Simultaneous Relationships Between Telecommunications and Activities

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Simultaneous Relationships Between Telecommunications and Activities

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Abstract

The relationships between the use of home phones and cellular phones, and the out-of-home activity and travel of individuals are examined. The use of these telecommunications devices is represented in the study by the frequency of calls, while activity engagement is represented by the time allocated to activities and the number of places visited for out-of-home activities. Likewise travel is represented by the time spent for traveling. We hypothesize that (a) use of telecommunications affects only activity times, and (b) use of telecommunications affects only activity engagement, i.e., the number of places visited. Simultaneous equations model systems are developed with the individual as the unit of decision making, to examine the hypotheses on trip making and the effects of telecommunications. Statistical results suggest that substitution effects prevail between telecommunications and travel when work activities are concerned. Complementary effects, on the other hand, are prevalent for discretionary activities. There appears to be neutral relationships between telecommunications and maintenance activities. The study thus shows that substitution, complementation, modification and neutrality (SCMN) effects do not apply universally to all types of activities.

Keywords

Telecommunications Use, Activity System, Structural Equations

Preferred citation

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Introduction

Telecommunications has become a significant element of our lives since Alexander Graham Bell's invention of the conventional telephone in the 19th century. Since those times, telephone changed and transformed many aspects of modern life as well as spatial relationships and organizations (see Pool, 1977, 1980, 1982, 1983). In fact, practically every aspect of the ways people work and produce things have changed.

Although there had already been a number of products (see Graham and Marvin, 1996[1]), telecommunications devices were too costly to be available to general public in the early days. Later on, the conventional telephone became available to general public and regarded as a family and business asset. The conventional telephone was the dominating mode of telecommunications then. Although fax machines, pagers and other devices were utilized by certain people (e.g., pagers by doctors, fax machines by logistics firms), they were not for general public. Yet gradually people gained access to a variety of telecommunications end-user devices, first with fax machines, then pagers. Deregulation of the telecommunications market then changed the whole situation.

The early 1990s witnessed end-user telecommunications devices flourish. The spread of newly available cellular phones among ordinary citizens has become overwhelming by the second half of 1990s. One of the primary reasons behind this is, as noted above, the deregulation (Cairncross, 1997; for a discussion see Crandall, 1997). The deregulation prompted price reductions of both end-use devices and services. Moreover, fierce competition to attract subscribers has forced companies to diversify their products and excel in services (for example, the fiber optical transmission technique was invented long before it was intro-

[1] Especially the figure given on page 16 in Simon and Marvin (1996) is illlustrative about this.

duced; the fierce competition created by the entry of new companies prompted its introduction into the market).

The increased telephone ownership, the variety of telecommunications devices as well as the volume of telephone traffic in contemporary society compel us to re-examine trip making from the perspective of the use of telecommunications. It has been shown elsewhere based on empirical data (see Senbil and Kitamura, 2003) that, apart from generally accepted contributing factors of activities and trips, e.g., sex, age, and work duration, the number of telephone calls also has significant effects on activity durations and frequencies, hence spatial patterns of behavior in urban area in the medium and long runs.

In this study we extend the analysis of Senbil and Kitamura (2003) by incorporating activity engagement and activity duration into its scope. The objectives of the study are to investigate into the mechanism through which telecommunications influences trip making, and also into the association between telecommunications and activity by the type of activity. To these ends, we deploy simultaneous structural equations models, which incorporate activity time, activity engagement, and trip time as in Golob (2000). In these models, out-of-home activities are divided into categories and trip times are tabulated by the type of activities at the destination. We introduce into the models different causal relationships with alternative hypotheses that (i) telecommunications affects activity times only, and (ii) telecommunications affects activity engagement only.

The empirical analysis of this study reveals the relationships between telecommunications and out-of-home activities by type, and thus the relationships between telecommunications and travel for activities. One of the findings indicates that the causal relations that telecommunications influences activity duration, and activity duration in turn influences the number of visits for out-of-home activities, best fit the observation. The results of model estimation also indicate that the model's goodness-of-fit improves substantially with the introduction of telecommunications variables into the model. Telecommunications is significantly associated with individuals' activity engagement and travel.

Most importantly, the study shows that none of the SCMN effects applies universally to all types of activities. The statistical results suggest that telecommunications reduces work activity while it increases discretionary activities. The former suggests substitution effects between telecommunications and travel when work activities are concerned. The latter implies complementary effects between telecommunications and travel for discretionary activities. There appears to be neutral relationships between telecommunications and maintenance activities. The results that substitution prevails for work activity and complementation for discretionary activities suggest that individuals take advantages of telecommunications technology to enhance the pleasure of their lives.

Background

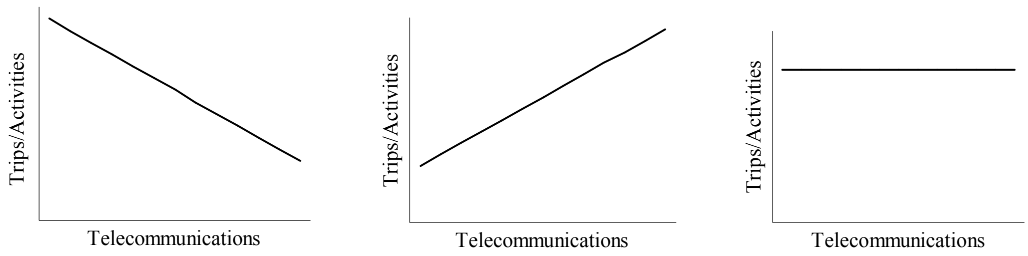
Telecommunications provides a medium to communicate without being at the same place as the other party involved in the communication (for more discussion on this, see Senbil and Kitamura, 2003). Telecommunicating produces interactive relations that have short-term or immediate effects on both travel and activities of the individuals. For example, Claisse and Rowe (1993) report that approximately 30 percent of telephone calls are directly connected to their spatial behaviours within a day.

To assess the effects in an elaborative way, we adopt four generic types of effects in our study considering individuals' short-term travel and activity behaviours:

i. substitution,
ii. complementation,
iii. modification and
iv. neutrality,

hereafter referred to as **SCMN** (see Salomon 1985, 1986 and Mokhtarian, 1990). Figure 1 illustrates these effects in our perspective. They are defined respectively as:

Figure 1 SCMN Relationships



a. Substitution b. Complementation c. Modification or Neutrality

i. **Substitution:** As telecommunications increases, the number of trips or activity durations decrease, hence they are substituted.
ii. **Complementation:** As telecommunications increases, the number of trips and activity durations also increase.
iii. **Modification:** Telecommunications leads to modification of aspects of trips and/or activities, such as the route and timing of trips, and the timing, location and sequence of activities
iv. **Neutrality**: Telecommunications has no effect on either activities or trips.

According to Chapin (1974), there are three types of activities. The first two are biologically necessary and socially obligatory activities. They would be eating, which falls into the category of biologically necessary activities, or working activities, which are obligatory economically to many people. The third type of activities are discretionary activities that individual is free to pursue, such as reading a book for pleasure, or listening to music. At this juncture, Chapin gives four factors that influence activity selection by individuals:

i. propensity,
ii. opportunity,
iii. appropriateness of timing and circumstances, and
iv. environmental context.

The propensity to engage in an activity is affected by motivational and constraining factors. Individuals are motivated by security, affection, achievement and status needs, which are closely related to personal characteristics such as sex, stage in life cycle, or health condition.

Opportunity is related to the spatial distribution and physical reach of activities. In this vein, the location of home is an important determinant of activity engagement by an individual as home location defines the accessibility to many activities. The appropriateness of timing and circumstances refers to the availability of time and other resources for the engagement in an activity. For example, if an individual plans to play tennis, it is probable that he has some arrangement whereby he can use a tennis court somewhere. Lastly an activity is engaged within some environment, which is subject to change both from the "internal sources of change" as called by Chapin, and from economic, cultural and social developments.

In addition to these, we believe that many of the constraints imposed on activity engagement change by telecommunication as telecommunications enhances information availability. This, in turn, affects activity engagement.

The hypotheses and the models

We have examined whether there is any association between the number of telephone calls and activity engagement (Senbil and Kitamura, 2003). The results indicated that the telephone calls and activity engagement are in general positively associated with each other; people who place more telephone calls tend to make more trips. The results thus indicate that complementation effects are more dominant. The scope of analysis is extended in this study to include the time dimension; we attempt to explore the relationships among the time spent for out-of-home activities, the number of places visited for out-of-home activities, and the time spent for traveling.

We postulate two alternative hypotheses about time allocation and activity engagement. In the first hypothesis, it is assumed that an individual allocates a certain amount of time for out-of-home activities, and then decides how many places to visit. Underlying this is the view that the individual allocates time to activities at different locations to best utilize the available amount of time. The time required to travel is determined as a consequence of the choice of activity locations.

At the same time, it can be anticipated that the individual would combine trips effectively such that the activity locations can be visited with a minimal amount of time. This would make more time available for out-of-home activities. On the other hand, activity locations may be so chosen that a substantial amount of time is needed to travel to them. This would tend to decrease the time available for out-of-home activities. These effects are represented as feedback loops in the models used in this study. This will be shown when the base models of this study are described later in this section.

The second hypothesis is based on the assumption that the number of activity locations is determined first. This represents the view that commitments or needs dictate the individual which locations to visit for out-of-home activities. The amount of time spent for activities is thus conditioned on the number of activity locations visited.

In addition to these relationships postulated among the activity time, number of places visited, and time spent for traveling, the effects of telecommunications are introduced into the scope. Namely, we examine the hypotheses that the number of telephone calls influences the time spent for out-of-home activities, and also that it influences the number of places visited for out-of-home activities. Although our previous study has indicated that the number of telephone calls is positively associated with trip making, a more fundamental understanding of the relationship between telecommunications and travel would be gained by examining the relationship between telecommunication and time allocation, or the number of locations visited, for out-of-home activities.

Structural equations models are developed in this study to test the two alternative hypotheses and to evaluate the effects of telecommunications. The variables included in the structural equations models are:

i. durations of activities by type (*activity times*)
ii. number of visits made to pursue activities by type (*activity engagements*)

iii. trip times for work and non-work activities, and trip times for return home trips (*travel times*).

See Golob (2000) for a similar modeling effort.

Chapin (1974) and Golob and McNally (1997) differentiate three types of out-of-home activities, viz., work and work-related activities, maintenance activities (eating, household maintenance, grocery shopping, medical care, etc.), and discretionary activities (leisure, hobby, sports, etc.).This classification scheme is also adopted in this study when tabulating the amount of time allocated to activities. When tabulating the number of visits by purpose, maintenance and discretionary activities are grouped together as non-work activities. Thus the binary classification of work visits and non-work visits is adopted. This is because individuals may pursue both discretionary and maintenance activities at the same visit location.

As telecommunications devices, we focus on the home phone and cellular phone. The logarithm of the frequency of calls made by each device is used to represent telecommunications use, for example,

$$ddTEL = log_2(1 + \mathrm{x}),$$

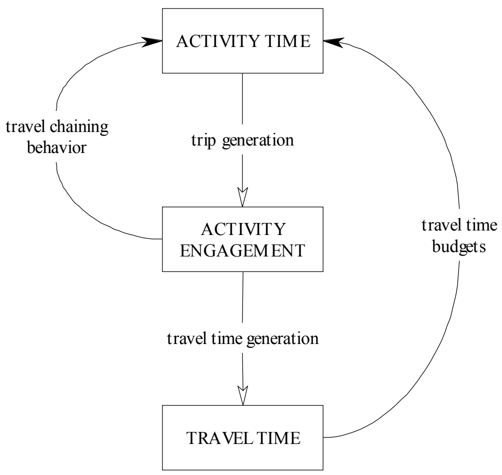
where x refers to the number of telephone calls and *dd* denotes the device, with HP referring to the home phone and CP to the cellular phone.

Two base models are formulated, representing respectively the above two hypotheses. In **Base Model 1** (see Figure 2), which draws from Golob (2000), the activity times, or activity time budgets, by activity type are determined first. The activity times then determine work and non-work activity engagements.[2] Since activity engagement is represented by the number of visits in this study, and because visiting a place necessitates a trip, activity engagement affects travel time in the lowest level.

[2] Note that, unlike Golob (2000), we do not incorporate tours into the models.

The model involves feedback loops. Activity engagements feed back on activity times. As noted earlier, this is due to trip chaining, which would make travel more streamlined, thus tends to provide more time for activities. Likewise travel times feed back on activity times. This is due to time budgeting; if more time is spent for traveling, then there tends to be less time left for activities.

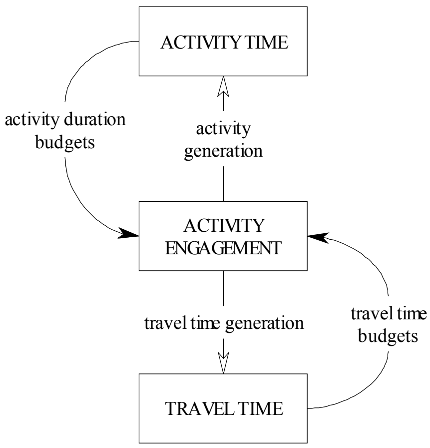
Figure 2 Base Model 1: General relationships among activity time, activity engagement and travel time



see Golob (2000) , page 357.

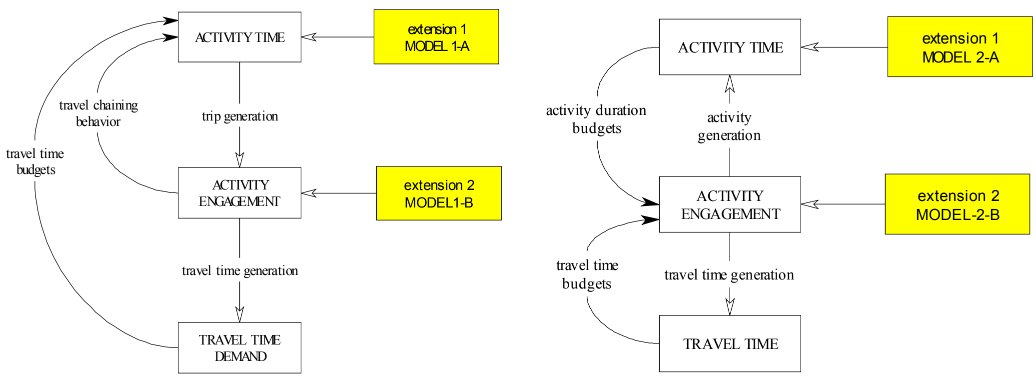
In **Base Model 2** (Figure 3), the causality is reversed between activity times and activity engagements; activity engagements determine activity times. This model thus represents the hypothesis that the individual first determines the number of visits, and then allocate time to those activities for which the visits are made. We introduce feedback loops from both activity times and travel times to activity engagements.

Figure 3 Base Model 2: General relationships among activity time, activity engagement and travel time



In order to assess the effects of telecommunications on activities and trips, the two base models are extended by introducing telecommunicating variables (Figure 4). We propose two extensions. In the first extension, telecommunications only affects activity times (**Extended Models 1-A** and **2-A**). In the second extension it only affects activity engagements (**Extended Models 1-B** and **2-B**). Thus a total of six models are generated: the two base models and four extended models. The Base Model 1 is presented again in Figure 5 with the variables used in the data analysis of this study.

Figure 4 Extended Models



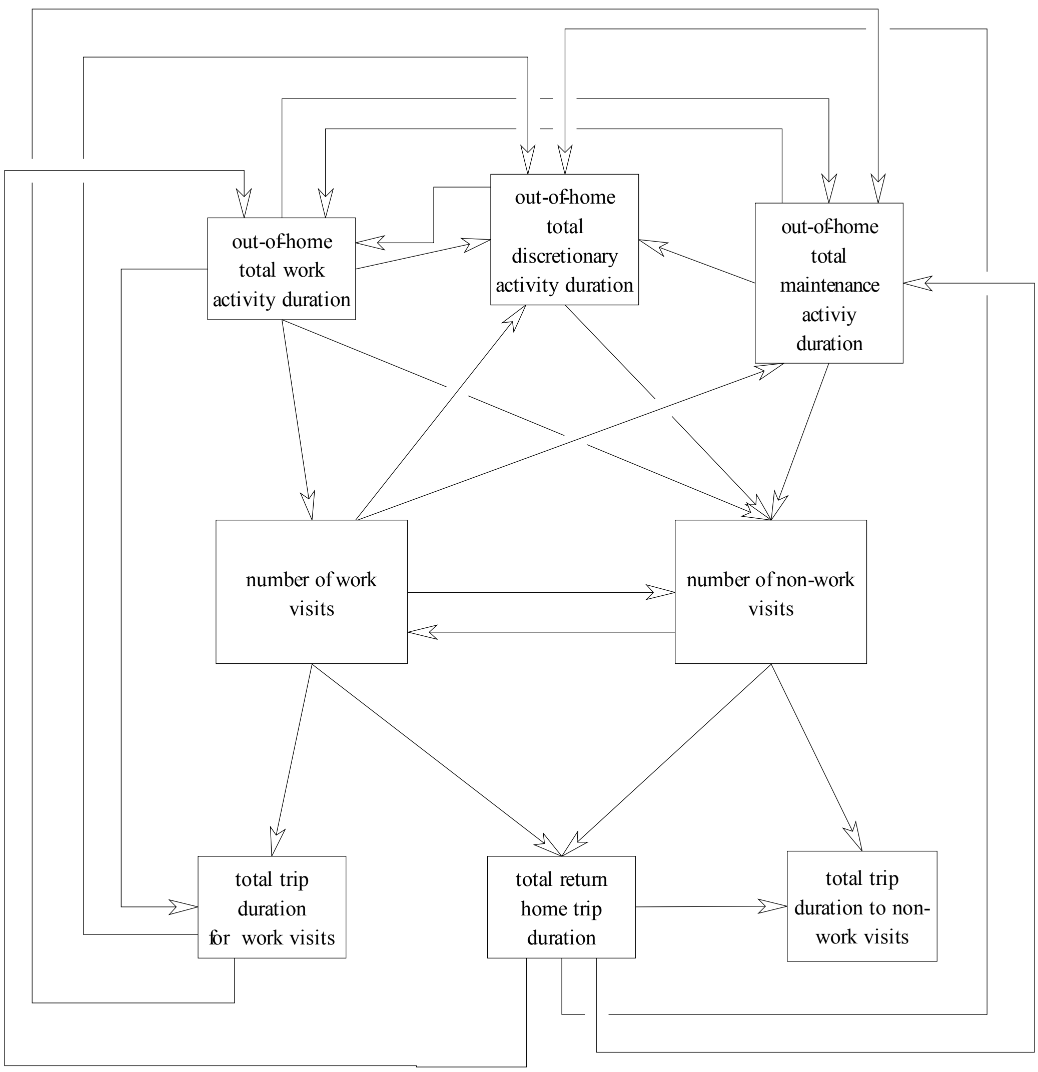
In Base Model 1, work activity duration is assumed to influence all other activity durations. Discretionary activity is taken as the lowest level activity in the sense that it can be adjusted more easily because by definition discretionary activities are less obligatory and therefore expected to be more flexible. At the same time we also allow discretionary and maintenance activities affect work activity duration as well. This represents the case where people shorten their work activity durations in order to participate in non-work activities.

On the second level, we have the number of work visits and the number of non-work visits. Work duration in the higher level affects both the number of work visits and non-work visits, while discretionary and maintenance activity durations affect only the number of non-work visits. The feedback from the second level to the first level represents the effect of the number of work visits on maintenance and discretionary activity durations.

On the lowest level are total trip duration for work visits, total return home trip duration, and total trip duration for non-work visits for discretionary and maintenance activities. Total return home trip duration is assumed to be affected by the number of work visits and that of non-work visits, both in the second level. The number of work visits affects trip duration to work visits and total return home trip duration. The number of non-work visits affects both total return home trip duration and total trip durations to other places. It is also hypothesized for this level that return home trip duration affects trip duration for non-work visits because it is likely that the duration of a trip to a visit location is associated with the duration of a trip from the location. The feedbacks from this level to the first level represent the assumption that both total trip duration for work visits and total return home trip duration affect the duration for maintenance and discretionary activities. This represents time budget effects in which travel time and activity time are traded off.

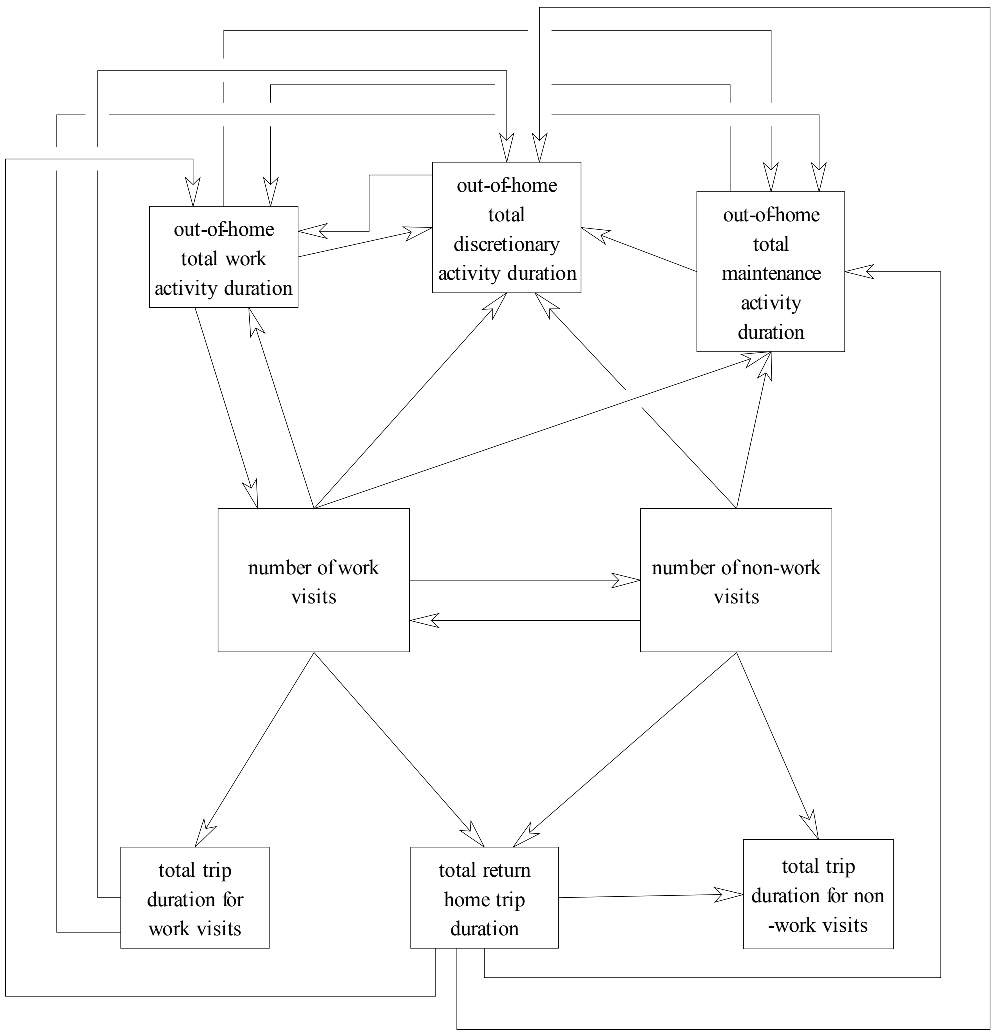
In Base Model 2 (Figure 6) we hypothesize that the individual first determines the number of visits for out-of-home activities, and then allocate time to different activities considering the amount of time available for out-of-home activities and travel. The number of non-work visits is assumed to affect only maintenance and discretionary activity durations. The only feedback is from work activity duration to the number of work visits.

Figure 5 Structural Relations in Base Model 1



The difference between the two base models may appear subtle, especially with the feed-back loops. They nonetheless represent different mechanisms of activity engagement. Base Model 1, where time allocation precedes the generation of visits for out-of-home activities, is based on an opportunistic view that the individual allocates the time available to make a visit, or multiple visits, at out-of-home locations, presumably in a way that will maximize his satisfaction. It is likely that the individual will adjust the number of locations to visit and the durations of activities at the respective locations. It is also likely that travel time is incorporated into the consideration; the amount of time that is available is allocated to activities at different locations, and trips to visit these locations. Naturally if one wishes to spend more time on activities, then the number of locations to visit will have to be reduced, or closer locations must be visited.

Figure 6 Structural Relations in Base Model 2



Base Model 2, on the other hand, is based on the view that activity engagement is more obligatory in nature. In this model, the number of visits for out-of-home activities is determined before the amount of time for activities is determined. This echoes the view that activity engagement is determined by needs or social commitments. The durations of these committed activities are adjusted to fit time budget constraints.

Actual decisions to engage in out-of-home activities are probably a mixture of these two models. For example, it would be obvious from the discussions above that the pattern of decision making is related to the type of activity; actual decisions are, then, likely to be mixtures of the two idealized models proposed here when activities of different types are pursued. Yet, it is reasonable to expect that insights into activity engagement decision can be gained by estimating the idealized models and examining their respective fit to observed data. This has motivated the empirical study whose results are presented in the following sections of this paper.

The Data and Preliminary Analysis

The data set is compiled from a survey of 766 individuals in the Osaka metropolitan area, conducted in November 1998. The survey was administered in mail out-mail back format, and sent to individuals who had given a prior agreement to participate in the survey in response to recruitment calls by telephone. The questionnaires were organized around seven areas of interest, which were concerned with the respondent's behavior in space and time as well as personal characteristics (Table 1).

Table 1 Question Groups in the Survey Data

1. Commuting
2. Work place or school
3. The place visited for activities, the transportation modes used, expenses made.
4. Time use (activity diary) on November 26, 1998 (Thursday),
5. Usage of Hanshin Expressways
6. Accessible telecommunications devices
7. Personal characteristics

The data used here contain parts of responses to Question Groups 4, 6 and 7. In Question Group 4, respondents supplied information about their activities and trips for the whole day.

In Question Group 6 they provided information on their uses of different telecommunications devices, i.e., the home phone, cellular phone, fax and pager. Among these, the analysis of this study is concerned with the home phone and the cellular phone which are the most prevalent devices.

Table 2 Sample Characteristics

		Count	Subgroup Column %	Subgroup Cumulative %
Age Groups	15-19	8	1.4%	1.4%
	20-24	24	4.2%	5.6%
	25-29	35	6.1%	11.7%
	30-34	33	5.8%	17.5%
	35-39	42	7.3%	24.8%
	40-44	57	10.0%	34.8%
	45-49	68	11.9%	46.7%
	50-54	67	11.7%	58.4%
	55-59	73	12.8%	71.2%
	60-64	64	11.2%	82.3%
	65-69	61	10.7%	93.0%
	70-74	29	5.1%	98.1%
	75-79	8	1.4%	99.5%
	80-84	2	.3%	99.8%
	85-89	1	.2%	100.0%
	Total	572	100.0%	100.0%
Sex	Female	221	39.0%	39.0%
	Male	346	61.0%	100.0%
	Total	567	100.0%	100.0%
Occupation	Salaryman, Official	272	48.1%	48.1%
	Self Employed	34	6.0%	54.1%
	Student	13	2.3%	56.4%
	Helping Household	106	18.7%	75.1%
	Housemaker	4	.7%	75.8%
	Part-time Employed	46	8.1%	83.9%
	Jobless	67	11.8%	95.8%
	Else	24	4.2%	100.0%
	Total	566	100.0%	100.0%
Work Status	Does't Work	214	37.8%	37.8%
	Full Time Employed	306	54.1%	91.9%
	Part Time Employed	46	8.1%	100.0%
	Total	566	100.0%	100.0%
Income (in 10,000\ units)	< 300	120	27.4%	27.4%
	300-500	96	21.9%	49.3%
	500-700	77	17.6%	66.9%
	700-1000	86	19.6%	86.5%
	>1000	59	13.5%	100.0%
	Total	438	100.0%	100.0%
Home Phone	Home Phone does not exist	6	1.1%	1.1%
	Home Phone exists.	560	98.9%	100.0%
	Total	566	100.0%	100.0%
Cellular Phone	Doesn't hold Cellular Phone	222	51.2%	51.2%
	Holds Cellular Phone	212	48.8%	100.0%
	Total	434	100.0%	100.0%

The information collected indicates: on average how many times they used these devices in an ordinary week, how much they paid for these devices per month, whether they got information about transportation systems via the devices, and whether these devices affected their joint activities with other individuals. By Question Group 7, information about age, sex, income, allowance for discretionary expenditures, driving license holding, driving experience, car availability, and average sleeping time, was given by respondents. Of the 766 individuals, 611 provided information usable in the analysis. The profiles of the sample of those 611 individuals are given in Table 2.

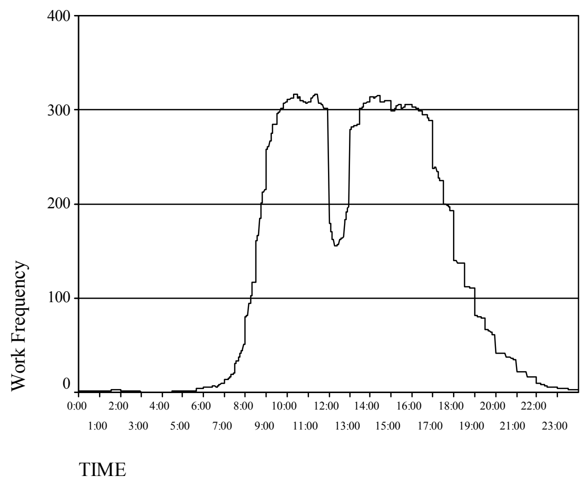
The data were screened with respect to the variables used in the models of the study. Individuals who did not report time use exhaustively were excluded from the sample used for model estimation. Also excluded are those individuals for whom information is not complete on sex, home phone and cellular phone use, available vehicles, and income. The descriptive statistics of the structural variables are given in Table 3.

Table 3 Basic Statistics of the Structural Variables

	All Observations			Non-Zero Observations Excluded		
	Count	Mean	Std. Deviation	Count	Mean	Std. Deviation
Out-of-Home Total Work Activities Duration	611	4.83	4.50	361	8.18	2.61
Out- of-Home Total Maintenance Activities Duration	611	0.98	1.19	431	1.38	1.20
Out-of-Home Total Discretionary Activities Duration	611	1.01	1.88	219	2.81	2.19
Number of Work Related Places Visited	611	0.79	0.85	363	1.33	0.70
Number of Discretionary and Maintenance Related Places Visited	611	1.11	1.09	404	1.68	0.92
Total Trip Duration to Work Activities	611	0.66	1.17	322	1.24	1.37
Total Trip Duration to Discretionary and Maintenance Activities	611	0.86	2.90	362	1.46	3.66
Total Return Home Trips Duration	611	1.01	2.46	572	1.08	2.52
Home Phone Telecommunicating Variable	566	4.44	2.38	507	4.96	1.94
Cellular Phone Telecommunicating Variable	434	2.14	2.69	196	4.75	1.90

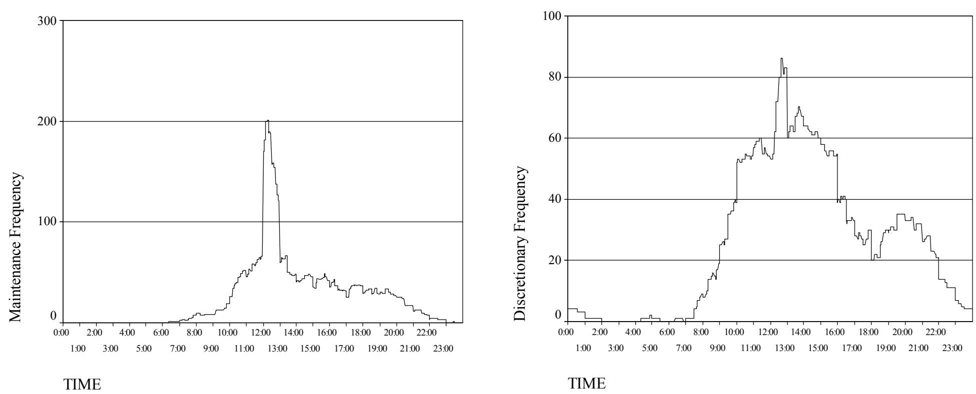
The characteristics of activity participation in the sample are briefly described here. As Figure 7 shows, work activities start to rise around 6:00 AM. At noon, about a half of the sample individuals are engaged in non-work activities, and the number of individuals working starts to decrease sharply after around 4:30 PM.

Figure 7. Work Activity Participation by Time of Day



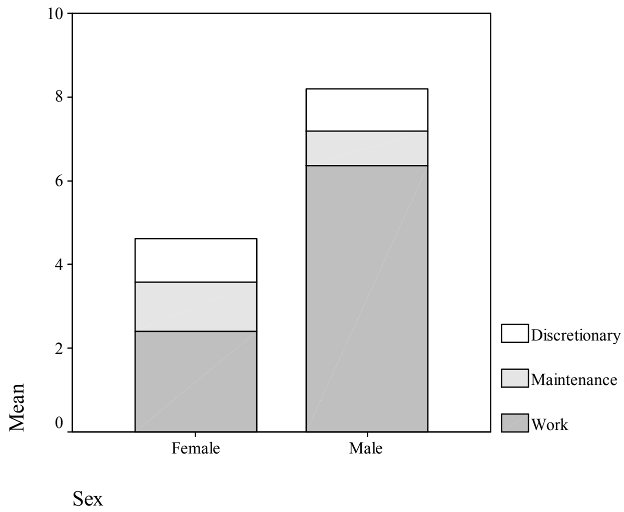
Both maintenance and discretionary activities show peaks at around noon and they gradually decrease with time, discretionary activities more slowly than maintenance activities (see Figure 8). At around 8:00 PM, we observe another peak for discretionary activities.

Figure 8. Maintenance and Discretionary Activity Participation by Time of Day



For out-of-home activities, significant differences are detected between sexes, with males working longer hours than females, but females having more out-of-home maintenance activities than males (see Figure 9). There is no significant difference between males and females with respect to discretionary activity duration.

Figure 9. Average Activity Durations by Sex



Methodology

The models of this study are formulated as structural equations models, whose general form can be expressed as

$$\mathbf{y} = \mathbf{B}\mathbf{y} + \mathbf{\Gamma}\mathbf{x} + \boldsymbol{\zeta} \qquad (1)$$

where $\mathbf{y}$ and $\mathbf{x}$ are column vectors of p endogenous and q exogenous variables, respectively; $\mathbf{B}$ and $\mathbf{\Gamma}$ are coefficient matrices of endogenous and exogenous variables, respectively; and $\boldsymbol{\zeta}$ is the vector of error terms distributed with a multivariate normal distribution with a mean vector of $\mathbf{0}$ and variance-covariance matrix $\mathbf{\Psi}$. The moment estimation procedure described below calls for the assumption that $\mathbf{y}$ and $\mathbf{x}$ also have multivariate normal distributions.

A moment estimator is used to estimate the model parameters. In this estimator, the sample covariance matrix of **x** and **y**, **S**, is equated with the covariance matrix implied by the model parameters, i.e., $\boldsymbol{\Sigma}(\boldsymbol{\theta})$. Given that $(\mathbf{I}-\mathbf{B})$ is not singular, Eq. (1) can be solved for **y** to yield the reduced form,

$$\mathbf{y} = (\mathbf{I}-\mathbf{B})^{-1}\boldsymbol{\Gamma}\mathbf{x} + (\mathbf{I}-\mathbf{B})^{-1}\boldsymbol{\zeta} \tag{3}$$

With this, and with the assumption that the exogenous variables **x** are not correlated with the error terms $\boldsymbol{\zeta}$, the implied covariance matrix becomes as follows:

$$\begin{aligned}\boldsymbol{\Sigma}(\boldsymbol{\theta}) &= \begin{pmatrix} \mathbf{yy}' & \mathbf{yx}' \\ \mathbf{xy}' & \mathbf{xx}' \end{pmatrix} \\ &= \begin{pmatrix} (\mathbf{I}-\mathbf{B})^{-1}(\boldsymbol{\Gamma}\boldsymbol{\Phi}\boldsymbol{\Gamma}' + \boldsymbol{\Psi})(\mathbf{I}-\mathbf{B})^{-1'} & (\mathbf{I}-\mathbf{B})^{-1}\boldsymbol{\Gamma}\boldsymbol{\Phi} \\ \boldsymbol{\Phi}\boldsymbol{\Gamma}'(\mathbf{I}-\mathbf{B})^{-1'} & \boldsymbol{\Phi} \end{pmatrix}\end{aligned} \tag{4}$$

The matrix $\boldsymbol{\Phi}$ is the covariance matrix of exogenous variables, **x**. The model parameters are estimated by a maximum likelihood estimation procedure with the assumption that sample covariance matrix, **S**, has a Wishart Distribution[3]. The log-likelihood function is given as

$$F_{ML} = \ln|\boldsymbol{\Sigma}(\boldsymbol{\Theta})| + tr[\mathbf{S}\boldsymbol{\Sigma}^{-1}(\boldsymbol{\Theta})] - \ln|\mathbf{S}| - (p+q) \tag{5}$$

where $\boldsymbol{\Sigma}(\boldsymbol{\theta})$ and **S** are assumed to be positive definite matrices (see Bollen, 1989; Jöreskog and Sörbom, 1993).

Results

We first estimate the two base models. Estimation results are presented in Appendix Table 1 for both base models to make their comparison easier. They are also presented in Figures 10 and 11. The models of the study contain attributes of the individual as exogenous variables.

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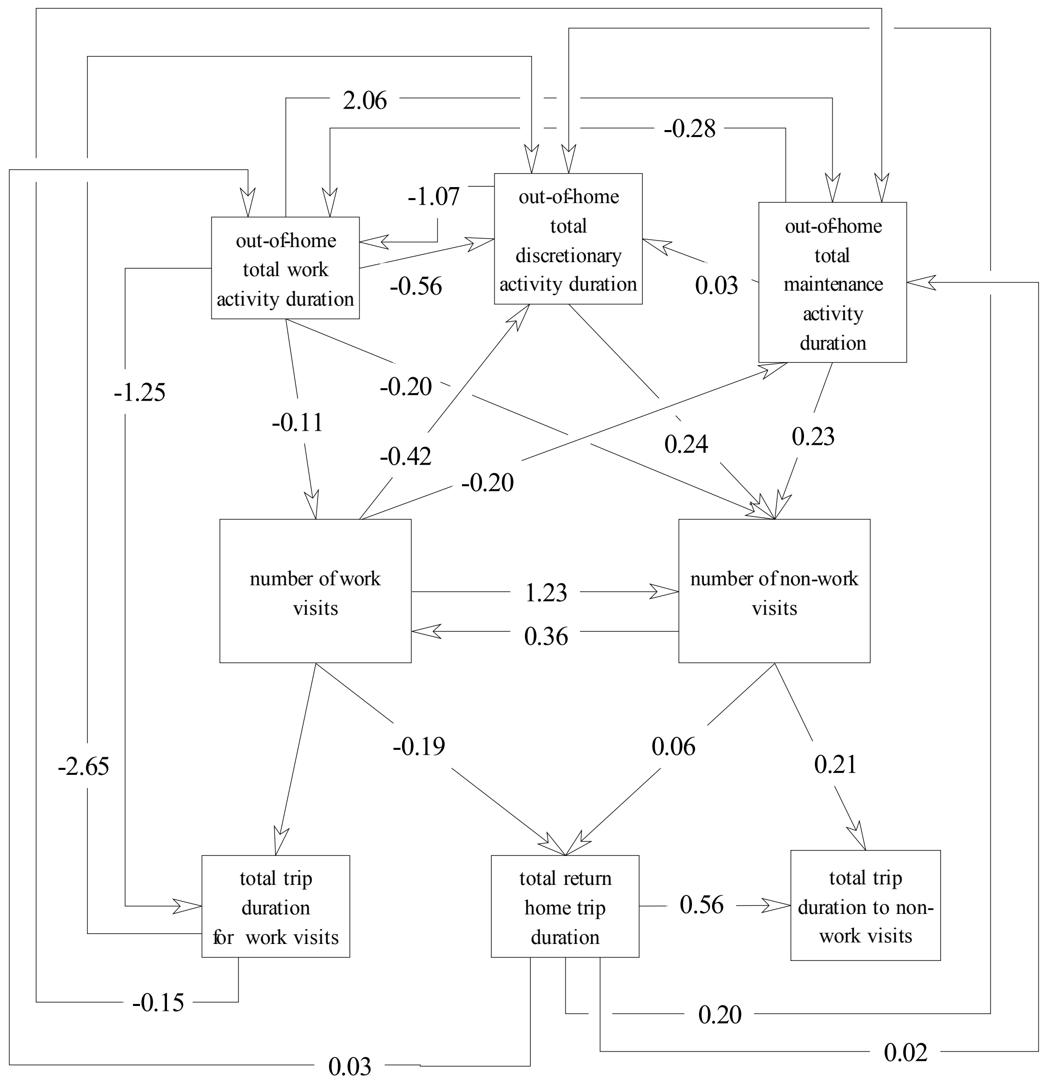
[3] See Anderson (1984).

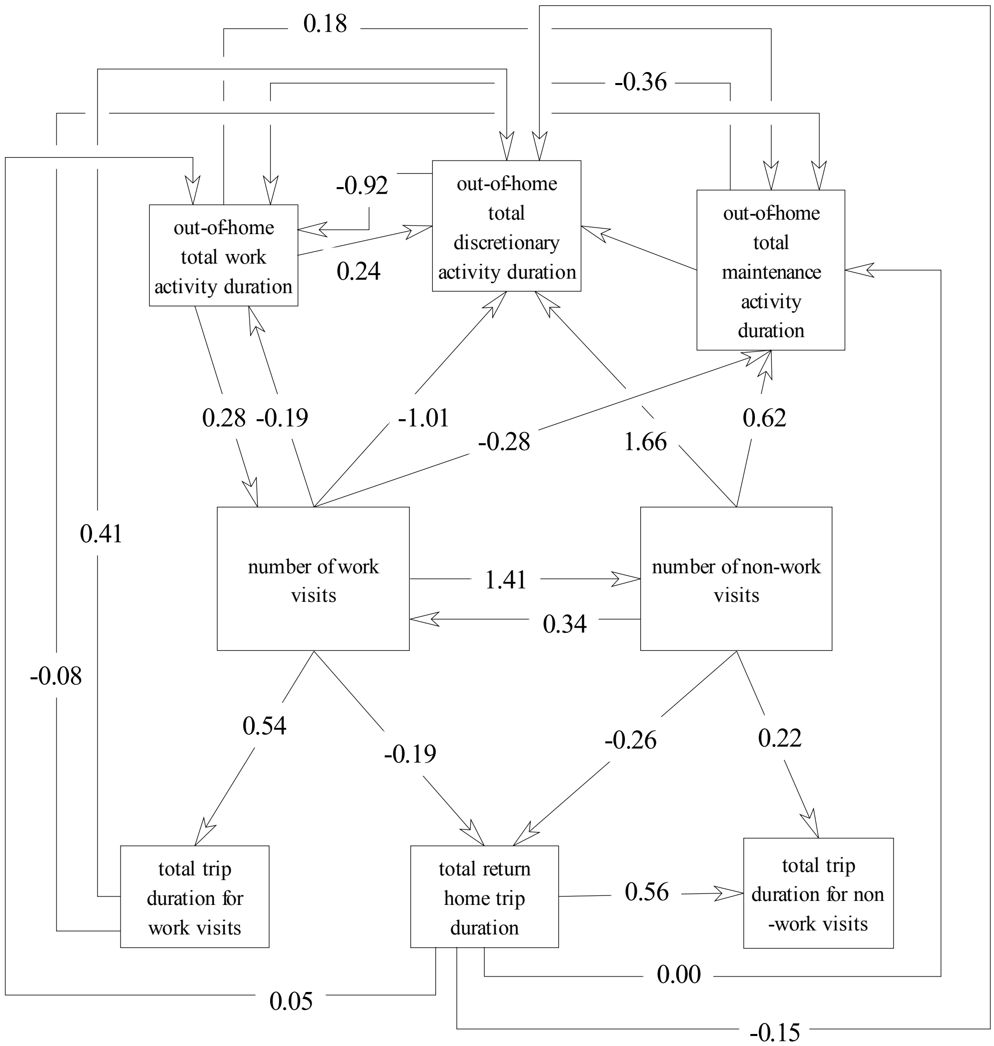
The discussions below, however, concentrate on the relationships among the endogenous variables and the telecommunicating variables as they are the focus of this study.

Figure 10 Structural Parameters in Base Model 1



In Base Model 1, where activity duration is determined before the number of visits, work activity duration tends to positively influence maintenance activity duration and negatively influence discretionary activity duration. But in Base Model 2, where the number of visits is predetermined, work activity duration positively influences discretionary activity duration as well. It is also the case that the magnitudes of the structural effects are substantially different between the two models. This is not surprising because the two models are formulated assuming different causal structures.

Figure 11 Structural Parameters in Base Model 2



With respect to the relationships for activity durations, notable differences can be found in the effect of work activity duration on maintenance activity duration (2.06 in Base Model 1 and 0.18 in Base Model 2) and also in the effect of work activity duration on discretionary activity duration (-0.56 in Base Model 1 and 0.24 in Base Model 2). Maintenance and discretionary activity durations affect work activity duration negatively in both models, although the coefficient values are quite different.

In Base Model 1, the effect from work activity duration to the number of work visits turned out to be insignificant. This effect is significant and positive in Base Model 2. The number of non-work visits is affected negatively by work activity duration in Base Model 1. This relationship is not assumed in Base Model 2.

The number of places visited feeds back on activity durations in Base Model 1. The number of work visits feeds back on both maintenance activity duration (negative but insignificant) and discretionary activity duration (negative and significant). In Base Model 2, the effect of the number of visits on activity duration is postulated as the main causal relation. All of the structural effects from the number of work visits to activity durations are significant and negative; work visits negatively influence non-work activity durations. On the other hand, the number of non-work visits affects maintenance and discretionary activity durations positively in Base Model 2. Obviously more non-work visits imply more time spent on non-work activities.

Generally activity engagement affects trip time positively, except for return home trip duration. The effect of the number of work visits on work trip time and that of the number of non-work visits on non-work trip time are both positive and significant in Base Model 2. On the other hand, the number of work visits and the number of non-work visits both influence return home trip time negatively. This may be because the probability increases that the last visit before returning home will lie closer to the home location as the number of visits increases. In Base Model 1, work activity duration affects work trip time negatively and the number of non-work visits affects non-work trip time positively, while return home trip time is not influenced by activity engagement.

In the extended models, we retain the structural relationships assumed in these two base models. We have two extensions. The first extension incorporates the hypothesis that telecommunicating affects activity duration only, while the second extension assumes that telecommunicating affects activity engagement only. We will only discuss the effects of the telecommunicating variables in these models (see Appendix Tables 2 and 3).

Extended Models 1-A and 2-A (based on Base Model 1 and 2, respectively) have the tele-communicating variables affecting activity durations. In both models we observe that the cellular phone affects work activity duration significantly and negatively (-0.10). It may be the case that the cellular phone gives flexibility to workers in conducting their work duties; they can be away from their work places while being accessible by cellular phones, which may make it easier for the workers to introduce non-work activities into their itineraries.

In Extended Model 1-A, both home phone and cellular phone affect discretionary activity duration positively (0.17 and 0.42, respectively). This suggests that individuals become more active pursuers of discretionary activities when they have telecommunications capa-bilities. The substantially larger coefficient of the cellular phone variable indicates that the ability to access and to be accessed any time significantly enhances this tendency. Thus telecommunication and discretionary activity are complementary. This is especially the case with cellular phones, which provides ubiquitous reachability. The duration of maintenance activities, on the other hand, does not show statistically significant relations with the tele-communicating variables.

Extended Model 1-B, where it is hypothesized that telecommunications affects only activity engagement, indicates that both home phones and cellular phones affect work activity sig-nificantly and negatively. This is consistent with the inference drawn for Extended Models 1-A and 2-A that the use of cellular phones shortens work activity duration. Additionally, in this model we have cellular phones affecting positively the number of non-work visits, al-though the effect is not statistically significant. In the case of Extended Model 2-B, the use of cellular phones positively affects the number of work visits.

The statistical indications are not entirely consistent. As an inspection of the goodness-of-fit statistics presented in Appendix Tables 1 through 3 would indicate, Base Model 1 and its derivatives, Extended Models 1-A and 1-B, fit the data better than Base Model 2 and Extended Model 2-A and 2-B. The causal relation that activity duration is determined first, and influences the number of visits for out-of-home activities, appears more prevalent. If we confine ourselves to Extended Models 1-A and 1-B, then there is a consistent indication that telecommunications influenced work activity negatively, and discretionary activity positively. Finally, it is important to note that the goodness-of-fit improves substantially with the introduction of the telecommunicating variables. Telecommunications is significantly associated with individuals' activity engagement and travel.

Although the statistical indications are not entirely robust and further empirical analysis is by all means necessary, we may tentatively conclude that telecommunications reduces work activity while it increases discretionary activities. The former suggests substitution effects between telecommunications and travel when work activities are concerned. The latter implies complementary effects between telecommunications and travel for discretionary activities. There appears to be neutral relationships between telecommunications and maintenance activities.

The empirical analysis of this study has revealed the relationships between telecommunications and out-of-home activities by type, and thus the relationships between telecommunications and travel for activities. Most importantly, the study has revealed that relations between telecommunications and out-of-home activity engagement, and therefore relations between telecommunication and travel, differ depending on the type of activity. In other words, none of the SCMN effects applies universally to all activities. The results that substitution prevails for work activity and complementation for discretionary activities further suggest that individuals take advantages of telecommunications technology to enhance the pleasure of their lives. This hypothesis, too, requires further empirical examination of the relationships among telecommunications, activity, and travel.

Conclusions

Results of a survey conducted in the Osaka metropolitan area of Japan are used in this study to explore the relationships among the use of home and cellular telephones, activity engagement, and travel. The analysis has shown that home phones and cellular phones have different effects on activity engagement because of the functional differences between the two. The results are in general consistent with the notion that the portability of cellular phones makes individuals more flexible in pursuing activities.

The use of cellular phones generally reduces work activities, both in duration and the frequency of visits made for work or work-related purposes. The use of both cellular phones and home phones complements the duration of discretionary activities. The effect on maintenance activities appears to be neutral. Although the use of cellular phones positively influences the number of non-work (maintenance plus discretionary) visits, the effect is not statistically significant. Thus the SCMS relationships suggested by this study are:

work = substitution
maintenance = neutral
discretionary = complementary

That none of the SCMS effects applies universally to all types of activities is an important conclusion of this study.

The estimation of two sets of models with different structures suggests that the causal relation that activity duration is pre-determined and affects the number of visits made for out-of-home activities, is more prevailing. However, the two sets of models offer sometimes conflicting indications about the effects of telecommunications. Further research is needed on this subject. Properly accounting for the non-negativity of the many of the endogenous variables of this study and also better differentiating workers and non-workers also remain as future subjects of study.

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Appendix

Appendix Table 1. Structural Parameters of The Base Models 1 and 2

			FROM															
			ACTIVITY TIME						ACTIVITY ENGAGEMENT				TRAVEL TIME					
			WORK		MAINTENANCE		DISCRETIONARY		WORK		OTHER		WORK		RETURN HOME		OTHER	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
TO	ACTIVITY TIME	WORK			-1.07	-0.36	-0.28	-0.92		-0.19					0.03			
		MAINTENANCE	2.06	0.18					-0.42	-0.28		0.62	-2.65	-0.08	0.20	0.21		
		DISCRETIONARY	-0.56	0.24					-0.20	-1.01		1.66	-0.15	0.41	0.02	0.05		
	ACTIVITY ENGAGEMENT	WORK	-0.11	0.28					1.07		0.36	0.34						
		OTHER	-0.20		0.24		0.23		1.23	1.41								
	TRAVEL TIME	WORK PLACES	-1.25							0.54								
		RETURN HOME							-0.19	-0.19	0.06	-0.26						
		OTHER PLACES									0.21	0.22			0.56	0.56		
Goodness of Fit Statistics		Base Model 1	Degrees of Freedom =16, Minimum Fit Function Chi-Square = 1723.52, Goodness of Fit= 0.87															
		Base Model 2	Degrees of Freedom =16, Minimum Fit Function Chi-Square = 1783.53, Goodness of Fit=0.88															

Double underlines represent a=0.01, single underlines reprensent a=0.05 significance.

Columns numbered as 1 indicate Base Model 1, Columns numbered as 2 indicate Base Model 2.

Minimum Fit Function Chi Square= $(N\text{-}1)L(\boldsymbol{\theta})$, Goodness of Fit= $1\text{-}L(\boldsymbol{\theta})/L(\mathbf{0})$ where N is the sample size, L is the fit function, and $\boldsymbol{\theta}$ is the vector of estimated parameter values. Minimum Fit Function is distributed approximately as χ^2 with model degrees of freedom.

Appendix Table 2. Structural Parameters of The Extended Models 1-A and 2-A

			FROM																			
			ACTIVITY TIME						ACTIVITY ENGAGEMENT				TRAVEL TIME						TELECOMMUNICATIONS			
			WORK		MAINTENANCE		DISCRETIONARY		WORK		OTHER		WORK		RETURN HOME		OTHER		HOME PHONE		CELLULAR PHONE	
			1-A	2-A	1-A	2-A	1-A	2-A	1-A	2-A	1-A	2-A	1-A	2-A	1-A	2-A	1-A	2-A	1-A	2-A	1-A	2-A
TO	ACTIVITY TIME	WORK			-0.17	-0.32	-0.74	-0.60		0.06					0.00	0.01					-0.10	-0.10
		MAINTENANCE	-0.44	0.42					-0.21	-0.44		0.66	-0.20	-0.05	0.03	0.02			0.03	0.04	0.01	
		DISCRETIONARY	1.86	1.31					-1.43	-1.04		0.92	-0.45	0.19	0.09				0.17	0.05	0.42	
	ACTIVITY ENGAGEMENT	WORK	0.02	-0.04							0.50	0.08										
		OTHER	-0.48		0.42		0.35		0.41	0.60												
	TRAVEL TIME	WORK PLACES	-0.52						0.70	0.49												
		RETURN HOME							-0.18	-0.16	0.06	0.10										
		OTHER PLACES									0.22	0.22			0.56	0.56						
Goodness of Fit Statistics		1-A	Degrees of Freedom =39, Minimum Fit Function Chi-Square = 193.72, Goodness of Fit= 0.96																			
		2-A	Degrees of Freedom =42, Minimum Fit Function Chi-Square = 209.02, Goodness of Fit=0.96																			

Hypothesis: Telecommunicating Affects Activity Demand

Double underlines represent a=0.01, single underlines represent a=0.05 significance.

Appendix Table 3. Structural Parameters of The Extended Models 1-B and 2-B

			FROM																			
			ACTIVITY TIME						ACTIVITY ENGAGEMENT				TRAVEL TIME						TELECOMMUNICATIONS			
			WORK		MAINTENANCE		DISCRETIONARY		WORK		OTHER		WORK		RETURN HOME		OTHER		HOME PHONE		CELLULAR PHONE	
			1-B	2-B	1-B	2-B	1-B	2-B	1-B	2-B	1-B	2-B	1-B	2-B	1-B	2-B	1-B	2-B	1-B	2-B	1-B	2-B
TO	ACTIVITY TIME	WORK			-0.24	-0.81	-1.10	-0.51		-0.30					0.01	0.01						
		MAINTENANCE	-0.61	1.34					-0.01	-0.48		1.38	-0.21	0.07	0.03	4.00						
		DISCRETIONARY	1.63	0.14					-2.70	-0.36		0.59	-3.04	0.02	0.29	0.02						
	ACTIVITY ENGAGEMENT	WORK	-0.94	1.03							0.64	-0.23							-0.10		-0.27	0.33
		OTHER	-0.51		0.38		0.38		0.56	1.44									0.00	0.06	0.12	0.16
	TRAVEL TIME	WORK PLACES	-0.84						1.26	0.51	0.07											
		RETURN HOME							-0.23	-0.15	0.22	0.11										
		OTHER PLACES										0.22			0.56	0.56						
Goodness of Fit Statistics		1-B	Degrees of Freedom =40, Minimum Fit Function Chi-Square = 195.95, Goodness of Fit= 0.96																			
		2-B	Degrees of Freedom =42, Minimum Fit Function Chi-Square = 246.75, Goodness of Fit=0.95																			

Hypothesis: Telecommunicating Affects Activity Engagement

Double underlines represent a=0.01, single underlines represent a=0.05 significance.

Appendix Table 4. Total Effects of The Base Models 1 and 2

			ACTIVITY TIME						ACTIVITY ENGAGEMENT				TRAVEL TIME					
			WORK		MAINTENANCE		DISCRETIONARY		WORK		OTHER		WORK		RETURN HOME		OTHER	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
TO	ACTIVITY TIME	WORK	-0.82	-0.75	-0.13	-0.09	0.01	-0.23	0.73	-0.78	0.26	-0.68	0.34	-0.09	-0.02	-0.09		
		MAINTENANCE	0.79	0.11	-0.89	-0.04	-0.26	-0.10	-0.49	0.53	-0.17	0.58	-0.26	-0.12	0.04	0.14		
		DISCRETIONARY	-0.08	0.74	0.03	-0.26	-0.04	-0.68	-0.76	0.30	-0.27	0.44	-0.21	0.15	0.02	0.08		
	ACTIVITY ENGAGEMENT	WORK	0.05	0.12	0.06	-0.04	0.10	-0.12	0.36	0.41	0.49	0.24	-0.18	-0.04	0.02	0.07		
		OTHER	0.20	0.16	0.14	-0.06	0.28	-0.15	1.22	1.84	0.44	0.27	-0.40	-0.06	0.04	0.29		
	TRAVEL TIME	WORK PLACES	-0.17	0.07	0.23	-0.02	0.09	-0.06	0.53	0.76	0.19	0.13	-0.61	-0.02	0.04	0.04		
		RETURN HOME	0.00	-0.07	0.00	0.02	0.00	0.06	-0.18	-0.76	-0.01	-0.38	0.01	0.02	0.00	-0.09		
		OTHER PLACES	0.20	0.00	0.03	0.00	0.06	0.00	0.16	-0.03	0.31	0.06	-0.08	0.00	0.56	0.57		

Double underlines represent a=0.01, single underlines reprensent a=0.05 significance.

Appendix Table 5. Total Effects of The Extended Models 1-A and 2-A

			FROM																			
			ACTIVITY TIME						ACTIVITY ENGAGEMENT				TRAVEL TIME						TELECOMMUNICATIONS			
			WORK		MAINTENANCE		DISCRETIONARY		WORK		OTHER		WORK		RETURN HOME		OTHER		HOME PHONE		CELLULAR PHONE	
			1-A	2-A	1-A	2-A	1-A	2-A	1-A	2-A	1-A	2-A	1-A	2-A	1-A	2-A	1-A	2-A	1-A	2-A	1-A	2-A
TO	ACTIVITY TIME	WORK	-0.59	-0.48	0.03	-0.17	-0.22	-0.31	0.48	0.17	0.24	-0.38	0.09	-0.05	-0.02	0.17			-0.04	-0.02	-0.13	-0.05
		MAINTENANCE	-0.15	0.22	-0.07	-0.07	0.03	-0.13	-0.47	0.01	-0.23	0.50	-0.20	-0.07	0.03	0.01			0.03	0.03	0.03	-0.02
		DISCRETIONARY	0.82	-0.07	-0.25	-0.22	-0.70	-0.41	-0.54	-0.19	-0.27	0.38	-0.08	0.12	-0.54	0.01			0.04	0.02	0.04	-0.07
	ACTIVITY ENGAGEMENT	WORK	0.03	0.01	0.18	0.01	0.21	0.01	-0.12	0.04	0.44	0.10	-0.10	0.00	-0.12	0.00			0.03	0.00	0.05	0.00
		OTHER	0.04	0.00	0.36	0.00	0.06	0.01	-0.25	0.63	-0.12	0.06	-0.20	0.00	-0.25	0.00			0.06	0.00	0.11	0.00
	TRAVEL TIME	WORK PLACES	-0.20	-0.01	0.11	0.00	-0.01	0.01	0.37	0.51	0.19	0.05	-0.12	0.00	0.37	0.00			0.04	0.00	0.11	0.00
		RETURN HOME	0.00	0.00	-0.01	0.00	0.13	0.00	-0.18	-0.11	-0.03	0.09	0.01	0.00	-0.18	0.00			0.00	0.00	0.00	0.00
		OTHER PLACES	0.01	0.00	0.07	0.00	0.28	0.00	-0.15	0.08	0.17	0.28	-0.04	0.00	0.17	0.56			0.01	0.00	0.02	0.00

Double underlines represent a=0.01, single underlines represent a=0.05 significance.

Appendix Table 6. Total Effects of The Extended Models 1-B and 2-B

			FROM																			
			ACTIVITY TIME						ACTIVITY ENGAGEMENT				TRAVEL TIME						TELECOMMUNICATIONS			
			WORK		MAINTENANCE		DISCRETIONARY		WORK		OTHER		WORK		RETURN HOME		OTHER		HOME PHONE		CELLULAR PHONE	
			1-B	2-B	1-B	2-B	1-B	2-B	1-B	2-B	1-B	2-B	1-B	2-B	1-B	2-B	1-B	2-B	1-B	2-B	1-B	2-B
TO	ACTIVITY TIME	WORK	-0.87	-0.72	0.09	-0.20	-0.05	-0.15	0.49	-0.38	0.31	-0.31	0.14	-0.02	-0.01	-0.01			-0.05	-0.02	-0.10	-0.17
		MAINTENANCE	-0.05	0.72	-0.06	-0.58	-0.01	-0.37	-0.31	0.19	-0.20	0.33	-0.17	0.02	0.03	0.01			0.03	0.02	0.06	0.11
		DISCRETIONARY	0.80	0.15	-0.28	-0.12	-0.95	-0.08	-0.37	0.17	-0.24	0.34	-0.19	0.01	0.01	0.00			0.04	0.02	0.07	0.11
	ACTIVITY ENGAGEMENT	WORK	-0.03	0.22	0.10	-0.18	0.11	-0.11	-0.64	-0.54	0.23	-0.42	-0.36	-0.01	0.04	-0.01			-0.01	-0.01	-0.07	0.04
		OTHER	0.14	0.31	0.28	-0.25	0.10	-0.16	-0.28	0.66	-0.18	-0.60	-0.36	-0.02	0.04	-0.01			0.01	0.01	0.17	0.07
	TRAVEL TIME	WORK PLACES	-0.16	0.11	0.05	-0.09	0.18	-0.06	0.05	0.23	0.04	-0.21	-0.57	-0.01	0.05	0.00			0.01	0.01	-0.01	0.02
		RETURN HOME	0.02	0.00	0.00	0.00	-0.02	0.00	-0.10	0.00	0.00	0.11	0.06	0.00	-0.01	0.55			-0.04	-0.02	0.03	0.08
		OTHER PLACES	0.04	0.07	0.06	-0.05	0.01	-0.03	-0.12	-0.54	0.18	0.15	-0.05	0.00	0.56	0.00			0.03	0.02	0.05	0.28

Double underlines represent a=0.01, single underlines represent a=0.05 significance.