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Research Paper

Explore the effect of Information and Communication Technology(ICT) on activity-based travel behavior of transportation system users: An application of Structural Equations Models

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Abstract

The Information and Communication Technologies (ICT) have penetrated into almost all spheres of human life and it is almost impossible to imagine life without ICT. Thus, the investigation of ICT impacts has practical policy-making importance since different policies might help solve social problems which are impacted by ICT and are related to transportation (e.g., traffic congestion, environmental pollution, urban and land-use planning). This study has been dedicated to analysis of ICT impacts on subsistence (e.g., work) and maintenance personal activities (e.g., shopping). The sample is derived from the travel-ICT characteristic survey conducted in Tehran in 2015. Total of 415 questionnaires were distributed in all of the region of Tehran. Among them 355 questionnaires were collected and 303 questionnaires were found to be effective. We use SEM in the further empirical research of this study for analyzing personal time-budget. The findings of this study provide further evidence on the Complementarity / Generation effects of ICT on travel, suggesting that the wide application of ICT probably leads to more travel. The study also demonstrates the importance of considering the interactions between activity and travel for better understanding of the nature and magnitude of the impacts of ICT on time use and trip making behavior.

Keywords: Information and Communication Technology(ICT), Time use Travel behavior, Structural Equation Modeling.

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1. Introduction

Information and Communication Technologies have penetrated into our life and have had impact which on almost all spheres of human life. Reichman's (1976) trichotomy of personal activities, such as is built on the principle of individual motivations or purposes to engage in an activity, expectations to earn money, satisfy physiological needs, enjoy, and relax, is developed and adopted in this study:

- Subsistence activities include work and work-related activities, which provide the economic basis for the remaining personal activities; noegenesis (e.g., school or university) is also included.
- Maintenance activities refer to purchasing and consumption of goods and services aimed to satisfy individual/household physiological needs (e.g., shopping, banking, medical services), or biological needs (e.g., sleep, hunger, thirst, personal care), and obligations

associated with being a member of a family and society (e.g., housework, passengers pick up and drop off).
- Leisure activities encompass discretionary activities (e.g., going to restaurants, physical fitness, watching TV/video).

Information and Communications Technologies (ICT) provide people alternatives to face-to-face communication and thus have the potentials to substitute physical travel. These potentials are particularly appealing for policy makers and planners who have been desperately looking for ways to mitigate traffic congestion. They have also motivated a great number of studies on the transportation impacts of ICT. These studies have greatly contributed to our understanding of the possible and potential impacts of ICT on physical travel. 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.

Compared to other ICTs, such as the cellular phone, the Internet allows people to conduct a greater range of activities in cyberspace which include e-mailing, Web surfing, blogging, online shopping, online banking, watching movies or videos, listening to music, sharing photos, online auctions, news groups, chat rooms, real-time voice and video communication, and many others.

While much work was published with regard to ICT impacts on subsistence and maintenance activities (Salomon, 2000; Mokhtarian et al., 2004), the role of ICT in the context of leisure activities remains mostly understudied (Hjorthol, 2002; Senbil and Kitamura, 2003; Mokhtarian et al., 2004). However, leisure does hold an essential segment of human activities and the share of technology-based leisure activities grows from year to year in comparison with non-technology-based (location-based and movement-based) leisure activities. 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.

The objective of this paper is to make such a contribution. We shall apply the activity-based framework to probe into the impacts of ICT on activity and travel behavior by identifying the causal relationships between ICT usage and travel behavior. Particularly, we will differentiate the direct and indirect effects of ICT on trip generation and travel behavior. Further, we will adopt the comprehensive approach, i.e., instead of focusing on specific ICT application such as telecommuting or e-shopping, the study will define ICT in a broad sense as the experience with the use of Internet (E-mail, E-Banking, E-learning, E-shopping, telecommunication, videoconference, online video, mobile phone usage in a day and internet usage in a day). the following questions are investigated: (a) how does the use of ICT directly affect travel rough behavior in terms of daily trip numbers? (b) what are the indirect effects of ICT on travel allocation among subsistence, maintenance and leisure activities?

(c) how are the ICT use socio-demographic characterized? To answer these questions, it is important to consider the interactions between activity participation and travel pattern. One typology, for first-order interactions, includes four major direct impacts of ICT: substitution, complementarity, modification, and neutrality.

- Substitution – ICT may cause a location-based activity to be substituted by an ICT-based counterpart activity, thus eliminating travel. In addition, an ICT-based activity might be new without a location-based analogy.
- Complementarity / Generation – ICT may lead to conducting new location-based activities, which may not occur otherwise, thus generating travel.

Modification - ICT may alter travel by a shift in different aspects of travel and activities, such as trip timing, trip chaining, and travel mode, with travel neither eliminated nor replaced by ICT but modified in different ways.

- Neutrality – ICT may have no effect on personal activities and their associated travel.

We therefore employ the structural equation modeling framework. The sample is derived from the 2015 travel characteristics survey of Tehran which is capital of Iran. This paper is organized as follows. A brief literature review will be provided in Section 2, which is followed by a description of the study area, dataset, and analytical methods in Section 3. Analysis of the results will be elaborated in Section 4, and finally conclusion will be provided in Section 5.

2. Literature review

2.1 Activity-based approaches

Activity patterns are summary characterizations of all attributes of an individual's daily activities and trips. These characteristics include the timing, duration, location, frequency and sequence of activities, and the travel time and distances of trips. Studies on human activity patterns normally rely on data collected through the use of activity–travel diary, which provides detailed record of a person's activities and travel for various periods of time (from one day to several weeks). Using these data, it is possible to gain significant insight about

the everyday life of a particular time and place, as well as the interaction between people's daily life and the local geographic and social context.

Modeling human activity patterns has been helpful for discovering the interconnectedness of a person's daily activities and the interaction between these activities and those undertaken by other members of the same household. One of the major advances made in this research area is the shift from trip-based modeling to activity-based modeling (e.g., Bhat and Koppelman, 1999; Golob, 1998, 2000; Golob and McNally, 1997; Goulias, 2002; Kitamura, 1988; Kwan, 1999; Lu and Pas, 1999; Pendyala and Goulias, 2002). Activity-based modeling takes people's daily activities and the associated trips as the fundamental analytical entities. It considers travel as a demand derived from the need to undertake activities at different locations. When compared with trip-based models, such as the four-step transportation model, activity-based models provide better frameworks for addressing the complexity of activity–travel behaviors as they consider a wider range of factors and interactions. For example, since an individual's daily activity arrangement is often influenced by other household members, the effect of the decision-making of household members (especially the female and male heads) on both individual and joint activity–travel participation can be taken into account (e.g. Chandraskharan and Goulias, 1999; Fujii et al., 1999; Gliebe and Koppelman, 2002; Golob and McNally, 1997; Townsend, 1987; Van Wissen, 1989).

2.2. ICTs and activity–travel patterns

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 ICT 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. Kim and Goulias (2004) studied the effects of changes in the availability and access to ICT on activity, travel and modal split.

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. Sanghoo choo et al (2009) explored relationships between actual amount of ICT use and travel by developing trip generation models. The data came from an ICT use and activity diary survey of 269 households of Seoul Metropolitan Area in 2006. The model results strongly suggest that ICT use positively affects travel (indicating complementary effects).

Fang Ren and Mei-Po Kwan (2009) by Using an Internet-activity diary dataset and multi-group structural equation modeling examined the complex interactions between different types of Internet and physical activities, with a special focus on gender differences and Internet maintenance and leisure activities. Filippo Dal Fiore, Patricia L. Mokhtarian et al (2014) identified a set of perspectives on how mobile phones and

computers might affect travel: by tapping into basic needs of travelers; by affecting some preconditions for its spatial configuration. They founded that mobile technology can impose new burdens on travelers and make travel less appealing in some ways and by altering its costs and benefits.

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 ICT usage with considering amount of ICT use and travel behavior in the context of trip generation.

3. Data and research methodology

3.1 Data

The dataset used in this study was collected through an activity-internet diary survey in the Tehran metropolitan area (Iran) in 2015. Besides collecting household, individual, and Internet use information, the survey instrument also included a two- normal weekday activity-travel diary. The diary collected detailed data about participants' physical activities for two designated survey days, including the reasons why a participant conducted a specific activity, the duration of the activity, travel time associated with the activity, the travel mode used, and so on. With regard to the primary purpose for undertaking an activity. Following the practice of previous studies (e.g., Lu and Pas 1999) we group total of 27 out -of -home activity into three categories: 'Subsistence activity' (including work at usual or other places of work), 'Maintenance activity' (including buying food; escorting children to/from school; consulting doctors, etc.) and 'leisure activity' (including seeing movies; visiting friends/relatives; sightseeing; sporting activities, having meals at restaurants, etc.). Total of 415 questionnaires were distributed in all of the region of Tehran. Among them 355 questionnaires were collected and 303 questionnaires were found to be effective (response rate: 86%).

The sample well represents the society in all aspects: about 61.4% of the respondents were females and 38.6% males. The average age of respondents was around 30 years old (minimum 9 years old and maximum 72 years old). In terms of employment status, 71.3% were employed and 73.6% had driver license. Regarding the experience of ICT usage, 79.5% of the respondents indicated that they had used e-mail, 71.9% had used e-shopping, 69% had used e-banking, 49.2 had experience of video call, 62.7% had used e-working, 44.6% had experience of e-learning and 71.9% had watched online movie for either business or personal purposes. On average, respondents in the sample spent 332 min for out-of -home subsistence activities, 65 min for maintenance activities and 20 min for recreation activities in a day. The daily average number of trips was 2.6.

3.2. Methodology

To process survey data, a variety of quantitative research methods, including SEM, Multinomial logit regression, and techniques inherent to the market segmentation analyses as cluster analysis and factor analyses could be employed.

For the last twenty years SEM was used in transportation research mainly by Golob (see e.g., Golob, 1988; Van Wissen et al., 1991; Golob et al., 1995; Golob and McNally, 1997; Golob, 1999, 2001) and Kitamura (see e.g., Yamamoto and Kitamura, 1999; Senbil and Kitamura, 2003). The main advantage of SEM is that it allows investigating not just direct effects of one factor on another but also various feedbacks and indirect effects.

We intend to use SEM in the further empirical research of this study for analyzing personal time-budget. Thus, each of time variables related to the particular activity type will be considered as dependent variable in each equation of the SEM equation system. Moreover, all remaining time variables will be included as explanatory variables. As a result, all time variables represent endogenous variables and variables related to socio-demographics, personal attitudes, and residential location characteristics will play the role of exogenous explanatory variables, resulting in the following typical structural equation system (without latent variables):

$$Y=BY+\Gamma X+\zeta$$

Where:

Y: a $N_Y \times 1$ matrix containing the endogenous variables (N_Y: the number of endogenous variables)

X: a $N_X \times 1$ matrix containing the exogenous variable (N_X: the number of exogenous variables)

B: a $N_Y \times N_Y$ structural matrix representing the direct impact of endogenous variables on each other

Γ: a $N_Y \times N_X$ structural matrix representing the direct impact of exogenous variables on endogenous ones

ζ: a $N_Y \times 1$ matrix representing the error.

Various researchers (Golob, 2001; Holbert and Stephenson, 2002) use different available methods for parameter estimation, such as Maximum Likelihood (ML), Generalized Least Squares (GLS),

Unweighted Least Squares (ULS), Scale Free Least Squares (SLS), and Asymptotically Distribution-Free (ADF). Factor analyses will allow to identify similar groups of survey respondents and to analyse variations of socio-demographics and attitudinal characters inherent in this or that group possessing certain travel-activity patterns. Cluster analyses will allow to group respondents according to socio-demographics and similar attitudinal behavior (e.g., the pro-technology, the homebody).

3.3. Model specification

model specification is based upon theory and past empirical evidence. In the context of travel behavior research, for instance, Golob (2000) proposed a conceptual activity-based model with three components and their causal relationships: (1) activity engagement generates travel demand; (2) travel demand leads to travel engagement; and (3) travel engagement in turn affects activity engagement as time spent on travel will compete for the time spent on activities (Fig. 1).

Another conceptual model, developed by Lu and Pas (1999), also suggested that activity participation influences travel behavior. It, however, ignores the feedback loop between travel engagement and activity participation. Drawing upon Golob's conceptual model, Senbil and Kitamura (2003) tested four model structures to study the impact of telecommunication devices (telephones) on people's activities. Their empirical results showed that the causal structure in which telecommunications affect activity duration (activity engagement) and activity duration influences the number of out-of-home visits (travel demand) fits the data best. Thus, the three-component conceptual model, which is theoretically sound and supported by considerable empirical evidence, was adopted in this study to examine the impact of the Internet on people's activity–travel patterns.

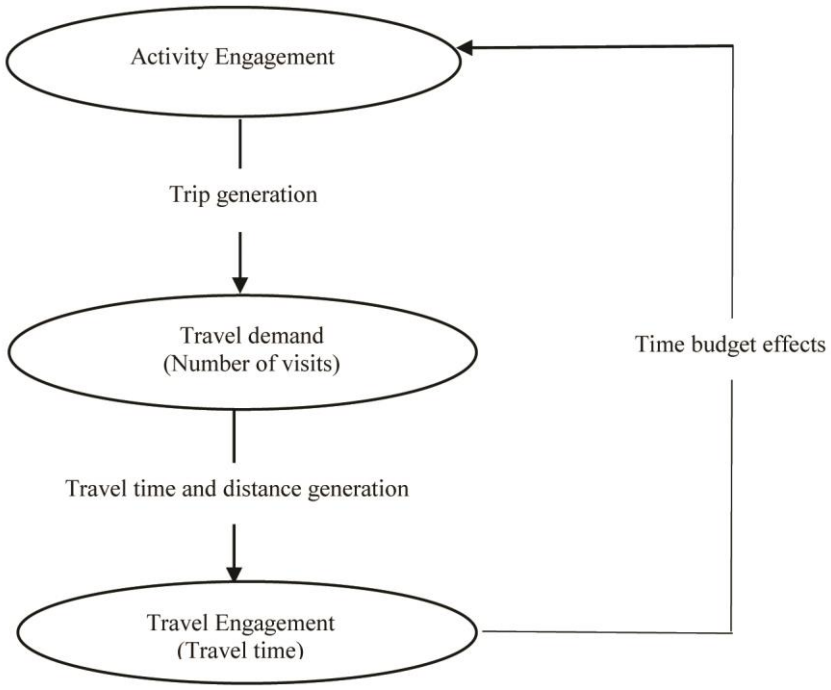

Fig 1. Relationship between activity and travel (Golob, 2000)

The model developed in this study involves four constructs: socio -demographics, ICT usage, time use for daily out-of-home activities, and travel behavior. Based on the findings of previous studies and the data availability, five socio-demographic variables are included as exogenous variables: 'Gender' (Male = '1'; Female = '0'), 'Age', 'Education', 'Employment' (full-time employed = '1'; otherwise = '0'), Occupation.

As for endogenous variables, three variables concern time use for out-of-home subsistence, maintenance, and Leisure activities respectively; one defines travel behavior in terms of daily total number of trips; and one measures ICT usage in terms of amount of use of application ICT. The hypothetical causal relationships among endogenous variables and between exogenous and endogenous variables are depicted in Fig 2.

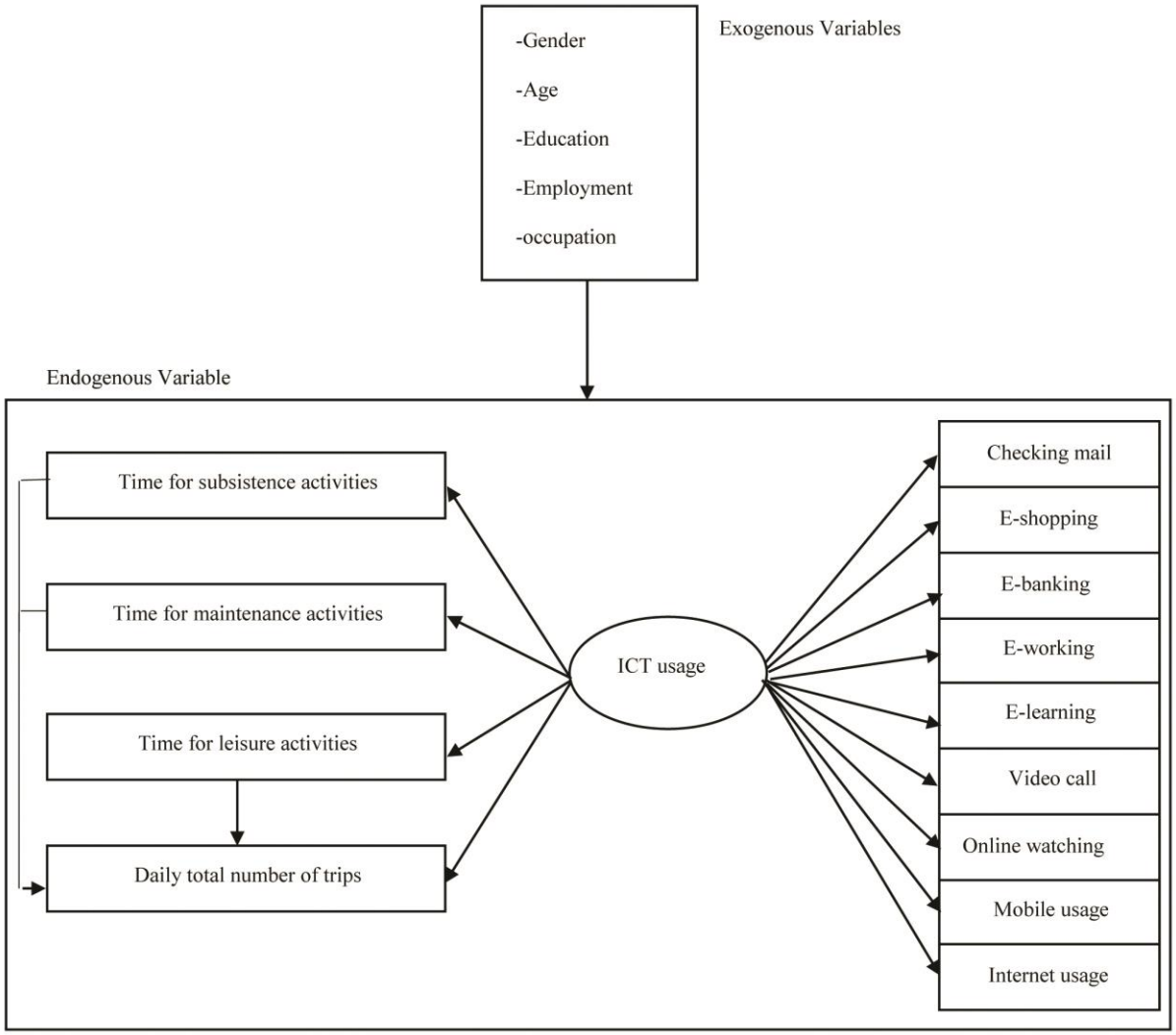

Fig.2 Hypothetical causal links between ICT usage, time use, travel behavior and socio-demographics

We hypothesize that ICT usage impacts on the time allocation among out-of-home subsistence, maintenance and recreation activities. It also affects individuals' travel behavior in terms of the number of trips and hypothesize that 9 variables effect on ICT usage as latent variable. Table 1 show confirmatory factor analysis of impact of ICT on mobile phone usage in a day, Internet usage in a day, checking mail, E-shopping, E-banking, E-working, Video call and watching online.

Table 1. Confirmatory factor analysis

	Estimate	S.E	T-value	P-value
ICT → Mobile usage in a day	0.092	0.084	1.100	0.271
ICT → Internet usage in a day	0.375	0.075	5.010	0.001
ICT → Checking mail	1			
ICT → E-shopping	0.716	0.087	8.268	0.001
ICT → E-banking	0.73	0.089	8.193	0.001
ICT → E-working	0.855	0.112	7.608	0.001
ICT → Video call	0.544	0.094	5.791	0.001
ICT → E-learning	0.447	0.084	5.294	0.001
ICT → Watching online	0.301	0.103	2.927	0.003
Chi-square=58.046 , Degrees of freedom=27 , Cmin/df=2.15 , RMSEA=0.062 , CFI=0.907				

4. Result

Based on the hypothesized relations discussed above, the causal structures of baseline models, were specified. They were estimated with maximum likelihood (ML) method using AMOS 23.0. The chi-square value of the estimated model is 367.685 with 128 degrees of freedom. (chi - square/df = 2.873). The other goodness-of-fit indicators also suggest that the model is fits. Details of the modeling results are presented in Tables 2 and 3.

4.1 Effects of ICT usage on time use and travel behavior

Table 2 shows that the standardized total, direct and indirect effects of 'ICT usage' on subsistence activities are all positive, which seem to suggest that ICT usage induces more time for subsistence activities and that on maintenance activities and leisure activity are all negative, which tend to propose that ICT may reduce the time for maintenance and leisure activities. Table 2 shows that 'use of ICT' have positive and significant direct and total effects on 'number of trips', whilst the indirect effect, which is channeled through time use for subsistence and maintenance, is negative but insignificant. In other words, the use of ICT directly induces individuals to make more trips. This is consistent to the finding of the study by Srinivasan and Athuru (2004), which revealed that ICT usage (particularly the use of Internet) led to more trips. The modeling results presented above seem to support the argument for complementarity /generation effects of ICT on travel, which were speculated and found in previous studies (Mokhtarian 2003, Choo 2009). Apart from the impacts of ICT on time use and travel behavior, Table 2 also lists the relations between time use for activities and travel behavior. Time use for subsistence activities negatively and significantly impacts on time use for maintenance and leisure activities, suggesting that more time spent for subsistence activities, less time left for maintenance and leisure activities. Further, more times spent for subsistence activities increase the number of trips. Similar to that for subsistence activities, time for maintenance activities has negative effect on leisure activity but it has significantly and positive effect on number of trips. Also leisure activity has positive effect on total number of daily trip.

Table 2. Standardized total, direct and indirect effects between endogenous variables

		Use of ICT	Subsistence activity	Maintenance activity	Leisure activity
Use of ICT	Total	0	0	0	0
	Direct	0	0	0	0
	Indirect	0	0	0	0
Subsistence activity	Total	0.328	0	0	0
	Direct	0.328	0	0	0
	Indirect	0	0	0	0
Maintenance activity	Total	-0.250	-0.394	0	0
	Direct	-0.121	-0.394	0	0
	Indirect	-0.129	0	0	0
Leisure activity	Total	-0.131	-0.141	-0.166	0
	Direct	-0.105	-0.207	-0.166	0
	Indirect	-0.026	0.066	0	0
Number of trips	Total	0.127	0.051	0.489	0.292
	Direct	0.200	0.305	0.538	0.292
	Indirect	-0.073	-0.254	-0.049	0
Chi-square=367.685 , Degrees of freedom=128 , Cmin/df=2.873 , RMSEA=0.079 , GFI=0.881 , AGFI=0.841					

4.2. Effect of exogenous variable on endogenous variable

Table 3 shows that most socio-demographics are significant determinants of ICT usage. Age significantly and negatively impact on the use of ICT. This finding confirms our hypothesis and supports previous studies that younger people are more likely to use the ICT than older generations (Casas et al. 2001). One possible explanation is that in comparison with the older ones, younger individuals are better equipped with ICT knowledge and more willing to explore new technologies like ICT appliances such as Internet, mobile phone, video call, etc.

Another highly significant variable is gender. It shows that males are more likely ICT users than females. Also work status positive effect on ICT usage. It means that people who work, use more

ICT because they want to do all of their work with the highest speed. This table shows that education has positive effect on ICT usage. Table 3 also lists the effects of socio -demographics on time uses for subsistence, maintenance and recreation activities and travel behavior in terms of number of trips.

Table 3. Standardized total, direct and indirect effects between endogenous and exogenous variables

		Gender	Age	Education	Work Status
Use of ICT	Total	0.309	-0.233	0.334	0.323
	Direct	0.309	-0.233	0.334	0.323
	Indirect	0	0	0	0
Subsistence activity	Total	-0.101	-0.077	0.11	0.106
	Direct	0	0	0	0
	Indirect	-0.101	-0.077	0.11	0.106
Maintenance activity	Total	-0.077	0.058	-0.084	-0.081
	Direct	0	0	0	0
	Indirect	-0.077	0.058	-0.084	-0.081
Leisure activity	Total	-0.04	0.031	-0.044	-0.042
	Direct	0	0	0	0
	Indirect	-0.04	0.031	-0.044	-0.042
Number of trips	Total	0.039	-0.03	-0.053	0.041
	Direct	0	0	-0.095	0
	Indirect	0.039	-0.03	0.043	0.041
Chi-square=367.685 , Degrees of freedom=128 , Cmin/df=2.873 , RMSEA=0.079 , GFI=0.881 , AGFI=0.841					

5.Conclusions

ICTs have penetrated into almost all spheres of human life and it is almost impossible to imagine life without ICT. Thus, the investigation of ICT impacts has practical policy-making importance since different policies might help solve social problems which are impacted by ICT and are related to transportation (e.g., traffic congestion, environmental pollution, urban and land-use planning). In the research arena, such fields as information systems, economics, and marketing could also benefit from deeper understanding of ICT impacts on personal (or consumer) and organizational behavior.

In an attempt to enrich the literature on the effects of ICT on activity and travel behavior, this paper empirically investigated the complex relationships among ICT usage, activity participation, travel behavior and socio-demographics in Tehran Metropolitan area (Iran) in 2015.

The structural equation modeling methodology was applied to identify the causal relationships among different factors. The use of ICT was found to increase trip making propensity. This finding provides further evidence on the complementarity/generation effects of ICT on travel, which were speculated and found in previous studies (Salomon 1986; Mokhtarian 2003; Choo 2009). This study provides another justification for the holistic and comprehensive approach studying the interrelationships between ICT and travel and the need to analyze indirect effect (Mokhtarian and Salomon 2002). Mokhtarian (2003) argued that the single application (e.g., telecommuting) studies often report substitution effects because they usually focus on direct and short-term impacts. If the more comprehensive approach that considers subtler and indirect effects is adopted, it is more likely to observe complementarity effects. This argument seems to be supported by this study. Nevertheless, we would also like to argue that with the further penetration of ICT into people's daily life, its inducing effects on activity and travel have become more important. In the past decade, the amount of information available on the Internet, the number of people connected to the Internet and the accessibility to all kinds of ICT devices have substantially increased. As a result, they have greatly increased the flexibility of activity engagement and trip making. More importantly they have created opportunities for new activities and induced changes in lifestyle. Consequently, though ICT might have substituted some physical activities and travel, it might have generated more.

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