships between electronic communications and personal meetings, or between electronic communications and trips.

Senbil and Kitamura (2003) examined the relationships between telecommunication devices (home and mobile phones) and activities (work, discretionary, and maintenance activities) using the survey data of 766 individuals in the Osaka metropolitan area, Japan. They estimated structural equation models for activities, considering numbers of home and mobile phone calls as exogenous variables. The authors found that there are different types of telecommunications effects on activity engagement: substitution for work activities, complementarity for discretionary activities, and neutrality for maintenance activities.

Srinivasan and Athuru (2004) identified that the relationships between ICT use and virtual activity (e.g. online banking and browsing) participation (using Internet) in maintenance and discretionary activities using the activity-diary survey data of 4,214 respondents from San Francisco Bay Area. They developed econometric models, the logit model for Internet use or not, the regression model for total trip duration, and the Poisson regression model for the frequency of travel activities. It was found that Internet use substitutes travel duration, while generates out-of-home maintenance activities and travel frequency,

Recently, Wang and Law (2007) explored the impacts of ICT usage (the experience of using e-mail, Internet service, video conferencing, and videophone) on time use and travel behavior. They also estimated a structural equation model using the 2002 travel characteristic survey data of 4,935 respondents in Hong Kong. The authors identified that the use of ICT generates recreation activities, total number of trips, and travel time. This result shows the complementary relationships between ICT usage and travel.

The empirical studies on the relationships between ICT use and travel have identified either a substitution or a complementary relationship. In fact, few studies have offered strong evidence for a complementary relationship, although this complementarity has been conceptually argued in the literature. In addition, most of the studies focused on ICT use or not, rather than physical amount of ICT use. This study will explore the relationships between actual amounts of ICT use and travel in the context of trip generation.

3. CHARACTERISTICS OF ICT USE AND TRAVEL

3.1 Data

The data for this study come from an ICT use and activity diary survey in Seoul[1] Metropolitan Area (SMA). The survey was designed to find out individual differences in the use of ICTs, and the subsequent influence on travel behaviors of individuals. Contents of the survey are composed of four aspects – household information, household member information, ICT use information, and activity information – and the details of them are as follow. The questionnaire can be reviewed in Choo, et al. (2006).

Total of 360 questionnaires were distributed in the region of Seoul and Gyeonggi-Do (surrounding province). Among them 310 questionnaires were collected and 296 questionnaires were found to be effective (response rate: 85%). The questionnaires were distributed a week before and it was asked that the questionnaire was to be filled out for the daily activities and trips (from the wake-up in the morning to the sleep at night) either on October 30 (Tuesday) or November 1 (Wednesday), 2006.

Table 1 shows selected demographics of the sample. For the gender distribution, the respondents were composed of 48.6% of females and 51.4% of males, showing similar ratios. Looking at the distribution of ages, the category of people in their 20s (29.0%) has the highest percentage. High percentages of the respondents were students (30.2%), homemakers (17.7%), and clerical/administrative assistants (16.0%). Approximately 60% of the sample has at least some college experience, while 37% have completed a 4-year college.

Major means of transportation of the respondents was composed of 60.2% of public transportation and 29.1% of private vehicles, showing high ratio of dependency on mass transportation, due to the well-connected public transportation network of SMA.

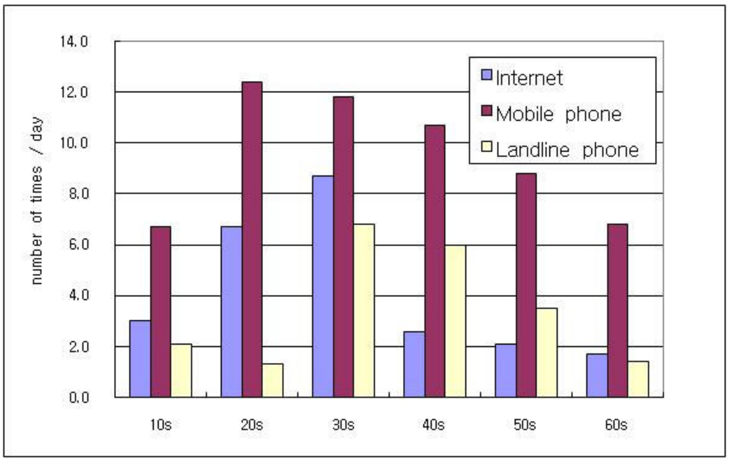
[1] Seoul is the capital city of Korea

Table 1 Demographics of the respondents

Characteristic		Frequency	Percent (%)
Gender	Female	414	48.6
	Male	438	51.4
	Total	852	100.0
Age	10s (13 ~ 19)	85	9.9
	20s (20 ~ 29)	249	29.0
	30s (30 ~ 39)	92	10.7
	40s (40 ~ 49)	185	21.5
	50s (50 ~ 59)	231	26.9
	60 or older	18	2.1
	Total	860	100.0
Occupation	Self-employed(small business)	95	11.3
	Sales	31	3.7
	Production/construction	31	3.7
	Clerical/administrative assistance	135	16.0
	Administrator/manager	47	5.6
	Professional	34	4.0
	Homemaker	149	17.7
	Student	255	30.2
	Others	66	7.8
	Total	843	100.0
Education	Some high school	119	14.2
	High school diploma	233	27.8
	Some college	177	21.1
	4-year college degree	263	31.3
	Some graduate school	15	1.8
	Completed graduate degree(s)	32	3.8
	Total	839	100.0
Major transportation means	Private vehicle	239	29.1
	Public transportation	495	60.2
	Others	88	10.7
	Total	822	100.0

3.2 Characteristics of ICT Use

Taking a look at the respondents' use of Internet, mobile phone and landline phone, they used Internet 4.3 times and 69.8 minutes a day on the average. As shown in Figure 1, people in their 30s used Internet most frequently – 8.7 times a day – and people in their 10s and 20s used 3.0 times and 6.7 times a day, respectively. In the aspect of time of Internet use, people in their 20s used Internet 109.8 minutes a day, while people in their 10s and 30s used 71.6 minutes and 93.8 minutes, respectively. Summarizing these results, people in their 30s accessed Internet most frequently, while people in their 20s accessed Internet for the longest hours a day. Also, it was found that more than 60 years old senior citizens used Internet at least once a day.



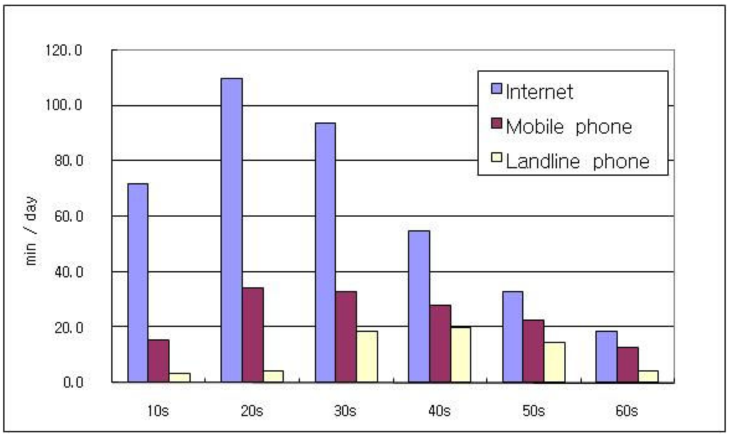


Figure 1 ICT use by age group

The average frequency of mobile phone use was 10.3 times and the average length of time of use was 27.1 minutes a day. Looking at the frequency of mobile phone use, people in their 20s used most frequently – 12.4 times a day – and people in their 30s and 40s used 11.8 times and 10.7 times a day, respectively. Also, looking at the average length of time of mobile phone use, people in their 20s used the longest length of time – 34.1 minutes a day – and people in their 30s and 40s used 32.8 minutes and 27.8 minutes, respectively. It can be found that people in their 20s used mobile phone most actively than people of any other ages.

The average frequency of landline phone use was 3.6 times and the average length of time of landline phone use was 11.6 minutes a day, showing that dependency on the landline phones was less than mobile phones. It is probably due to the fact that most people prefer mobile phone to landline phone since it can be used regardless of place and time. Looking at the average frequency of landline phone use, people in their 30s used 6.8 times a day, while people in their 40s and 50s used 6.0 times and 3.5 times a day, respectively. The average length of time of landline phone use by people in their 40s was 19.7 minutes a day, while people in their 30s and 50s used 18.3 minutes and 14.5 minutes, respectively. These results show that elder people are more dependent on landline phone, while younger people prefer mobile phone.

The respondents were also asked about major purposes of ICT use by device type. Internet was used for information searching like news (36.4%); game/leisure/amusement (17.2%); chatting and exchange of information (6.8%); and purchase (4.9%). Also, mobile phone was used mainly for the purpose of friendly communication and appointment (47.3%) and chatting and exchange of information (20.4%). Landline phone was also used for the purpose of friendly communication and appointment (26.1%) and chatting and exchange of information (14.4%).

3.3 Characteristics of Travel

For travel characteristics of the respondents, the average number of trips was 3.33 trips a day. In the aspect of age distribution, people in their 20s showed the highest number of trips (3.78 trips/day), and the average number of trips of people in their 60 or older was 3.45 trips. Looking at Table 2 for the average number of trips of the respondents by mode, people in their 30s through 50s mainly used personal vehicles while the others used public transportation. Other means (including walking) appeared the highest for people in their 10s who are mostly students.

Table 2 Average number of trips by age group

Unit: trips/day

Age group	Personal vehicle	Public transportation	Other (including walking)
10s	0.28	1.02	1.59
20s	0.34	2.70	0.75
30s	0.96	1.33	1.21
40s	1.35	0.99	0.91
50s	1.16	0.98	0.84
60s or older	0.75	2.08	0.73
Total	0.85	1.56	0.93

3.4 Relationships between ICT Use and Travel

In order to find out the relationships between ICT use and travel, Pearson correlation tests between the total number of trips and the actual amount (frequency and length of time) of Internet, mobile phone, or landline phone use were conducted. Table 3 shows the test results. Three pairs are significantly positively correlated with each other at $\alpha = 0.1$, even though their absolute values are small : the total number of trips and number of mobile phone calls, length of time of Internet use, or length of time of mobile phone use. This implies that as ICT use increases, the number of trips increases, or vice versa.

The respondents were categorized into two groups – the group who usually use personal vehicles and the other group who use public transportation – to analyze the correlation between travel and ICT use. By using the independent t-test, it was analyzed whether there was difference of the amount of ICT use between the two groups. As shown in Table 4, personal vehicle (PV) users used mobile phone and landline phone 2-3 calls more per day than the public transportation (PT) users. On the other hand, there was no statistically significant difference in the frequency of Internet use between the two groups. For the length of time of ICT use, PV users tend to use landline phone 4 minutes longer than PT users. There was no difference in the average length of time of Internet and mobile phone use between the two groups.

Based on the above results, it can be inferred that there are significant relationships between ICT use and travel. Therefore, ICT-related variables should be taken into account in trip generation models.

Table 3 Correlations between number of trips and ICT use

ICT use		Total number of trips
Frequency of ICT use	Internet	0.017
	Mobile phone	0.121**
	Landline phone	0.046
Length of time of ICT use	Internet	0.093*
	Mobile phone	0.102**
	Landline phone	0.010

Note: * correlation with 0.01 < p-value ≤ 0.05, ** correlation with p-value ≤ 0.01.

Table 4 Average ICT use by group of major transportation mode

ICT use		Personal vehicle user	Public transportation user
Frequency of ICT use (times /day)	Internet (number of access times)	4.03	4.57
	Mobile phone (number of calls)*	12.25	9.95
	Landline phone (number of calls)*	5.91	2.65
Length of time of ICT use (min /day)	Internet	63.91	73.36
	Mobile phone	29.04	27.29
	Landline phone *	14.95	10.58

Note: * means that the mean values of the two groups are statistically different at $\alpha = 0.05$.

4. METHODOLOGY

We develop trip generation models considering ICT use variables, together with socio-demographic variables, to explore relationships between ICT use and travel. Generally, trip generation models can be classified into single equation and simultaneous equation and the specific details are as follow.

Single Equation Model

The general trip generation model of single equation usually employs a regression equation. This equation comprises a dependent variable (typically number of trips) and one or more independent variables. The dependent variable is modeled as a linear function of the independent variables, showing causal relationships. The general formula is as follows:

$$y_i = b_0 + b_1 x_1 + b_2 x_2 + \cdots + b_n x_{ni} + \in_i \tag{1}$$

where y is a dependent variable, x is an independent variable, b is a coefficient, and ε is the error term. Usually the coefficients are estimated by using the lease squares method.

Simultaneous Equation Model

In the regression equation which is a single equation, the estimated coefficient can cause an endogenous bias if an independent variable is not independent of an error term. Therefore a simultaneous equation model is necessary in order to reduce such bias. Among simultaneous equation models, a structural equation model is mainly adopted to analyze the causal relationships between the endogenous variables or the endogenous variable and the exogenous variable. Therefore, the structural equation model can offer better estimation results for causal relationships without the endogeneity bias. In addition, the model is able to provide coefficients for direct (e.g. $X \rightarrow Y_2$), indirect (e.g. $X \rightarrow Y_1 \rightarrow Y_2$), and total effects (combined both effects) of variables on each other (Jöreskog, 1973). A general structural equation model in which all variables are observed can be written as

$$Y = BY + \Gamma X \quad + \zeta \tag{2}$$

where Y is a ($N_Y \times 1$) column vector of endogenous variables (N_Y is the number of endogenous variables, e.g. $[y_1, y_2, \ldots, y_n]^T$), X is a ($N_X \times 1$) column vector of exogenous variables (N_X is the number of exogenous variables, e.g. e.g. $[x_1, x_2, \ldots, x_n]^T$), B is a ($N_Y \times N_Y$) matrix of structural coefficients representing the direct effects of endogenous on other endogenous variables, Γ is a ($N_Y \times N_X$) matrix of structural coefficients representing the direct effects of exogenous on endogenous variables, and ζ is a ($N_Y \times 1$) column vector of error terms.

Then, the variance-covariance matrix of the exogenous variables is denoted as Φ, and the variance-covariance matrix of the error terms is denoted as Ψ (thus, ζ ~ (0, Ψ)). Both variance-covariance matrices need to be specified. In the structural equation model, Σ, the population variance-covariance matrix of only the observed variables, X and Y, can be written as a function of the set of unknown parameters θ. In this study, latent variables are not included in the structural equation model because the conceptual model does not presently include such variables. Then, Σ(θ) may be written as

$$\Sigma(\theta) = \begin{bmatrix} \Sigma_{YY}(\theta) & \Sigma_{YX}(\theta) \\ \Sigma_{XY}(\theta) & \Sigma_{XX}(\theta) \end{bmatrix} = \begin{bmatrix} (I-B)^{-1}(\Gamma\Phi\Gamma' + \Psi)[(I-B)^{-1}]' & (I-B)^{-1}\Gamma\Phi \\ \Phi\Gamma'[(I-B)^{-1}]' & \Phi \end{bmatrix} \tag{3}$$

in terms of B, Γ, Φ, and Ψ, where X and Y are measured from their means (E[X] = E[Y] = 0), and exogenous variables and errors are uncorrelated (E(Xζ′)=0). Thus, the population variance-covariance matrix is unknown, for which the sample variance-covariance matrix S constitutes an unbiased estimator. Then, the unknown parameters (such as B, Γ, Φ, and Ψ) need to be estimated to minimize the difference between the model-implied population variance-covariance matrix and the sample variance-covariance matrix.

The structural equation model uses the method of maximum likelihood estimation, the generalized least squares method and ADF (Asymptotic Distribution Free). Also, the goodness-of-fit of the structural equation model uses the value of χ^2 which represents degree of similarity between the dispersion-covariance matrix estimated by the model and the dispersion-covariance matrix of population. In addition, indexes – such as GFI (goodness of fit index), NFI (normed fit index) and CFI (comparative fit index) – that can measure model fit are used and the closer the value of the indexes to 1, the higher the suitability. In the estimation of the structural equation model of this study, AMOS 5.0 was used.

5. MODEL ESTIMATION

Using the data from the survey on ICT use and travel, two types of trip generation models – the regression models and the structural equation models – were estimated.

5.1 Regression Models

Regression models were estimated in consideration of ICT use variables to total number of trips, number of personal vehicle trips, and number of public transportation trips. The model results are shown in Tables 5 through 7. The R^2 values of the models ranged from 0.06 to 0.24. All explanatory variables are statistically significant at $\alpha = 0.05$ and conceptually interpretable.

From the model of total trips, it is found that higher education and more frequent use of mobile phone increase the number of trips. It implies that those who use mobile phone frequently are more likely to generate activities, resulting in more trips. This result supports that ICT use and travel have a complementary relationship. In addition, younger people are likely to travel more. On the other hand, the number of trips is found to be less if there are more personal vehicles. It is not surprising that public transportation users show more trips than personal vehicle users due to the transfer between public transportation modes in SMA. In fact, in case of the model of number of personal vehicle trips, the number of vehicles owned appeared to have positive sign while it showed negative sign in the model of number of public transportation trips.

Table 5 Regression model estimation for total number of trips

Variable	Coefficient	T-value
Constant	3.361	11.73
Education	0.252	4.61
Frequency of mobile phone use	0.0157	2.57
Age	-0.0173	-3.49
Number of personal vehicles in household	-0.312	-2.78

Note: R^2=0.06, N=614

In the model of number of personal vehicle trips[2], the mobile phone use positively affects number of personal vehicle trips, indicating a complementary effect. Ii is not surprising that personal vehicle trips are more likely to be flexible than public transit trips, so activities generated by mobile phone tend to affect the personal vehicle trips. In addition, older people make more personal vehicle trips because they tend to be high income. As expected, full time employment and presence of driver's license are found to increase number of personal vehicle trips. Females tend to show fewer trips by personal vehicles than males.

Table 6 Regression model estimation for number of personal vehicle trips

Variable	Coefficient	T-value
Constant	-0.815	-4.58
Frequency of mobile phone use	0.0088	2.11
Age	0.0220	6.05
Number of personal vehicles in household	0.451	5.87
Female*	-0.342	-3.59
Possession of driver's license *	0.439	4.13
Full-time employment *	0.361	3.53

Note: R^2=0.24, N=614, and * is a dummy variable.

For the model of number of public transportation trips, the length of time of Internet use positively affects the number of public transportation trips. That is, those who use Internet frequently are more likely to take public transit, compared to mobile phone users. This is because people in their 20s use Internet longer than any other people, and they seem to be university students and relatively low income. On the other hand, Internet is able to provide powerful information about public transit use such as arrival time and waiting time for buses in SMA. It encourages people to take public transit. Overall, ICT use positively affects travel regardless of transportation mode. Unlike the model of number of personal vehicle trips, people who spend more time on Internet use tend to increase number of public transportation trips. Interestingly, people engaged in clerical/administrative assistance are revealed to use personal vehicles more often. Clearly, people with higher education or high income tend to use less public transportation. Public transportation is more used in Seoul which has better infrastructure for public transportation than Gyeonggi-Do.

Table 7 Regression model estimation for number of public transportation trips

Variable	Coefficient	T-value
Constant	3.537	10.78
Age	-0.0379	-7.54
Number of personal vehicles in household	-0.415	-3.59
Residence in Seoul*	0.471	3.67
Clerical/Administrative assistance *	-0.0018	-2.77
Average monthly household income	-0.143	-1.99
Length of time of Internet Use	0.0021	2.79

Note: R^2=0.18, N=614, and * is a dummy variable.

[2] The personal vehicle trips include car-as-driver trips, car-as-passenger trips, and taxi trips.

5.2 Structural Equation Models

A conceptual model – which assumes the directions of causal relationships between either two endogenous variables or other exogenous variable and endogenous variable – was established as shown in Figure 2 in order to estimate the structural equation model. In the model, the variables in the circle represent endogenous variables, the variables in the rectangles indicate exogenous variables, and the arrows denote the direction of causal relationships.

It is assumed that ICT use and number of trips influence each other. This means that as ICT use increases, number of trips either increases or decreases, and vice versa. In addition, socio-demographic variables – such as age, gender, occupation and employment status – and economical variables – such as household income and number of vehicles owned – are assumed to directly and indirectly affect ICT use and number of trips.

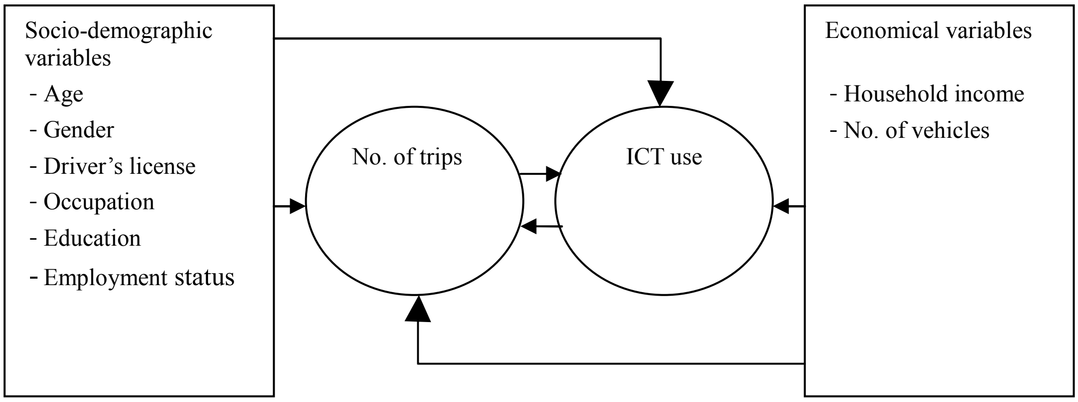


Figure 2 Conceptual model of ICT use and travel

The structural equation of this study assumed number of trips (total number of trips, number of personal vehicle trips, number of public transportation trips) and frequency and length of time of ICT (Internet, mobile phone, and landline phone) use as endogenous variables. The models were estimated by the combination of endogenous variables, resulting in 3×6 = 18 alternatives of structural equation. Among them, the results of three models – which are possible to estimate, show better model fit and bear no problem in interpretation – were explained.

Total Trips and Mobile Phone Use

Table 8 shows the result of structural equation model for total number of trips and frequency of mobile phone use. All goodness-of-fit measures of GFI, NFI, and CFI are close to 1, representing the model has a good fit, and the coefficients (indicating total effects) of all the variables are statistically significant at $\alpha = 0.05$. Looking at the coefficients of the explanatory variables, it can be seen that mobile phone use positively affects total number of trips. That is, as ICT use increases, travel increases. This indicates that ICT use and travel have a complementary effect. However, total number of trips is found not to influence mobile phone use. When compared with the regression equation for total number of trips, it is found that all the variables are the same and additionally the variable of female negatively affects total number of trips. This means that males show more number of trips than females. Also, the effect (0.036) of frequency of mobile phone use on total number of trips in the structural equation appears to be twice as much as that in the regression equation (0.016).

Table 8 Structural equation model estimation for total number of trips and frequency of mobile phone use (total effects)

Variable		Endogenous valuable	
		Total number of trips	Frequency of mobile phone use
Endogenous variable	Frequency of mobile phone use	0.036	
Exogenous variable	Female*	-0.128	-3.534
	Number of personal vehicles in household	-0.313	
	Age	-0.019	-0.086
	Education	0.249	
GFI		0.996	
NFI		0.906	
CFI		0.917	
$\chi 2$		8.29 (degree of freedom = 2)	

Note: N=614, * is a dummy variable, and all variable are statistically significant at α = 0.05.

Personal Vehicle Trips and Mobile Phone Use

As shown in Table 9, the structural equation model for number of personal vehicles trips and frequency of mobile phone use has a good fit. All the variables are statistically significant at α = 0.05. Similar to the above model, mobile phone use positively affects personal vehicle trips, and personal vehicles trips have no impact on mobile phone use. From comparing with the regression model for the number of personal vehicles trips, all the variables are similar and education is found to be additionally significant. It is clear that people with high educational levels tend to increase personal vehicle trips. The impact of the frequency of mobile phone use on the number of personal vehicle trips is found to be larger in the structural equation model than in the regression model.

Public Transportation Trips and Internet Use

Table 10 shows the results of structural equation model for number of public transportation trips and length of time of Internet use. The model has a good fit and all the variables are statistically significant at α = 0.05. Internet use positively affects public transportation trips, but public transportation trips do not significantly affect Internet use. All the explanatory variables were similar and only the variable of education additionally appeared to be statistically significant by comparing with the regression equation for public transportation trips. People with higher education show higher number of trips by public transportation as well as higher number of trips by personal vehicles. Also, the influence of length of time of use of Internet on the number of public transportation trips is bigger than that in the regression model.

Table 9 Structural equation model estimation for number of personal vehicle trips and frequency of mobile phone use (total effects)

Variable		Endogenous variable: Number of personal vehicle trips	Endogenous variable: Frequency of mobile phone use
Endogenous variable	Frequency of mobile phone use	0.061	
Exogenous variable	Education	0.058	0.951
	Number of personal vehicles in household	0.455	
	Age	0.022	-0.088
	Full-time employment*	0.325	
	Driver's license*	0.394	
	Female*	-0.375	-3.301
	GFI	0.998	
	NFI	0.992	
	CFI	0.998	
	$\chi 2$	4.23 (degree of freedom = 3)	

Note: N=614, * is a dummy variable, and all variable are statistically significant at α = 0.05.

Table 10 Structural equation model estimation for number of public transportation trips and length of time of internet use (total effects)

Variable		Endogenous variable: Number of public transportation trips	Endogenous variable: Length of time of Internet use
Endogenous variable	Length of time of Internet use	0.009	
Exogenous variable	Education	0.142	15.385
	Average monthly household income	-0.157	
	Clerical/Administrative assistance*	-0.002	
	Residence in Seoul*	0.482	
	Number of personal vehicles in household	-0.408	
	Age	-0.044	-2.471
	GFI	0.997	
	NFI	0.981	
	CFI	0.991	
	$\chi 2$	7.11 (degree of freedom = 4)	

Note: :N=614, * is a dummy variable, and all variable are statistically significant at α = 0.05.

5.3 Model Comparisons

The model results are statistically compared to prove the significance of ICT use in trip generation models. For the regression model, F-test was conducted to verify the significance of ICT use variables. This F-test compares the restricted model (not including ICT use variables) with the unrestricted model (adding ICT use variables).[3] As shown in Table 11, the model that includes ICT use variables is found to be statistically better than the model that does not include the variables. For the structural equation model, however, there is no method of statistical verification for addition of ICT use variables because they are treated as endogenous variables.

In addition, since the statistical comparison of the regression equation and the structural equation is not possible, significant variables and coefficients are compared. The structural equation models are found to have more significant variables than the regression models. As was explained in each model, the coefficients for the ICT use variables are found to appear relatively larger in the structural equation. This implies that the influence of ICT use appears large in the comprehensive system that takes into consideration of ICT and travel.

Table 11 F-Test Results

Classification	General variables	ICT use variables	F_value (P-value)
Total number of trips	Education, Age, Number of personal vehicles	Frequency of mobile phone use	6.61 (0.010)
Number of personal vehicle trips	Age , Female, Number of personal vehicles, Driver's license, Full-time employment	Frequency of mobile phone use	4.46 (0.035)
Number of public transportation trips	Age , Number of personal vehicles, Residence in Seoul, Clerical/Administrative assistance, Average monthly household income	Length of time of Internet use	7.77 (0.005)

Note: The restricted model includes constant and general variables and the unrestricted model adds an ICT use variable to the restricted model.

6. CONCLUSIONS

This study explores the relationships between ICT use and travel by developing trip generation models considering ICT use variables. The data for this study comes from an ICT use and activity diary survey of 269 households (860 individuals) in Seoul Metropolitan Area

[3] F_value = [(SSE(R) − SSE(U)) / J] / [SSE(U) / (N-K)], where SSE is the square of residual, R is the restricted model, U is the unrestricted model, J is difference of the number of variables between R and U, N is the number of samples, and k is number of variables (including constant).

in 2006. We first conducted pair-wise correlation tests between ICT (Internet, mobile phone, and land-line phone) use and travel (number of trips). The test results show that ICT use and travel are positively correlated. We also developed regression models of trip generation (number of trips by mode) considering socio-demographic variables as well as ICT use variables. It turned out that ICT use variables have statistically significant effects on travel. Furthermore, assuming that interrelations between ICT and travel exist, structural equation models were developed by taking them as endogenous variables. The model results strongly suggest that ICT use positively affects travel (indicating complementary effects), but the other direction is not significant. Interestingly, the impacts of the ICT use on travel turn out to be larger in the structural equation models than in the regression models.

In conclusion, this study has significance in a sense that ICT use and travel have a complementary relationship and furthermore it has proven the importance of the role of ICT-related variables in the context of trip generation.

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