EXPLORING THE IMPACTS OF IN-HOME VIRTUAL ACTIVITES ON DAILY ACTIVITY AND TRAVEL BEHAVIOUR: AN ANALYSIS USING CAIRO ACTIVITY AND TELECOMMUNICATION DIARY DATA 2006

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ABSTRACT

The boom in telecommunications technologies is expected to have great impact on the lifestyles of the individuals and their households and also on transportation system. Recent advances in information and communication technologies (ICTs) make it possible to conduct activities virtually, thus obviating the need for physical travel, at least for some types of activities. Further, ICT use may contribute towards reducing urban congestion and air-quality problems (by replacing travel with virtual activities); on the other hand they may also generate significant additional and induced travel due to increased connectivity and access to resources. Thus empirical insights on how the growing ICT use affects travel patterns and vice-versa have important application for planning, travel demand forecasting, and urban environment. So far, however, in transport research the effects of ICTs have mainly been analyzed by focusing on e-activity, especially e-shopping and telecommunicating. Although these studies allow essential insights, there is still no complete picture that shows the interrelationships between ICT use and individual activity and travel behavior. Further, to our knowledge, little attention has been directed to the understanding of how ICT affect activity participation and travel patterns of individuals in Egypt. The objective of this study is to investigate the effects of ICT on household members' daily activity-travel patterns using empirical activity and telecommunication diary survey conducted in Greater Cairo Region, in Egypt.

In this paper, activity participation and travel behavior are compared between two population groups, those currently with Internet access at home and those without Internet access at home. Structural equation models (SEMs) are developed to determine the structural relationship between virtual in-home activity participation, out-of-home activity participation, Internet use patterns, and observed travel dimensions. The information analyzed includes personal and household socio-demographic, ICT ownership and familiarity, and the role of constraints on time, and vehicle availability on activity patterns among household members. With this approach significant relationships were found among socio-demographics, social roles, technological familiarity, activity participation and travel behavior. Furthermore, the results show that in-home virtual activity participation has both a substitution and complementary impacts on out-of-home activity and travel patterns. These results have

important implication for activity-travel demand estimation and forecasting, given the growing adoption and use of ICT among various segments of the population.

Keywords: Information and Communication Technologies; physical activity participation; activity-Telecommunication dairy survey; Structural equations modelling; Virtual activity participation; Cairo activity-travel behaviour

INTRODUCTION

According to the government of the Arab Republic of Egypt, the number of subscription of mobile phones is 53 million with a penetration rate has increased from about 10% in 1999 to 65% in Dec. 2009. Similarly, the number of home Internet users has increased by about 25-fold between 1999 and 2009 (in Dec.2009, total 24.5 million user with approximately 30 subscribers per 100 inhabitants). Projections suggest that technology improvements will further fuel the adoption and use of Internet and mobile communication devices by individuals and households in the future. The boom in telecommunications is expected to have many reflections on individuals' activity and travel behaviour as well as the household interactions in daily activity-travel patterns.

The impacts of ICT adoption and use are likely to be far-reaching, with the potential to fundamentally alter the life styles of businesses and individuals (see, for example, Droege, 1997, Graham and Marvin, 1996, Boden, 1999, French et al., 1999 and Zimmerman et al., 2001, for broad discussions of the potential influence of ICTs on urban planning, medical care and services, education, and family responsibilities). An interesting aspect of ICT use from a transportation perspective is its impact on personal activity-travel behaviour. Three significant effects of ICT's on activity and travel patterns have been postulated in prior research: substitution, generation, and modification (Mokhtarian, 1990; Salomon, 1998, 2000). Substitution and modification of activity and travel patterns can have a significant impact on transportation system performance. For instance, recent advances in information and communication technologies (ICTs) make it possible to conduct activities virtually, thus obviating the need for physical travel, at least for some types of activities. Further, ICT use may contribute towards reducing urban congestion and air-quality problems (by replacing travel with virtual activities); on the other hand they may also generate significant additional and induced travel due to increased connectivity and access to resources.

These potentials have motivated a great number of studies on the transportation impacts of ICT. Many studies focus on specific applications of ICT, such as tele-commuting - the role of ICT's on work activity participation or e-shopping - the role of ICT's in shopping activities. In the context of tele-commuting, Mokhtarian and Solomon (1997 a,b) observed that attitudinal factors (including attiudes towards commute stress), facilitating factors, and constraints play a key role in observed telecommunication decisions. In another related study Mokhtarian and Salomon (2002) argued that the reported net impact of substitution of telecommuting might be less if the induced demand, latent demand, and long-term residential relocation effects were taken into account. Hamer et al (1991) studied the impact of tele-working on the travel behaviour of telecommuters and their family members. They found that tele-working resulted in significant decreases in the total number of trips made by tele-workers (17%) and peak-hour traffic by car (26%). Pendyala et al (1991) investigated the impact of telecommuting on spatial and temporal patterns of household travel. They found that the trip making and the total distance traveled by telecommuters were significantly reduced.

The influence of ICTs on shopping behaviour has also receiving increasing attention recently. Mokhtarian (2004) suggested that ICT leads to the fragmentation and recombination of the basic elements of the shopping process. She argued that there are many factors influencing the interaction between e-shopping and travel: some result in reduced travel while others lead to increased travel. As a result, the combined outcome may be negative (i.e. more travel may be generated). Farag et al (2004) found that e-shoppers were people who like to shop in general, suggesting that e-shopping might not lead to the reduction of shopping trips. Douma et al (2004) revealed that e-shopping had little substitution effects, rather, the Internet was used to modify shopping behaviour by gathering information of products or making trip more efficient.

Apart from defining ICT application in a broad way, findings of the studies on single ICT application may be further enriched by adopting the holistic approach and broadening the scope of investigation from single trip purpose to activity and time use patterns. 'The analysis of total human activity may lead to different conclusions from the analyses of single trip purpose' (Salomon 1985). The activity-based framework should thus be used to capture the ICT and travel interactions (Golob and Regan 2001). In recent years, few attempts have been made along this line. Along this line, Hjorthol (2002) tried to explain the relation between daily travel and computer use at home, especially with regard to the degree of substitution. Access to information technology is found to have significant impact on travel activities. However, the author could not see any direct substitution effect of computer access at home on travel patterns. Bhat et al (2003) focused on the effects of mobile phone and home computer usage on out-of home Non-maintenance shopping patterns. Their results show some evidence to substitution and complementary effects among different groups of individuals. For instance, mobile phone usage can result in a substitution effect on shopping trips for individuals, with certain educational and demographic characteristics. Senbil and Kitamura (2003) investigated the effect of cellular and home phones on travel behaviour. In this study frequency and duration of activities like home, work, discretionary and joint discretionary activities are modelled in relation to the number of phone-based communication activities. Poisson, Tobit regression and structural equation models are used to estimate these effects. The empirical findings suggested that the use of cell phones is positively correlated with work duration, and the frequency of joint discretionary activities. Srinivasan and Athuru (2004) studied the adoption of ICT, participation in physical and virtual activities and their impacts on travel patterns. The study, however, did not simultaneously model the interrelationship between ICT usage, activity participation and travel pattern. Consequently, the complex causal relationships between ICT usage, time use and travel behaviour could not be identified.

The studies cited above provide valuable insights on various aspects of ICT use and their effect on travel patterns. Despite of the drawbacks, these recent attempts have demonstrated that the holistic approach of studying the interactions between ICT and transportation is a promising avenue towards a better understanding of the transportation impacts of ICT. In light of this discussion, the overall purpose of this study is to contribute toward a better understanding of the interaction between ICTs use and daily activity and travel patterns.

The current study may be distinguished from previous ICT-related studies in several ways. The study focuses on an analysis of ICT use as well as the interactions between household members in daily in-home and out-of-home physical and virtual activity-travel decisions in a joint framework. Earlier studies, on the other hand, have either focused only on ICT use or only on the impact of ICTs on activity-travel behaviour. These earlier studies do not account for the possible endogeneity of ICT use decisions in analyzing household interactions in daily activity-travel patterns and, therefore, may not capture the true impact of ICT use on activity-travel patterns. Furthermore, this study examines use of telecommunication and Internet

technologies more broadly by considering a comprehensive set of ICTs, whereas many priori studies have focused on specific virtual activities such as tele-work or tele-shopping. To our knowledge, this is the first attempt in the literature to address all of the above issues in a comprehensive unifying framework. Moreover, much of literature on household interactions employs data from Anglo-Saxon countries. However, to our knowledge there have not been any studies that tried to explore either ICT use or inter-personal dependences in daily activity and travel behaviour of individuals in Arabic countries whose cultures are largely different from western countries. Studies from countries like Egypt can provide further insights into household interactions in daily activity and travel patterns.

In this paper, two simultaneous structure equations models were proposed and estimated using the recent two-day activity and travel diary survey conducted in the Cairo Region. The structure equations models were utilized to investigate the differences in household interactions and telecommunication impacts between two population groups those currently with Internet access at home and those without Internet access at home. All of these complicated relationships would be represented endogenously and simultaneously by models that we develop.

The organization of this paper is as follows. The next section provides a description of the data source and sample formation. This is followed by an overview of the methodology of structure equation modelling in Section 3. Section 4 identifies our hypotheses and describes the initial model specification employed in the research. Modelling results are presented and explained in Section 5. Finally, Section 6 concludes the paper by highlighting the important findings from the research.

DATA AND VARIABLES

Data Sources

The primary data source used for this analysis is the activity-travel and telecommunication diary survey spanned the period from December 2005 to January 2006. The survey was administrated in three academic and research institutions in Cairo, Egypt. Particularly; Egyptian national institute of transportation, Ain-shams University, and the Information and Technology Institute (ITI). Respondents from the three locations were contacted first by face to face interview to solicit their participations. Respondents who agreed to participate received the relevant activity diary sheets. In addition, a comprehensive explanations of the diary sheets and how can they enter the diary were done Further, they were requested to arrange that all of their household members above 12 years old to log their activities for two days. The response rate was 75.2% (of the 270 households to which questionnaires were distributed).

The activity diary instrument consisted of 4 questionnaires parts, and a core diaries part. The first two parts concerned with various individual and household characteristics, the third part of the survey instrument aimed to collect general data about the physical activities of the respondents, the fourth part of the instrument concerned with daily and non-daily Internet use and availability. The core part of the instrument consists of two diaries; the physical and Internet activities diary; and the telecommunication diary. The physical and Internet activities diary, aimed to collect data about participants' all in-home and out-of-home activities. For each successive activity, respondents were asked to provide information about the type of activity (based on 42 pre-coded scheme of activities), the start and end times of activities (beginning with 3 a.m. on the first diary sheet and ending with 3 a.m. following the second

diary sheet), location of participation (respondents were asked to record the location where the activity took place based on 12 pre-coded activity locations, i.e., in-home, shopping centres, work place, school, restaurant, relative/friends house, etc.) and exact geographical location for out-of-home activities. Further, for each successive activity, respondents were asked to report "with whom" they were doing this activity and "for whom" they did it. Respondents were provided with eleven pre-coded social contacts categories. The category reflects the most important social networks of immediate family, relatives and friendships. The information gathered on travel episodes included information on travel mode used, transfer location, and travel time.

The telecommunication diary asked the respondents to record all of their daily telecommunications over the two consecutive days. The telecommunication modes were classified into four types: fixed location land line calls, mobile phone calls, short messages services (SMS), and e-mail. For each successive telecommunication activity, respondents were asked to record timing of telecommunication, whether it was initiated or received, and purpose of each telecommunication activity. Purpose of telecommunication was classified into four categories: work or study, chatting, social, and arranging for an appointment purposes. Moreover, similar to activity diary, respondents were asked to report "with whom" each telecommunication activity was done.

Respondents were asked to complete the diaries for two consecutive days (starting either on a Saturday or a Thursday, so that data would be obtained for one weekend day and one weekday)1. After data cleaning and verification the final sample from the survey consisted of 459 respondents belong to 150 households, and contain a total of 15935 weekday and weekend activity and travel episodes. To our knowledge, this is the first attempt to conduct an activity diary and telecommunication survey in Cairo, Egypt.

After data cleaning and verification the final sample from the survey consisted of 459 respondents belong to 150 households, and contain a total of 15935 weekday and weekend activity and travel episodes. The income distribution of the sample ranges from low income households (less than 500 L.E/month) 23%, middle income households (501-2000 L.E/month) 53% and high income households (more than 2000 L.E) 24%. The average household size in the sample is 4.27. A very high percentage of the households in the sample 57% have two or more workers, while 7 % of the households in the sample have no workers, and 37% of the households with one worker. In terms of household mobility levels, approximately 72% of the sampled households have an access to the internet of which nearly 37% of them have no private car. The sample was nearly balanced in terms of gender (49.69% males). 53% of the respondents fell in the 12-29 year age categories, and nearly 19%, 28% were middle and old age, respectively. 48% of sampled respondents were full time workers; nearly 27% of the sampled respondents were high school or university student, and around 12% of the sampled respondents were housewives.

In terms of activity and travel, the respondents allocate the majority of their time for in home activities. The respondents spent an average 552 minutes for in-home non-mandatory activity per day, 321 minutes for out-of-home mandatory activity during weekday, while the time respondents allocate for out-of-home non-mandatory activity is around 128 minutes per day. Total amount of time respondents allocate for travel is about 85 minutes per day.

[1] The weekend in Egypt is Friday and Saturday. Sunday is an ordinary workday.

A secondary data source used in the analysis is a zonal-level land-use, transport level of service and demographic data obtained from the Greater Cairo Transportation Master Plan Study (CRETS, 2001). The secondary data provides the following information for each Traffic Analysis Zones (TAZ): (a) total employment and employment levels disaggregated by sector, (b) zonal population, income and age distribution of the population, (c) the area type of the zone (CBD zone, an urban zone, a suburban zone, or a rural zone), and (d) transportation system level of service in terms of average travel, waiting, and access time for bus and transit services. This information was used to study the impact of the characteristics of the residence zone on household interactions in daily activity and travel patterns.

Sample formation and variables used

As indicated early in this paper, two population groups are of interest in this study, those currently with Internet access at home and those without Internet access at home. This is needed to distinguish differences in intra-household interactions and telecommunication impacts between the households in the two groups. Understanding the differences can help to identify the effects of Internet availability and use on household interactions in daily activity and travel patterns. Further, we limit the analysis to multi-person households, single person households are excluded from the analysis, as the question of interpersonal dependencies in household does not arise in this context.

The Endogenous Variables

Solo and joint activity participation
The process of generating the solo and joint activity participation endogenous variables involved several steps. First, activity and travel data for both weekday and weekend are pooled together in one data set. Second, although 42 activity type are reported in the data set, there were several categories that contained only very few non-zero observations. Therefore, based on a preliminary analysis of the distributions of various activity categories and travel behaviour literature (Lu and Pas, 1999; Golob, 2000; Kuppam and Pendyala, 2001), we used the following five activity purpose typology in the modelling process: (1) mandatory (such as work, work-related, school, school related, personal care and sleep), (2) physical maintenance (including: grocery shopping, non-daily shopping, shopping using delivery services, leisure window shopping, banking, purchasing bills, child care, housework. Preparing and eating meals, pick-up/drop-off passengers, and medical care), (3) physical recreational (including: restaurants, meals, reading , hobbies and exercising, cinema/theater/ library, listening to music, watching T.V/DVD'S, playing games, religious, visiting family/friends, and rest and relaxation), (4) in-home virtual activities (including: e-shopping, e-banking/paying bills, online restaurant/hotel/ cinema reservations, e-government services, web serving, downloading, and chatting), and (5) travel activities. As suggested by Gliebe and Koppelman (2002), mandatory activities were not considered since they are individual specific and cannot be allocated or participated jointly across household members. Third, we disaggregated the physical maintenance and recreational activities based on the location of the activity into: out-of-home physical maintenance, in-home physical maintenance, out-of-home physical recreational and in-home physical recreational. Fourth, all of in-home virtual activities, in and out-of-home physical maintenance and recreational activities, and travel activities were disaggregated into seven categories in terms of companion type: solo out-of-home maintenance, joint out-of-home maintenance, joint out-of-home recreational, solo in-home physical maintenance, joint in-home physical maintenance, solo in-home physical recreational, joint in-home physical recreational, solo virtual activities, joint virtual activities, and joint travel. Solo out-of-home recreational and travel activities were not considered in the

analysis because of low participation share. Fifth, for each of the seven activity types, total duration was computed over each individual's two diary days. Travel frequency was computed by summing the travel frequency for all activity types.

Finally, two separate data sets were prepared for the two household groups. Thus we have a total of seven solo and joint activity participation variables for the households with internet access at home group. In a similar manner, five solo and joint activity endogenous variables are employed for the households without internet access at home group, with the solo and joint in-home virtual activities were specified only for the households with internet access at home group.

Telecommunication Variables

The process of generating the telecommunication endogenous variables involved several steps. First, total telecommunication frequencies by three modes (land line calls, mobile phone calls, and SMS) were computed over each individual's two days. Second, we aggregated the four telecommunication purposes reported in the data into two categories: 1) work-study (including: work –study telecommunication purpose), and 2) social purpose (including: chatting, social related, and for meeting appointment purposes).similar to the solo and joint endogenous variables, we limit our analysis to the social purpose. Finally, all of social purpose telecommunication frequencies of land line, mobile phone, and SMS were disaggregated into two categories of within and out-of family telecommunication based on "with whom" the telecommunication was done. This results into six pairs of telecommunication variables as follows: within family land line calls, within family mobile phone calls, within family SMS, out-of-family land line calls, out-of-family mobile phone calls, and out-of-family SMS.

The Exogenous Variables

Several types of exogenous variables were considered as potential determinants in the analysis. These included household socio-demographic, individual socio-demographics, location and transportation level of service variables, technological familiarity and frequency of religious activities variables. The household socio-demographic characteristics considered in the specifications included percentage of adult females inside the household, number of children by age, number of household vehicles, household income, family type (*i.e.,* whether the individual belongs to a nuclear, couple, etc), and dwelling type (*i.e.,* whether the individual lives in a rented, or owned units). The individual socio-demographics variables explored in the specifications included gender, age, license holding to drive, and employment ststus. The location and transportation level of service variables included the area type variables classifying residential zones into one of the four categories (CBD, urban, a suburban zone, and rural), employment density of the residential zone and the proportion of jobs in retailing and services as indicators of land-use diversity. The land-use diversity variable is computed as a fraction between 0 and 1. Zones with a value closer to one on this land-use diversity variable have a richer land-use mix than zones with a value closer to zero (Bhat and Gossen, 2004).

The selection of exogenous variables was guided through a systematic process of adding groups of variables to the initial model and evaluating the inclusion of the variables based on the statistically significant of the variables, and assessing the improvement of model fit.

METHODOLOGY

The methodology of structural equation model (SEM) is applied in this research, because of our desire to estimate a simultaneous model of the interrelationships among ICT use, socio-demographics, and in-home and out-of-home solo and joint "with whom" physical and virtual activity and travel participation.

SEM has recently become a popular modeling tool in transport studies (Golob et al 1997; Golob, 2000). Moreover, SEM is attractive because it distinguishes between direct, indirect, and total effects of variables (Bollen, 1989). A total effect consists of a direct and one or more indirect effects. The SEM used here consists of two equations: a measurement model and a latent model. In the measurement model, latent variables are explained by their indicators (observed variables). The structural model, relationships between the latent variables can be modeled. The structure model captures the regression effects of exogenous (independent) variables on endogenous (dependent variables), and the regression effects of endogenous variables on each other. The SEM used here consists of two equations (Bollen, 1989):

Structural equation:

$$\eta = \mathrm{B}\eta + \Gamma x + \zeta$$

Measurement equation:

$$y = \Lambda\eta + \varepsilon$$

where

η=m×1 vector of latent endogenous variables,
x= q×1 vector of observed exogenous variables,
y= p×1 vector of observed endogenous variables,
ζ= m×1 vector of error terms associated with the latent variables, with the standard assumption that $[\mathrm{E}(\zeta) = 0]$ and ζ is not correlated with x,
ε= p×1 vector of measurement errors.

Further, Φ denotes the covariance matrix of x, Ψ represents the covariance matrix of ζ, and Θ_ε is covariance matrix of ε. B is the (m×m) coefficient matrix showing the direct effects between each pair of the m latent variables, Γ is the (m×q) coefficient matrix for the regression effects of x on η, Λ is a (m×p) matrix of coefficients in the measurement model relating the latent variable constructs and the observed endogenous variables. The structure parameters are the elements of the three matrices B, Γ and Λ. The fundamental concept of estimating the model presented above is that the population covariance matrix of observed variables (∑) can be expressed in terms of unknown parameters Θ (which includes all the unknown parameters in B, Γ, Λ, Φ, Ψ, and Θ_ε). That is, each element of the population covariance matrix can be written as a function of one or more parameters, or ∑=∑ (Θ). Hence, the parameters Θ can be estimated by making ∑(Θ) be as close as possible to sample covariance matrix S. in order to achieve this, a fitting function $F(S, \sum(\Theta))$ which is to be minimized, is defined. Maximum likelihood (ML) estimation method assuming a multivariate normal distribution was employed for this study. ML estimation has been found to be fairly robust against violations of multivariate normality and improper solutions as a function of sample size (Golob, 2001, Golob, et al, 2002). The ML fitting function that is minimized is:

$$F_{ML} = \log\left|\sum(\theta)\right| + tr(S\sum^{-1}(\theta) - \log|S| - (p+q)$$

Two separate non-recursive structural equations models with latent constructs were constructed using LISREL software version 8.8 (JÖreskog et al, 2001) to compare solo and joint activity participation and travel behaviour between the two groups with and without internet access at home. With each model, parameters were estimated of the relationships between the endogenous and exogenous variables, and among the endogenous variables. Further, in order to assess the relationships between telecommunications demand and solo and joint activity and travel participation, two endogenous latent variables "within family telecommunication demand" and "out family telecommunication demand" were specified for the two models. The two latent variables can be interpreted as household member's virtual social network within and out-of-family. These two latent variables were measured by observed frequencies of land line calls, mobile phone calls, and SMS classified by within and out-of-family. The latent model and the structural model were estimated simultaneously. Maximum likelihood estimation was used to obtain the results presented here. In addition to a covariance matrix, an asymptotic covariance matrix was calculated as input for the analysis. In this way, standard errors and chi-squares were corrected for non-normality (JÖreskog et al, 2005). The measurement model and the structural model were estimated simultaneously.

A wide range of indicators has been proposed for determining the model goodness of fit. Frequently used measures include (Golob, 2001, Ullman, 1996, Mokhtarian et al., 1999): the root mean square error of approximation (RMSEA), (a good model has an RMSEA value of less than 0.05); and the comparative fit index (CFI), (a good model should exhibit a value greater than 0.90). Another goodness of fit measures is the Satorra-Bentler chi-square, which takes non-normality into account by using asymptotic covariance (JÖreskog et al, 2005).

MODEL SPECIFICATIONS

The model for households with internet access at home was initially specified with thirteen direct effects among the solo and joint endogenous variables, one direct effect among latent demand variables and four direct effects between the solo and joint endogenous variables and telecommunication demand variables. The model for households without internet access at home uses a similar model structure; however; nine direct effects among the observed endogenous variables were specified. The hypothetical casual relationships among the observed endogenous variables and between the latent and endogenous variables are depicted in Figure 1. The rectangle boxes represent observed endogenous variables, while the ellipses represent latent variables. The casual relationships represented in the model are shown by single headed arrows between pairs of endogenous variables. Similarly error covariance's postulated in the model are shown by curved double arrows in the figure.
The postulated direct effects represent three types of casual relationships:

1. *Relationships between latent telecommunication variables*. Specifically, it is expected that latent "within family telecommunication demand" has a positive direct effect on "out of family telecommunication demand" latent variable. This relationship is postulated as a manifestation that telecommunications offer the opportunity to build up, maintain, and expand social relationships.
2. *Relationships among solo and joint activity endogenous variables*. It is believed that two major kinds of effects may exist in terms of the intra-personal and inter-personal relationships and trade-offs between the times allocated to different solo and joint in-home, out-of-home, and virtual activity types. First, we expect substitution effects

between joint and solo participation for activities of the same type within each level of daily activity participations. These are operationalized in the negative direct effects from joint out-home maintenance to solo out-of-home maintenance, joint in-home maintenance to solo in-home maintenance, joint in-home recreational to solo in-home recreational, and joint in-home virtual to solo in-home virtual. These relationships postulate our hypothesis that participation in joint activities constitutes a core preference of household members and has a high priority over solo activities. Further, as the findings from the survey data suggest, substitution effects are expected between each type of joint in-home physical activity and the same type of joint out-of-home activity (negative direct effects from joint in-home physical maintenance to joint out-of-home maintenance and from joint in-home physical recreational to joint out-of-home recreational). Another two substitution relationships are expected to exist: 1) negative direct effect from solo out-of-home maintenance to solo in-home maintenance activity, and 2) negative direct effects from solo in-home virtual activity to solo in-home maintenance and recreational activities. This is presumably a reflection of role specialization and task allocation with regard to solo in-home and out-of-home maintenance activities. Second, we hypothesize that there are a complementary relationships (positive direct effects) between joint in-home virtual and joint out-of-home maintenance and recreational activities. Moreover, we expect complementary relationships between joint activities within each level of daily activity participations. This is postulated in the positive direct effects from joint out-of-home maintenance to joint out-of-home recreational, and from joint in-home physical maintenance to joint in-home physical recreational activities. Also, since travel is derived demand, it is expected that out-of-home joint maintenance and recreational activities have a positive direct effects on joint travel frequency.

3. *Relationships between latent telecommunication demand constructs and solo and joint activity participation*. We postulate that the major pressure on telecommunication demand will come from the joint out-of-home activities. These are shown in the positive direct effects from joint out-of-home maintenance and recreational activities to within and out-family-telecommunication demand latent variables.
4. *Relationships between exogenous and endogenous variables*. we hypothesis that higher levels of employment, higher fraction of high education students inside the household, presence of children and multiple cars tend to reduce joint activity between household members. While, percentage of females inside the household tend to increase joint activity propensity due to tradition and gender role issues. Households with internet available enjoy connectivity to a wide horizon of opportunities, services and social network. Households with one car tend to engage in more out-of-home activities than zero-car households, due to greater mobility and access to activity locations.

In addition to the effects between the endogenous variables, we also specified free disturbance-term correlations between corresponding pairs of observed telecommunication indicators that were used for constructing the latent variables. It is reasonable to believe that the unexplained portions of six pairs of within and out-of-family indicators variables to be correlated (between within family land line calls and out-of- family land line calls, within family mobile phone calls and out-of- family mobile phone calls and within family SMS and out-of-family SMS), with positive correlation between error terms of two indicator variables indicates that unobserved factors affect the two variables in the same direction, whereas, negative sign shows that the unobserved factors affect the two indicator variables in opposite ways. The three specified error covariances are shown in Figure 1.

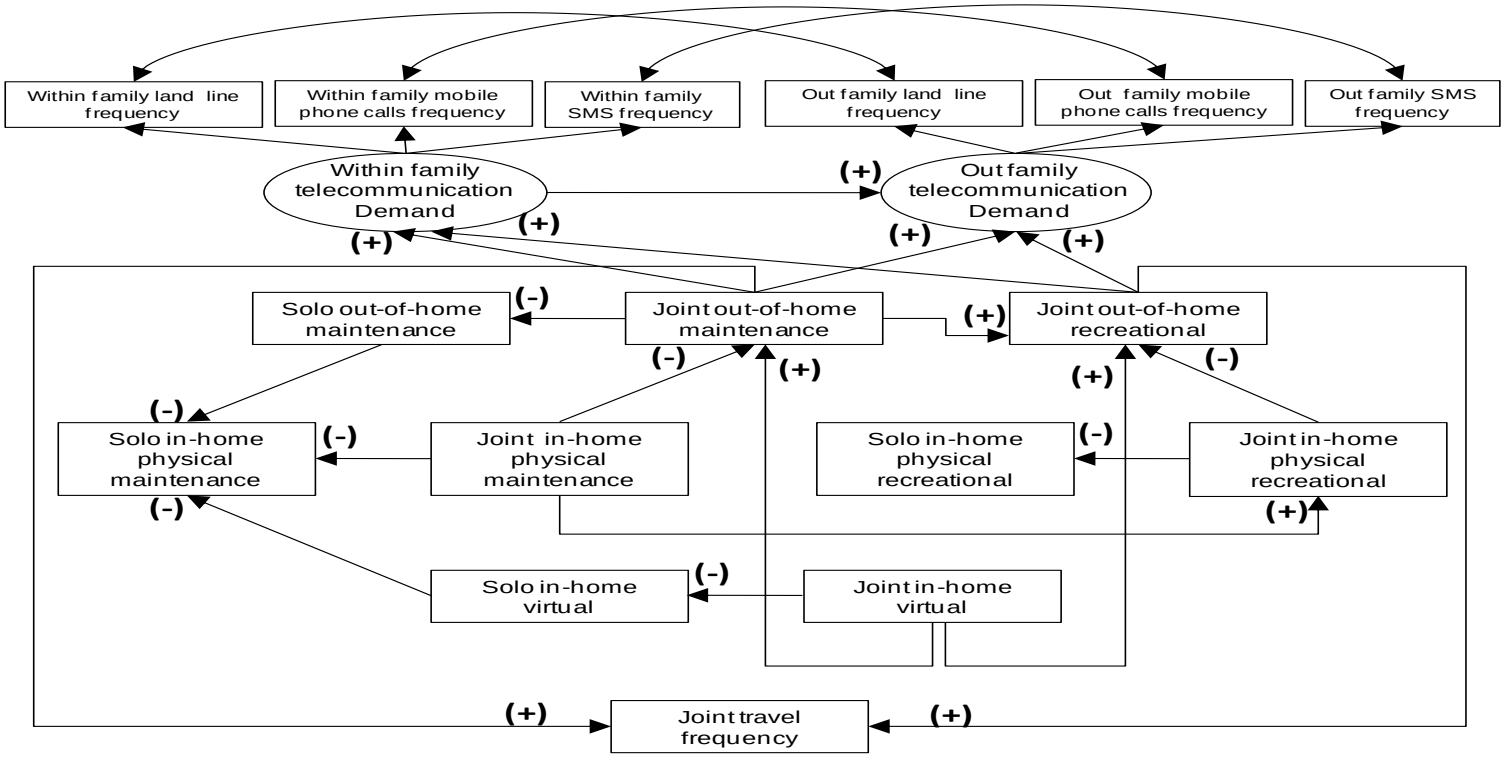

Figure 1 – Postulated Direct Effects between Endogenous Variables.
(Note: solo and joint in-home virtual endogenous variables were only specified for the household with internet access at home group).

STRUCTURE EQUATIONS MODELING RESULTS

For ease in presentation the results are presented in two broad sections. The first section presents and interprets the results for households with internet access at home model. The second section discuses the results for households without internet access at home model.

Model A: Households with internet access at home model

Specification refinement and overall model fit

Similar to Lu and Pas, (1999), different specifications of the model, adding/deleting different direct effects between endogenous variables, were tested in details. The final model indices of overall model fit show that the model fit very well (Table 2). The model Satorra-Bentler $\chi 2$ was 177.05 with 167 degree of freedom, corresponding to probability value of 0.962. This indicates that the model cannot be rejected at the *P* =0.05 level. Other measures of fit such as comparative fit index (CFI= 0.969), Tucker-Lewis index (TLI= 0.960), and root mean square error of approximation (RMSEA= 0.032) are also found to be acceptable by model fit criteria for structural equations models.

The casual relationships among the observed endogenous variables and between the latent and endogenous variables of the final model are shown in Figure 2. The final model endogenous structure differed in some details from the postulated structure of Figure 1. In particular, the model output suggested the existence of four important complementary casual effects that were missing from the initial model specification. These relationships are: in-home joint virtual affects latent out-of-family construct, joint travel affects latent out-of-family construct, solo out-of-home maintenance affects solo in-home physical recreational and solo in-home maintenance affects solo in-home recreational, with all signs are being positive. Similarly, other links were added according to their significance as suggested by the model output and their interpretability, while links that were not significant were deleted. These are shown in Figure 2 with bolded arrows with positive or negative coefficients for added links and dotted arrows for deleted links.

Noteworthy, contrary to our hypotheses no direct effect between the latent telecommunication demand variables was found. However, the three specified error covariance were tested. The one that provided the best statistical results included one positive error covariance for within and out-of-family land line calls observed indicators (error covariance = 0.842 with *t*-statistics=2.877,and correlation=0.351). This implies that the more one use the land line to telecommunicate with his family members, the more the opportunity to use land line to telecommunicate with others out of his family. In addition, a negative error covariance between within family SMS and out-of-family mobile phone calls was suggested by the model (covariance=-0.518 with *t*-statistics= -1.725, and correlation= -0.261). These results are intuitive, since they indicate the existence of complementary and substitution impacts among and cross telecommunication modes.

The final model estimation results and their *t*-statistics are reported in Tables1-3. In these tables standardized coefficients are given. All the model coefficients are statistically significant at a *p*-value of 0.05 or lower, except in a few cases where excluding an insignificant variable degraded the interpretability of the rest of the model. Table 1 lists the estimates of the observed variables used to construct the latent telecommunication use variables. Table 2-3 lists the effects among endogenous variables and effects of exogenous variables on endogenous variables in direct and total effects. The rest of this section will explain the results listed in these three tables in terms of relationships distinguished in the previous section. The sign of the relevant coefficient estimates indicate the direction of the effects.

The latent measurement model

The measurement model describes how well the two latent demand variables, “within family” and “out-of-family” are measured by the frequency of land line calls, Mobile phone calls and SMS classified by within and out-of the family telecommunications. Table 1 shows the standardized parameters estimates and *t*-values of the observed indicators, with the land line observed indicators were fixed to one for both the latent variables. This is done to obtain a scale that can be interpreted for latent demand constructs. As indicated by the *t*-statistics, all observed indicators for the latent variables perform well. Standardized observed indicators parameters (see Table 1) indicated the strengths of the contribution of each observed variable to the measurement of the latent variable. The larger a parameter is, the more variances of the observed variable the latent variable explains, and the more the observed variable contributes to the latent measurement.

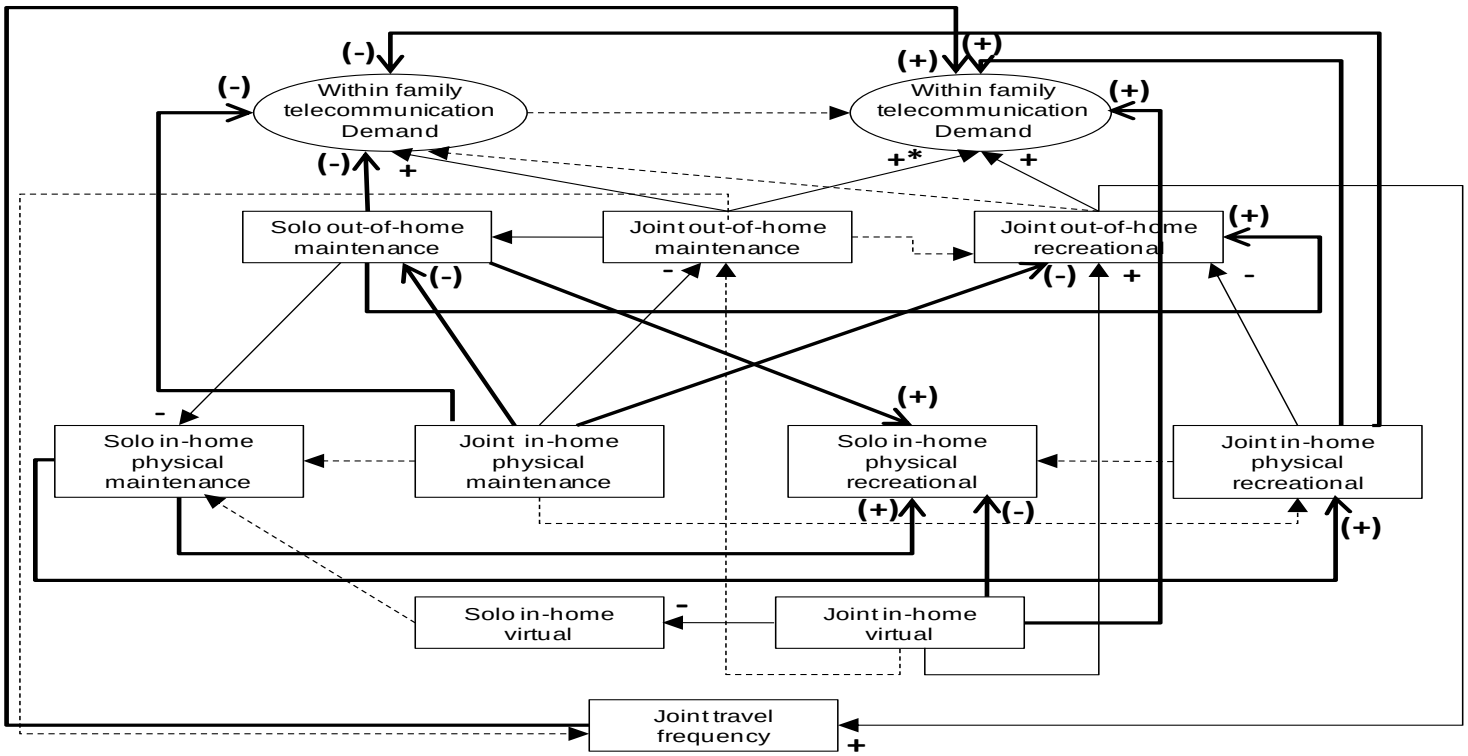

Figure 2- Direct Effects between Endogenous Variables (Model A: Households with internet access at home group).

(Note- - - ▶ indicates insignificant deleted links; ⟶ with + or - : indicates significant links similar to hypothesized; ⟶ with (+) or (-): indicates added direct effects different from hypothesized; *: indicates direct effect with different sign from hypothesized).

Table1-Standardized Parameters Estimates of the Observed Indicators for the Latent Variables (Model A: Households with internet access group)

Latent Variables	**Parameters estimate**	**t-statistic**
Within Family Telecommunication		
Within family land line calls frequency	0.277[a]	
Within family mobile phone calls frequency	0.760	2.269
Within family SMS frequency	0.773	2.264
Out-of-Family Telecommunication		
Out-of-family land line calls frequency	0.472[a]	
Out-of-family mobile phone calls frequency	0.812	4.478
Out-of-family SMS frequency	0.718	4.242

[a] Items fixed to 1

Relationships between the solo and joint endogenous variables

Tables 3 and 4 present the results of the model in direct and total effects. Three distinct types of relationships obtained for the final model are of interest. These are intra-personal physical

activity-travel interactions, intra-personal virtual-physical activity interactions, and inter-personal interactions. First, consider the inter-personal interactions. The findings are logically consistent and reflect the special nature of inter-personal interactions in households. As expected, joint out-of-home maintenance duration impose a significant negative direct effect on solo out-of-home maintenance duration, while a significant positive total (indirect) effect of joint out-of-home maintenance duration on solo in-home physical maintenance has been found. This may indicate a preference for joint engagement in these activities. Further, this could be attributed to the role specification and task allocation inside the household, in the sense that most of out-of-home household maintenance activities are participated jointly by the male and female heads of the household, while female spouse tend to carry more in-home physical maintenance responsibilities than male head.

Similarly, although there is no direct effect of joint in-home physical maintenance duration on solo in-home physical maintenance duration, there appears a positive total (indirect) effect, which is channelled through the duration of solo out-of-home maintenance activities. This is again a piece of evidence on the role specification and task allocation inside the household.

Additionally, a significant positive direct effect of solo out-of-home maintenance duration on duration of joint out-of-home recreational activities was found. A potential explanation could be that individuals who are allocated to take a part in solo maintenance activities outside the home also exhibit a greater tendency to participate in joint out-of-home recreational (more likely with non-family members). Similarly, a significant positive direct effect of solo in-home physical maintenance duration on joint in-home physical recreational was found, and could be explained along similar lines. On the other hand, solo in-home physical maintenance has a significant negative total (indirect) effect on joint out-of-home recreational. Additionally, the results show that solo out-of-home maintenance affects joint in-home recreational negatively. These later results suggest a hierarchical process, in the sense that decisions about recreational are made conditional on time spent on maintenance. These findings on interpersonal tradeoffs are consistent with the literature (Golob and McNally, 1997, Srinivasan and Bhat, 2005). However, contrary to the literature suggesting that these trade-offs are stronger for within level of daily activity participation (i.e. in-home level, out-of-home level), we find that the trade-offs are only exist across levels of daily activity participation (i.e. between in-home and out-of-home).

Finally, as expected, a strong substitution effect was found between joint in-home virtual and solo in-home virtual, with a significant negative direct effect from joint in-home virtual to solo in-home virtual was found. This is largely in line with the hypothesis presented in model specifications section.

Also, a significant substitution effect was found between joint in-home virtual and solo in-home physical recreational. This effect may be indication that individuals have a higher preference for virtual recreational activities over physical activities. That is individuals are more likely to perform joint recreational activities online compared to solo physical activities.

With respect to intra-personal physical activity-travel interactions, the model results provide some very logical consistent finding with our hypothesis. Here are the main findings:

- The model has clearly shown that there are a strong trade-offs between joint in-home and out-of-home physical maintenance and recreational activity engagement behavior. Durations of joint in-home physical maintenance and recreational activities are both found to have a significant negative effect on corresponding joint out-of-home activities. Moreover, joint in-home physical maintenance has a significant

negative direct and total effect on joint out-of-home recreational.

- However, a complementary relationship was found between joint-in-home physical maintenance and joint-in-home physical recreational.
- Another complementary relationship was found between duration of joint out-of-home recreational and joint travel frequency. On the other hand, the results show that joint-out-of-home maintenance has a negative total (indirect) effect on joint travel frequency. This is intuitive; perhaps it indicates that individuals engage frequently in joint recreational activities with shorter episode duration and trips may be destined to nearby locations, while engage less frequently in joint out-of-home maintenance with longer episode duration.

Looking at the intra-personal virtual-physical interactions, as expected, a strong complementary effect was found between joint in-home virtual and joint out-of-home recreational, with a significant positive direct effect from joint in-home virtual to joint out-home recreational was found.

Relationships between latent telecommunication demand variables and solo and joint activity participation variables

The model results provide very consistent findings with our hypothesis. As expected, the strongest causes of demand for telecommunications are from joint out-of-home activity participation. Joint out-of-home recreational has positive and significant direct and total effects on out-of-family telecommunication demand, whilst no direct effect of joint out-of-home recreational on within family telecommunication demand was found. These results may be a reflection of the higher propensity of joint out-of-home recreational activities to be pursued with non-family members or with a combination of family and non-family members, which in turn impose more demand on out-of-family telecommunication. Moreover, joint out-of-home maintenance activity impacts positively (although insignificant) on within family telecommunication demand, but negatively on out-of-family telecommunication demand. This is reasonable since joint out-of-home maintenance activities are mostly pursued with family members only.

As indicated earlier, a positive direct effect of joint in-home virtual activity on out-of-family telecommunication demand was found, with a higher positive total effect being observed. The explanation is that the direct effect of joint in-home virtual on out-of-home telecommunication demand is strongly reinforced by an indirect effect of the same sign caused through the effect of joint in-home virtual on joint-out-of-home recreational. This reflects a “snowballing” effect; that is, the longer the time individuals engage in joint in-home virtual activities, the greater the availability of information about recreational activity opportunities and people of interest, the more likely to participate in those activities and the more demand will be imposed on telecommunication. This is an interesting result which apparently supports our hypothesis that both telecommunication and internet use have a complementary impact on household sociability out-side home. Similarly, the results show that joint travel frequency directly affects out-of-family telecommunication demand positively, which is logical given that joint travel is derived from joint participation in out-of-home activities. This is largely in line with the findings presented in previous Section.

Finally, the model shows that duration of joint in-home recreational has a significant positive direct effect on out-of-family telecommunication demand, while it has a very negative smaller total effect. The negative total effect is caused by the negative indirect effect through joint out-of-home recreational, which serves as the mediating variable. Likely explanation of this is

joint in-home recreational serve as a proxy of performing in-home social activities (hosting friends, relatives), while such social interaction needs are more demanded in the case of joint out-of-home recreational activities.

Relationships between the exogenous and endogenous variables

The results indicate that adults in couple households are unlikely to participate in any of in-home activities, while they are very likely to pursue joint out-of-home recreational activities. This is reasonable. Couple households have fewer household responsibilities than other household types which in turn increase the time available for them for recreational activities. In addition, as the case of the study sample, young couple households are likely to be in their early marriage years. Therefore, both of them want to spend more time participating in joint recreational out-of-home activities. Furthermore, couple household's exhibit more demand for "within family" telecommunications. The later result is to be expected, and reflects the derived demand of telecommunications that stems from the individuals needs to coordinate their schedules to be able to generate feasible joint activity participation. As the percentage of adult females in the household increase, strong tendency away from out-of-home joint recreational participation was found. The negative sign of this coefficient may represent a tendency for households with higher percentage of adult females to be more oriented to in-home activities. This is also an evidence of the existence of strong traditional gender role effect in addition to that.

Adult employed full-time are unlikely to participate in joint-out-of-home maintenance activities relative to other adults, but are more likely to participate in joint out-of-home recreational activities and joint travel, perhaps with non family members such as friends or colleges. The latter result explains the positive total effect on out-of-family telecommunication demand.

Perhaps one of the most interesting effects found in the model are those related to technological familiarity variable. Individuals familiar with e-government services are more likely to participate in joint in-home virtual activities followed by solo out-of-home maintenance. This leads indirectly to a positive effect on duration of joint out-of-home recreational, which in turn influences the frequency of joint travel in positive direction. Furthermore, positively influences the out-of-family telecommunication frequency. This is intuitive, and reflects that internet use have a complementary effect on household sociability out-side the home.

Table 2- Direct Effects Given in standardized coefficients (Model A: Households with internet access group)

	Affected variable											
	Telecommunication		Out-of-home activity			In-home physical activity				In-home virtual activity		Travel
Causal Variable	Within family	Out-of-family	Solo maintenance	Joint maintenance	Joint Recreational	Solo maintenance	Joint maintenance	Solo Recreational	Joint Recreational	Solo virtual	Joint virtual	Joint Travel
Endogenous Variables												
Out-of-home activity participation												
Solo maintenance	-0.328				0.194	-0.337		0.249				
Joint maintenance	0.077	-0.158	-0.311									
Joint Recreational		0.660										0.502
In-home physical activity participation												
Solo maintenance								0.274	0.288			
Joint maintenance	-0.474		-0.228	-0.135	-0.215							
Joint Recreational	-0.281	0.254			-0.542							
In-home virtual activity participation												
Joint virtual		0.095			0.172			-0.406		-0.272		
Travel												
Joint Travel		0.458										
Exogenous Variables												
Couple household							-0.267				0.168	
Percentage of adult females					-0.211							0.153
Number of vehicles				0.381								
Full time worker				-0.227	0.198					-0.232		0.240
Technological familiarity			0.267								0.416	0.241

Table 3- Total Effects Given in Standardized Coefficients (Model A: Households with internet access group)

	Affected variable											
	Telecommunication		Out-of-home activity			In-home physical activity				In-home virtual activity		Travel
Causal Variable	Within family	Out-of-family	Solo maintenance	Joint maintenance	Joint Recreational	Solo maintenance	Joint maintenance	Solo Recreational	Joint Recreational	Solo virtual	Joint virtual	Joint Travel
Endogenous Variables												
Out-of-home activity participation												
Solo maintenance	-0.301	0.195			0.246	-0.337		0.157	-0.097			0.124
Joint maintenance	0.171	-0.218	-0.311		-0.077	0.105		-0.049	0.030			-0.039
Joint recreational		0.890										0.502
In-home physical activity participation												
Solo maintenance	-0.081	-0.066			-0.156			0.274	0.288			-0.078
Joint maintenance	-0.428	-0.207	-0.186	-0.135	-0.261	0.063		-0.029	0.018			-0.131
Joint recreational	-0.281	-0.228			-0.542							-0.272
In-home virtual activity participation												
Joint virtual		0.248			0.172			-0.406		-0.272		0.086
Travel												
Joint Travel		0.458										
Exogenous Variables												
Couple household	0.114	0.097	0.050	0.036	0.099	-0.017	-0.267	-0.060	-0.005	-0.046	0.168	0.050
Percentage of adult		-0.117			-0.211							0.047
Number of vehicles	0.065	-0.083	-0.118	0.381	-0.029	0.040		-0.019	0.011			-0.015
Full time worker	-0.039	0.335	0.071	-0.227	0.215	-0.024		0.011	-0.007	-0.232		0.348
Technological familiarity	-0.080	0.266	0.267		0.137	-0.090		-0.127	-0.026	-0.113	0.416	0.310

Model B: Households without internet access at home model

Specification refinement and overall model fit

As in the case of model A, all statistical goodness-of-fit measures are acceptable. The model Satorra-Bentler $\chi 2$ value was 126.70 with 131 degree of freedom. The likelihood ratio test statistics is associated with the null hypothesis that the estimated model is consistent with the observed sample variance-covariance matrix. This value corresponds to a probability value of 0.590, indicating that the model definitely cannot be rejected at the p=0.05 level. The other measures of fit are also in line with agreeable standards of fit for a structural equations model of this nature.

Similar to model A, the casual structure between the endogenous variables was pre-specified based on the initial postulated structure of Figure 1. The initial model structure was adjusted depending on 95 percent statistical significance of the causal relations previously assumed. New relations were tried till a perfect fit was obtained. The final model is depicted in Figure 3. As shown in Figure 3, the final model has fifteen direct effects, with four new relations were found to be important in explaining the casual structure. These are shown as bolded arrows with positive or negative coefficient indicators in Figure 3. On the other hand, four of the postulated effects were rejected at the p=0.05 level, and these are shown by dotted links in Figure 3.

Although, no direct effect between the two latent telecommunication demand variables was found, two of the postulated error covariance (Figure 1) found to be statistically significant. The error covariance for within family land line calls and out-of-family land line calls is 0.458 with t-statistics=2.635, and correlation=0.385; the error covariance for within family mobile phone calls and out-of-family mobile phone calls is 0.508 with t-statistics=2.218, and correlation=0.260.

Tables 5 and 6 present the outcomes of the final model in direct and total effects. Table 4 presents the results of latent measurement model. In these tables standardized coefficients are given, which facilitate the comparison of the magnitude of the effects. All the coefficients presented are significant at a p-value of 0.05 or lower, unless indicated otherwise.

The latent measurement model

Similar to model A, the measurement model was initially specified with the two latent demand variables “within family telecommunication demand” and “out-of-family telecommunication demand” each is measured by the frequency of land line calls, Mobile phone calls and SMS. However, the final model suggested that a better model fit would result by dropping two indicators with low loadings on their targeted latent variables namely, within family SMS frequency and out-of-family SMS frequency. Table 4 shows the standardized parameter estimate of the observed indicators and their associated t-values, with the land line observed indicators were fixed to one for both of the two latent variables. Mobile phone score highly on “within family telecommunication demand” latent variable, while it has a small loading on out-of-family telecommunication latent variable.

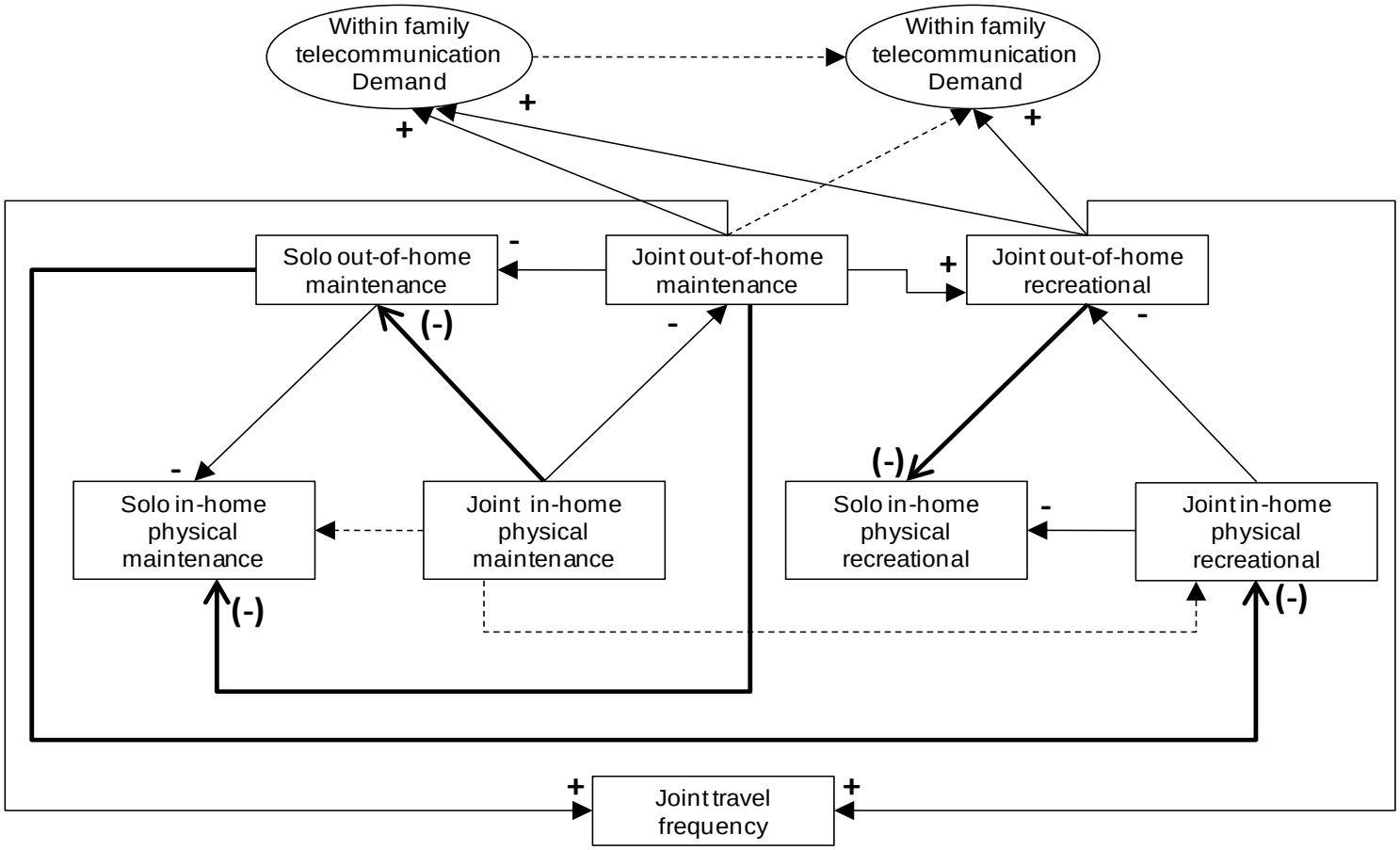

Figure 3- Direct Effects between Endogenous Variables (Model B: Households without internet access at home group).

(Note: - - - -► indicates insignificant deleted links; ——► with + or - : indicates significant links similar to hypothesized; ——→ with (+) or (-): indicates added direct effects different from hypothesized; *: indicates direct effect with different sign from hypothesized).

Table4-Standardized Parameters Estimates of the Observed Indicators for the Latent Variables (Model B: Households without internet access at home group).

Latent Variables	**Parameters estimate**	**t-statistic**
Within Family Telecommunication		
Within family land line calls frequency	0.513[a]	3.158
Within family mobile phone calls frequency	0.736	
Out-of-Family Telecommunication		
Out-of-family land line calls frequency	0.035[a]	
Out-of-family mobile phone calls frequency	0.093	1.674

[a] Items fixed to 1

Relationships between the solo and joint endogenous variables

The finding shows that inter-personal and intra-personal interactions in daily activity and travel behaviour of the households without internet access at home group are different from those with internet access at home group. First, with respect to inter-personal interactions, here are the main differences:

- Strong substitution effect was found between joint in-home physical recreational and solo in-home physical recreational, with a significant negative direct effect from joint in-home physical recreational to solo in-home physical recreational was found. Similarly, the model suggests that duration of joint out-of-home recreational has a significant negative direct effect on duration of solo-in-home physical recreational.
- Duration of solo out-of-home maintenance has a significant positive direct effect on duration of joint in-home recreational.
- Duration of joint out-of-home maintenance has a significant negative direct effect on solo in-home physical maintenance.

Moving to intra-personal interactions, here are the main differences:

- The model suggests a clear complementary relationship between joint out-of-home maintenance and joint out-of-home recreational. Apparently, these activities tend to be combined. Furthermore, complementary relationships are also seen in the interaction between joint out-of-home maintenance and recreational and joint travel frequency. These results suggest that individuals in this group are more likely to participate in shorter but more frequent out-of-home maintenance and recreational activities.

Relationships between latent telecommunication demand variables and solo and joint activity participation variables

Tables 5 and 6 show that, the total and direct effects of all of joint-out-of-home activities duration on telecommunication demand variables are all positive, which seems to be consistent with findings reported for the household with internet access group. However, the direct effects of joint-out-home maintenance and recreational activities on telecommunication demand variables in this group are much stronger than household with internet access at home group. Moreover, a significant positive direct effect of joint out-of-home recreational activity on “within-family telecommunication demand” was found in this group, whereas joint-out-of home recreational has neither a direct nor a total effects on “within family telecommunication demand” for those with internet access group. A potential explanation could be that effects of joint activity participation on telecommunication demand are mediated by internet availability at home and propensity to conduct virtual activities. In other words, individuals in households without internet try to compensate their limited connectivity by demanding more telecommunications.

Similar to that of joint out-of-home recreational, Table 6 shows that although there is no direct effect of joint out-of-home maintenance activity duration on “out-of-family telecommunication demand”, there appears a significant positive total effect, implying that more time spent for joint out-of-home maintenance activity leads to more demand for out-of-family telecommunication. This effect comes through the effect of joint out-of-home maintenance on joint-out-of-home recreational. This effect may be indication that individuals who are more inclined to take a part in joint maintenance activities outside the home (more likely with family members) also exhibit a greater tendency to participate in joint out-of-home recreational (more likely with a combination of family and non-family members), which in turn impose more demand on out-of-family telecommunication.

Table 5- Direct Effects Given in Standardized Coefficients (Model B: Households without internet access group)

	Affected variable									
	Telecommunication		Out-of-home activity			In-home physical activity				Travel
Causal Variable	Within family	Out-of-family	Solo maintenance	Joint maintenance	Joint Recreational	Solo maintenance	Joint maintenance	Solo Recreational	Joint Recreational	Joint Travel
Endogenous Variables										
Out-of-home activity participation										
Solo maintenance						-0.443			0.322	
Joint maintenance	0.160		-0.335		0.372	-0.331				0.201
Joint recreational	0.731	7.067						-0.773		0.585
In-home physical activity participation										
Joint maintenance			-0.403	-0.156						
Joint Recreational					-0.302			-0.318		
Exogenous Variables										
Couple household	-0.178			-0.240						
Number of kids less than 6years old					-0.265		0.268	-0.245		
Rented apartment									-0.315	0.191
Full time worker	0.282					-0.302	-0.585	-0.317	-0.462	0.405
Part time worker							-0.234		-0.279	
Frequency of religious activities					0.208	0.270		0.328		
Employment mix diversity			-0.292							

Table 6- Total Effects Given in Standardized Coefficients (Model B: Households without internet access group)

	Affected variable									
	Telecommunication		Out-of-home activity			In-home physical activity				Travel
Causal Variable	Within family	Out-of-family	Solo maintenance	Joint maintenance	Joint Recreational	Solo maintenance	Joint maintenance	Solo Recreational	Joint Recreational	Joint Travel
Endogenous Variables										
Out-of-home activity										
Solo maintenance	-0.071	-0.686			-0.097	-0.443		-0.027	0.322	-0.057
Joint maintenance	0.456	2.856	-0.335		0.404	-0.182		-0.278	-0.108	0.437
Joint Recreational	0.731	7.067						-0.773		0.585
In-home physical activity										
Joint maintenance	-0.043	-0.170	-0.350	-0.156	-0.024	0.207		0.054	-0.113	-0.046
Joint Recreational	-0.221	-2.134			-0.302			-0.084		-0.177
Exogenous Variables										
Couple household	-0.287	-0.684	0.080	-0.240	-0.097	0.044		0.067	0.026	-0.105
Number of kids less than 6years old	-0.205	-1.917	-0.094	-0.042	-0.271	0.056	0.268	-0.025	-0.030	-0.167
Rented apartment	0.069	0.672			0.095			0.027	-0.315	0.247
Full time worker	0.409	1.085	0.205	0.092	0.154	-0.423	-0.585	-0.310	-0.396	0.513
Part time worker	0.071	0.634	0.082	0.037	0.090	-0.048	-0.234	0.011	-0.252	0.060
Frequency of religious activities	0.152	1.472			0.208	0.270		0.167		0.122
Employment diversity mix	0.021	0.200	-0.292		0.028	0.129		0.008	-0.094	0.017

Relationships between the exogenous and endogenous variables

The impacts of exogenous variables on endogenous variables in terms of total effects are shown in Table 6. As expected, the presence of one or more children aged 6 or below appears to significantly increase the duration of joint in-home maintenance activities. On the other hand, presence of one or more children aged 6 or below in the household has a significant negative impact for all of out-of-home solo and joint activity durations. These results support the time-pressure hypothesis, which assume that the presence of children implies more maintenance activities and thus less time for recreational/social activities. This is also may be a reflection of household caretaking and care-sharing responsibility.

Being full or part-time worker impacts negatively on time spent for in-home activities, but positively on joint travel and time use for out-of-home solo and joint maintenance and recreational activities. These results support the hypothesis that employment separates household members for large portion of the day, making joint in-home participation either more difficult to coordinate (due to time constraints) or less desirable. Further, these results may be due to one or both of the following reasons. First, employment level may be seen as an indicator for income-earning potential of the individual, adult employed full-time are more likely to have more income available for participation in recreational out-of-home activities particularly those involving entertainment and socializing. Furthermore, full-time workers tend to have more purchasing power and better affordability for ICT devices and services, thus they are able to communicate more with wider social networks. Second, part-time workers tend to have less time constraint and fewer household responsibilities than those working full-time, which in turn leave more time for out-of-home recreational activities.

The diversity of economical activities of the household residential zone provides interesting results. Economical diversity has positive impacts on the duration of joint out-of-home recreational and on joint travel frequency. On the other hand, has a significant negative impact on duration of solo out-of-home maintenance activities. These results may be a reflection of greater opportunities for recreational activities, and good distribution of opportunities for shopping within close proximity, in residential zones with more diverse in economical activities.

Finally, the results show an interesting statistically significant and positive direct effect of frequency of religious activities on duration of joint-out-of-home recreational activities, with a high total positive effect on demand for out-of-family telecommunication has been found. A plausible perspective on this result is that religious activities provide individuals with a wide range of opportunities to socialize with others from their wider society. Furthermore, individuals who participate more in religious activities tend to have more active lifestyles, which in turn tigers in individuals a desire to participate more in community oriented activities.

DISCUSSION AND CONCLUSION

The study reported in this paper has thought to provide more insights into the relationships among household interactions in daily physical-virtual activity and travel, ICT use and socio-demographics. Further, the analysis take account of other factors known to affect the intra and inter-personal dependences associated with daily activity and travel patterns of individuals in Cairo, Egypt. Activity participation and travel behaviour are compared between two population groups: a group currently with internet access at home and those without internet access at home. Understanding the differences is very important in Cairo because

the adoption and use of ICTs continues to grow rapidly. Therefore, it is expected that the growing ICT use will have many reflections on individual activity and travel patterns as well as the household interactions in the near future.

Two simultaneous non-recursive structural equations models with latent variables were proposed and estimated using data from recent two-day activity and travel diary survey conducted in the Greater Cairo Region. The observed endogenous variables are solo and joint out-of-home and in-home physical and virtual activity durations and joint travel frequency. Further, in order to accommodate the possible endogeneity of demand on ICT, two endogenous latent variables "within family telecommunication demand" and "out family telecommunication demand" are specified for the two models. These two latent variables were measured by observed frequencies of land line calls, mobile phone calls, and SMS classified by within and out-of-family.

The modelling effort in this study may be distinguished from previous related studies in several ways. First, the current modelling effort simultaneously captures the intra-personal and inter-personal interactions in daily in-home and out-of-home physical and virtual activity-travel decisions, where some of prior literature was mostly focused on household interactions in daily out-of-home activity participation. Second, this study examines ICT use more broadly by considering a comprehensive set of ICTs, whereas many priori studies have focused on specific virtual activities such as tele-work or tele-shopping. Third, the models explicitly capture the correlations due to shared unobservable factors influencing the choice of telecommunication modes. To our knowledge, this is the first attempt in the literature to address all of the above issues in a comprehensive unifying framework.

Several results from the empirical analysis in the paper are noteworthy. The general findings can be summarized as follows. First, model estimation results indicate that there are strong inter- personal relationships among physical and virtual activity participation and travel. As expected, the models show significant tradeoffs between joint and solo out-of-home maintenance activities. However, the results show a strong role specification and task allocation inside the household, in the sense that both joint in-home and out-of-home maintenance activities have a positive total (indirect) effect on solo in-home maintenance activity. On the other hand, significant complementary relationships were found between solo maintenance and joint recreational for both in-home and out-of-home activities respectively. However, a strong trade-offs were found between solo out-of-home maintenance and joint in-home recreational and between solo in-home maintenance and joint out-of-home recreational suggesting that decisions about recreational activities take place in a hierarchical process. Looking at the inter-personal interactions in daily virtual activities decisions, the results suggest a strong trade-off between joint in-home virtual and solo in-home virtual activities.

With respect to intra-personal activity and travel interactions, the model results provide some interesting findings. The model results revealed that virtual in-home activities have complementarity or generation effects on time use for out-of-home recreational activities. More specifically, individuals who spent more time performing joint in-home virtual activities, the more likely to spent more time for out-of-home recreational activities. Another interesting finding is that there is a positive relationship between joint out-of-home maintenance and joint out-of-home recreational activities, which means that individuals who are more inclined to take part in maintenance activities outside the home may also exhibit a greater tendency to participate in out-of-home recreation.

Furthermore, this study provides another justification for the holistic and comprehensive approach to studying the interrelationships between ICT and household interactions in daily

activity and travel behaviour. The results revealed complementary relationships between joint activity participation and telecommunication demand. The models show that the strongest cause of demand for telecommunications are from joint out-of-home activity participation.

Overall, the results indicate substantial linkages among joint and solo activity participations patterns, household/individual characteristics and travel behaviour. These interactions need to be recognized within the framework of activity based travel modelling for accurate travel forecasting and reliable transportation policy analysis.

To conclude, the empirical results support many of our hypotheses regarding the possible relationships between socio-demographic, ICT use and intra-household interactions in daily in-home and out-of-home physical and virtual activity and travel. Household traditions and believes, social roles, and technological familiarity were found to be the main factors which affect intra and inter-personal interactions. Furthermore, the results suggested additional two inter-related motivations behind joint activity namely opportunity and sociability. Opportunity refers to the ability of the household to engage in different in and out-home activities, which is strongly related to the household levels of virtual as well as physical mobility. Sociability refers to the degree of social network between the household and the wider social world beyond the household.

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