A PATH ANALYSIS OF SOCIAL NETWORKS, ICT USE AND SOCIAL ACTIVITY-TRAVEL PATTERNS IN THE NETHERLANDS

Pauline van den Berg, Eindhoven University of Technology, P.E.W.v.d.Berg@tue.nl

Theo Arentze, Eindhoven Universtiy of Technology, T.A.Arentze@tue.nl

Harry Timmermans, Eindhoven University of Technology, H.J.P.Timmermans@tue.nl

ABSTRACT

Face-to-face social activities are responsible for an important part of travel demand and are therefore important for transport planners to take into account. Social activities and the involved travel are likely to be influenced by the use of new information and communication technologies (ICT's), as these ICT's offer new possibilities for social interaction. Moreover, social activities and the travel for these activities can emerge from the individuals' social networks. Although international transportation researchers have recognized the relevance of social trip generation and the impacts of social networks and ICT on activity travel patterns, empirical studies on this matter are scarce. The purpose of the paper is to add to our understanding of social travel demand by analyzing the relationships between personal characteristics, properties of the built environment, social networks, ICT use and social activity-travel patterns. Using path analysis, hypotheses on these links are tested. The analyses are based on data collected in 2008 in the Eindhoven region in the Netherlands among 747 respondents, using a two-day social interaction diary and a questionnaire. The paper presents the results of the path analysis and discusses the implications of the findings for transport planning and modeling.

Keywords: *Social activities, ICT, social networks, activity-travel behavior, path analysis, structural equation modeling*

1. INTRODUCTION

Social activities account for a large part of trips and they constitute the fastest growing segment of travel (Axhausen, 2003). In order to assess future transportation needs for social activities, we need to understand the nature of people's social activities and the travel

involved in these activities. Social activities and the travel demand they induce, are likely to be influenced by the use of new information and communication technologies (ICT's), such as the Internet and mobile phones, as these ICT's offer new ways of communicating. These alternatives for face-to-face communication have raised speculation about the consequences of ICT's for social interactions (Haythornthwaite and Wellman, 2002; Matei and Ball-Rokeach, 2002; Cho et al., 2003; Baym et al., 2004; Boase et al, 2006). Some are concerned that using the Internet is a solitary activity, which can be harmful to social relations, while others stress that ICT is actively used for socializing with others. In any case, ICT is likely to affect the intensity and nature of social interaction, which in turn will have an effect on (social) activity-travel behavior.

Moreover, social activities and the travel for these activities can emerge from the individuals' social networks. Recently, the impact of social networks and activities has been acknowledged within the activity-based approach of travel demand, and it is gaining interest. The need to incorporate the effects of social influence in decision making has been stressed by Dugundji and Walker (2005) and Paez and Scott (2007). Arentze and Timmermans (2008) proposed a theoretical framework to incorporate social activities and changing social networks in the micro simulation of activity-travel patterns. Although it has been recognized that the study of individuals' social network characteristics can provide new insights into the generation of social activities and travel involved, only a few data collection efforts have been made so far in order to incorporate social networks in models of travel demand (Carrasco et al., 2008; Axhausen, 2008; Van den Berg, Arentze and Timmermans, 2009).

The purpose of the paper is to add to our understanding of social travel demand by analyzing the relationships between personal characteristics, properties of the built environment, social networks, ICT use and social activity-travel patterns. For the purpose of this study data were collected in 2008 in Eindhoven among 747 respondents, using a social interaction diary and a questionnaire. Path analysis is used to test a set of hypotheses on the causal relationships between personal and environmental characteristics, social networks, ICT use and social activity-travel.

The remainder of the paper is organized as follows. In the next section the hypotheses are posed, based on a discussion of the existing literature. Section 3 describes the data used for the analysis. Next, the structure of the path model is outlined, followed by the results. The final section summarizes the results and discusses the implications of the findings for transport planning and modeling.

2. CONCEPTS AND HYPOTHESES

Social activities constitute a growing segment of travel. Trips that are made for the purpose of social activities, are longer than average trips. Moreover, the distances of social trips are growing, as social networks are spread over longer geographical distances than before (Axhausen, 2002; Urry, 2003; McPherson, Smith-Lovin and Brashears, 2006). Therefore, access to means of transportation, especially a car, is becoming more important with regard to social trips. As it increases access to geographically dispersed social contacts, car ownership can increase people's social activity participation (Farber and Páez, 2008). In a

study among older people, Bannister and Bowling (2004) found that car access is positively related to the number of social activities.

Over the last decades, researchers have attempted to explain individual (social) travel behavior as a result of socio-demographic variables. Recent travel behavior research has added several other variables as motivators for mobility, such as ICT's, social networks and social activities. This section describes the literature on the links between ICT use and (social) activity travel and social networks. This section concludes with some hypotheses on the links between these concepts, based on the existing literature.

ICT and (social) travel

The use of ICT is changing social life and these changes have significant implications for activity-travel patterns. Face-to-face communication often requires travel; whereas ICT-mediated communication does not. However, personal meetings and trips are not completely interchangeable. Not all trips are undertaken for the purpose of face-to-face interaction and not all personal meetings involve a trip (Mokhtarian and Meenakshisundaram, 1999).

Nevertheless, in the literature on travel behavior, the relationship between ICT and activity-travel patterns has received increasing attention. Usually, four possible effects of ICT on travel are distinguished: substitution, complementarity, neutrality and modification (Salomon, 1986; Mokhtarian, 1990; Graham and Marvin, 1996). The substitution effect, meaning that ICT provides alternatives for physical presence, which can make physical presence and travel redundant, has attracted most attention, especially with regard to work or shopping activities (Mokhtarian, 1990).

With regard to the effect of ICT on travel for leisure or social activities relatively little is known so far (Mokhtarian, Salomon and Handy, 2006). It is to be expected that the effect of ICT on social travel differs from the effect on travel for other work or shopping activities. Using cellular phones and email may reduce the need to meet face-to-face and the associated travel. However, the ICT-based alternatives that are available for social activities are not as good as the alternatives for other activities such as working or shopping. Therefore increased social contacts via ICT are not likely to decrease the need for face-to-face social contact. Instead, increased contacts via ICT are more likely to increase the making of plans and appointments for face-to-face social activities and the number of social trips. Therefore complementarity is more likely than substitution for social activities (Mokhtarian et al., 2006). This finding is supported by Senbil and Kitamura (2003) who used a simultaneous equations model on data from a survey in the Osaka area. They studied the effects of home phone and cell phone use on the duration of work, maintenance and discretionary activities, and the number of work and non-work trips. They found substitution effects for work activities and trips, neutrality for maintenance activities and complementary effects for discretionary activities.

Mokhtarian and Meenakshisundaram (1999) used a communication diary to gather data on three types of communication: personal meetings (and related trips), transfer of an information object and electronic communication at two points in time six months apart. Using structural equations modeling, they estimated the number of each type of communication at time 2 as a function of the number of communications per type at time 1,

the elapsed time and socio-demographic variables. They found that the relationship between electronic communication modes and personal meetings or trips was not significant in either direction, suggesting neutrality instead of substitution or complementation.

Social networks and social travel

Beside the recent focus on the relationship between ICT use and travel, social networks are viewed as motivators for social travel. Social networks are relatively new to transportation research, however, they have been studied for many years in social sciences. In those studies, different approaches were employed (e.g. community studies and the social capital approach; the small-world approach; and social network analysis). Community studies and the social capital approach usually look at social networks as traditional tight structures of kinship, friendship and support that are highly place attached. Small world analysis attempts to explain the small world phenomenon: the notion that all people are separated by only a short chain of intermediaries. In our study the social network approach is applied. Social network analysis approaches social networks as a set of actors (nodes) and relationships connecting these actors (Wasserman and Faust, 1994).

Within this approach, social networks can be studied as *whole* or as *egocentric* networks. In studies on whole networks, all actors are known beforehand and are regarded as social collectives (Marsden, 2005). Whole networks are usually organized communities or groups with shared interests, like school classes, clubs, the employees of a company or the inhabitants of a neighborhood. If strict boundaries can not be defined, or one is concerned with behavior on the level of individuals, such as in the case of travel behavior research, the egocentric approach should be used. Egocentric network studies concentrate on the network of a person (ego) which consists of all the people (or groups) he or she has a relationship with (alters) (Carrasco et al, 2008). The social network is elicited using a certain set of questions: a name generator (Degenne and Forsé, 1999; Marsden, 2005; Carrasco et al, 2008).

Although social networks have been thoroughly studied, to date, only little is known about the way social networks affect people's social activity travel behavior (Carrasco et al., 2008). This lack of research in transportation on social networks is probably due to the fact that datasets focusing on the social interactions in the transportation context are sparse and if available, they usually focus on small numbers of people. Larsen et al. (2005) interviewed 24 young people in the North West of England to study the geographical scale of people's social networks, the degree to which it will be necessary for network members to meet up and the implications these meetings may have on travel forms and demand. Silvis et al. (2006) used data from 24 three-day activity diaries in which respondents were asked to record all trips as well as all social interactions with friends and family to study how social networks influence travel behavior. Ohnmacht (2006) combines quantitative data measuring an individual's network geography with qualitative data of 30 interviews to examine the interplay between social networks and travel behavior.

Social networks, ICT and social travel

As knowledge of the relationships between ICT and social travel on the one hand, and social networks and social travel on the other hand is scarce, knowledge of the relationships between all three mechanisms is even more limited. The Connected Lives project has been the first study linking social networks, ICT's and activity and travel behavior (Wellman et al, 2006). Findings of this study suggest that ICT's are a catalyst for social activities. Analyzing data from the Connected Lives study, Carrasco and Miller (2006; 2009) tested the effect of personal and household characteristics, social network composition and social interaction through ICT use on people's propensity to perform social activities, using structural equation modeling. In their study, network composition is defined as the number of alters of each role, the number of alters living at a certain distance and the number of alters with the same gender. ICT use is defined as the number of people with whom the ego communicates using cell phone, regular phone, e-mail and IM, by tie strength and by frequency. Their results show many significant effects, indicating that the incorporation of social networks provides useful insights into ICT use and social activities.

Hypotheses

Based on the existing literature some hypotheses can be formed about the influences of ICT use, social network characteristics, personal characteristics, properties of the spatial environment, and the day of the week on social travel (the number of trips per day by different transport modes and the travelled distance for social purposes per day). The proposed links can be seen in the path diagram in figure 1. The variables on the right are endogenous variables, hypothesized to be influenced by the exogenous variables on the left. The endogenous variables are also hypothesized to affect the endogenous variables below them in the diagram.

Social interaction between network members is necessary for the maintenance of a social network. This maintenance depends on the frequency and the kind of contact. We assume that people have certain attitudes, needs, opportunities and constraints regarding this frequency and type of interaction, depending on personal and household characteristics, such as gender, age, household composition and work status.

For example, with respect to the use of mobile phones and the internet, young, high educated males were the forerunners and they may still have a higher ICT-mediated contact frequency. Apart from a different attitude towards ICT-use, older people are likely to have a different attitude towards and more possibilities (time) for club membership. They may be less mobile and therefore have fewer possibilities to maintain their social network, resulting in a smaller social network and fewer social trips. Household composition (the presence of a partner and/or children in the household) is likely to affect the number of cars in the household, the number of trips for social activities by different transport modes and the travel distance. For example, the presence of children in the household may be a constraint for conducting social activities at long distance locations. The opportunities for social interaction will also depend on the available time. For example, people with more free time (less work or

study) may have more possibilities for more frequent (or longer) social activities. Full time workers are likely to have more need for a car to go to work.

In addition to personal characteristics, the spatial environment may also offer opportunities or limitations for social interaction. For example, one would expect that increasing travel times, as a result of longer distances (low urban density), are associated with a higher need for a car and lower frequency of face-to-face contact. On the other hand, in lower density areas the traditional social ties in the community are stronger than in the higher urbanized areas (Aoki, 1996; Tillema et al., 2007). This may result in a higher likelihood of interacting with people at short distances. In line with this we hypothesize the involvement in clubs is likely to be higher in low density areas. Lower density areas may offer fewer opportunities for frequent social interaction than urban areas. The longer distances in low urban density areas are likely to increase car ownership and use, or may decrease the frequency of social trips. The number of facilities accessible in a walking distance is also a measure for activity opportunities (Simma et al., 2001).

Finally, the day of the week may also affect ICT-mediated social interaction as well as the social travel variables. We hypothesize the number of social interactions to be lower in the weekend, compared to weekdays. Evidence for that effect was found by Mokhtarian and Meenakshisundaram (1999) and Kemperman et al. (2006). On the other hand, the travel distances will probably be longer, as people have more free time during the weekend and therefore more opportunities to make longer social trips.

Moreover, the endogenous variables are not only affected by the exogenous variables, but also by the other endogenous variables. We assume that the endogenous variables on a higher level in the path diagram influence all the endogenous variables below them.

Car possession makes it easier to travel to a distant location for (face-to-face) social interaction. We therefore hypothesize car ownership to have a positive effect on the number of car trips and the distance travelled for social activities. As clubs generate (institutionalized) social activities, the involvement in clubs or unions is likely to have a positive effect on the number of social trips and probably also on social network size. As social interaction (and the travel involved) can emerge from a person's social network (Carrasco et al. 2006), the size of their social network is likely to influence people's social travel behavior as well as ICT use for social purposes. Therefore, social network size, consisting of the number of very strong ties and the number of reasonably strong ties in a person's social network, is hypothesized to have a positive effect on the number of social interactions via telephone and Internet and on the number of social trips per day. We hypothesize that the relationship between telephone and Internet social interactions is complementary. Based on the literature discussed above, we assume that the number of ICT-mediated social interactions will have a small positive effect on the number of social trips. There will probably be a substitution effect between the number of social trips by different transport modes. Finally, we hypothesize that the number of trips per transport mode is related to travel distance, with positive effects for the number of car trips and negative effects for the number of walking trips on average trip distance per day.

3. DATA

The analysis of the complex interrelationships between properties of the built environment, ICT-use, social networks and social travel patterns, requires data on each of these components for the same individuals. To capture these links we developed a data collection instrument, consisting of a two-day paper-and-pencil social interaction diary which also contained a questionnaire. The social interaction diaries were distributed between January and March 2008 in the region of Eindhoven, a medium-sized city in the south of the Netherlands. People aged 15 or over could participate. To recruit respondents, a personal approach was employed. We went by people's homes to ask them if they were willing to participate in this study. If they were, they were given an explanation and received a diary, which was collected approximately one week later. This personal approach resulted in an overall response rate of 20%.

Another requirement for data collection, to allow the estimation of the impact of the built environment, is to secure sufficient variation in characteristics of the built environment. Therefore, the sample was stratified by urban density.

In the social interaction diary, respondents were asked to record all their social interactions during two days. Social interactions were defined as all forms of contact: a joint activity, a conversation (either face-to-face, by telephone or online), a letter, fax, SMS (text message) or an e-mail. Interactions at home with members of the household are not included, nor are interactions as a customer or work-related interactions.

In the social interaction diary, detailed information was gathered about all social interactions. The purpose of this study required the social interaction diary to provide information on social travel and ICT use for social purposes, as well as the day of the week. In this study social travel is defined as the number of trips for social activities by three modes: car, bicycle and walking, and the total distance traveled for social activities per diary day. Social activities can be social visits, joint activities, as well as a conversation. In this study, ICT was defined as the number of social interactions by telephone and the number of social interactions via the Internet per day. Therefore, the diary provides, for each social interaction, information on the communication mode used and if the social interaction involved travel (especially for the social interaction), the travel distance and transport mode were recorded in the diary. Information on social network size, personal characteristics of the respondents and characteristics of the environment was gathered through the questionnaire that was part of the social interaction diary. Table 1 shows the descriptive statistics of the sets of variables that are relevant for this study.

To elicit social network size, in our study the same name generators were used as shown in the Connected Lives study (Carrasco et al. 2008):

1. Think about the people you feel **very close** to. They are:
   - people with whom you discuss important matters,
   - or regularly keep in touch with,
   - or that are there for you if you need help

   They can be household members, relatives, colleagues or fellow students, neighbors, club members and (other) friends.
2. Think about the people you feel **somewhat close** to.

They are: people that are more than just casual acquaintances, but not very close
They can be household members, relatives, colleagues or fellow students, neighbors, club members and (other) friends.

The number of very strong ties and the number of reasonably strong ties are both used as exogenous variables.

The number of facilities accessible in a walking distance from home (1 kilometer) was also collected using the questionnaire. A distinction was made between different types of facilities: shop, school, doctor, library, indoor sport facility, outdoor sport facility, community center, bar / restaurant. If the respondent indicated to have none of these facilities within a kilometer from their home, the measure is 0 and if all of these facility types can be reached the measure is 8.

Table 1: Descriptive statistics of the sample (N=1494 diary days recorded by 747 respondents)

		Sample averages
Endogenous variables		
Social travel		
Number of cars in household	[n]	1.28
Number of walks	[n]	0.19
Number of bike trips	[n]	0.33
Number of car trips	[n]	0.72
Average social travel distance	[km]	6.71
ICT use		
Number of telephone calls	[n]	1.57
Number of internet interactions (e-mail, IM, chat)	[n]	0.68
Social network		
Number of active club /association memberships	[n]	1.13
Number of very strong ties	[n]	8.90
Number of reasonably strong ties	[n]	13.29
Exogenous variables		
Personal and household characteristics		
Male *(1 if true, 0 otherwise)*	[%]	39
Age	[years]	46.53
Higher education *(1 if BSc or higher, 0 otherwise)*	[%]	46
Lives with partner *(1 if true, 0 otherwise)*	[%]	78
Child(ren) under 18 in household *(1 if true, 0 otherwise)*	[%]	45
Full time work *(1 if >35 hours per week, 0 otherwise)*	[%]	32
Spatial characteristics		
Low urban density *(1 if <1500 addresses/km^2, 0 otherwise)*	[%]	40
Number of facilities within 1 km	[n]	4.04
Day of the week		
Weekend *(1 if true, 0 otherwise)*	[%]	25

4. MODEL STRUCTURE

The question posed in this paper requires a method that can capture the relationships between several dependent and independent variables. Path analysis is a method that meets this requirement. Path analysis is a special case of structural equation modeling (SEM). Whereas SEM can deal with measured (or observed) variables and latent variables (also known as factors, constructs or unobserved variables), path analysis deals only with measured variables. In this study we use path analysis, because the variables all refer to characteristics or behavior that is observed.

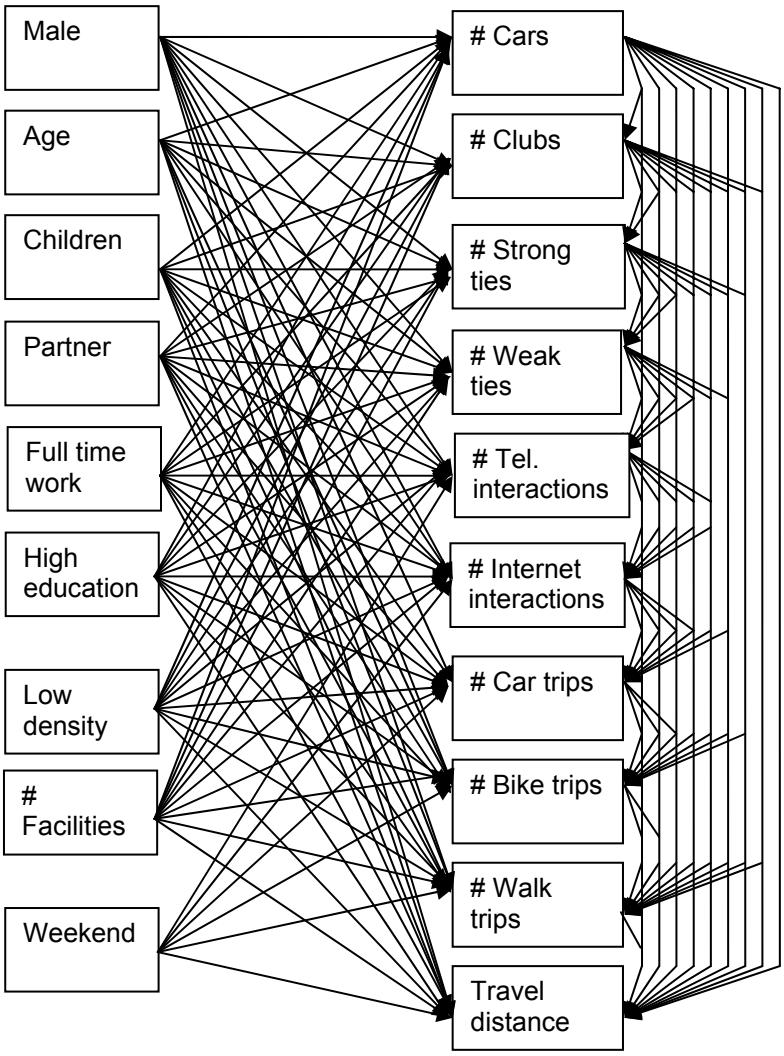

Figure 1: Path diagram of the model

In path analysis a set of equations can be computed simultaneously. A path analysis model can have a number of endogenous variables, which can be functions of the exogenous variables and of other endogenous variables. A variable can thus play a double role in a path model: independent as well dependent. Using path analysis, both direct and indirect effects

can be calculated. These characteristics make that path analysis is more useful than linear regression analysis.

Recently, path analysis and SEM have been used more frequently in travel demand modeling (e.g. Lu and Pas, 1999; Golob, 2001). The method is a confirmatory rather than exploratory, requiring the researcher to construct a model in terms of hypothesized effects of one variable on another (Golob, 2001).

The path diagram of the model capturing the links between personal and environmental characteristics, social networks, ICT use and social travel can be seen in Figure 1. The pathways (arrows) in the path model represent the hypothesized effects. The exogenous variables are on the left; the endogenous variables are on the right, and can be recognized as the receivers of an arrowhead in the model.

5. RESULTS

This section presents the results of the path analysis model. The model was estimated using the statistical software package LISREL (Jöreskog and Sörbom, 2001). A number of different model specifications were tested, with different (transformations and levels of) explanatory variables. Variables that did not significantly affect any of the endogenous variables were removed. The estimates of the final model that are significant at the 0.1 significance level, are shown in Table 2.

There are many criteria that have been developed to assess the goodness-of-fit of an SEM. The statistic Chi Square divided by the model degrees of freedom has been suggested a useful measure. Rules of thumb suggest that for correct models this measure should be smaller than 2 (Golob, 2001) or at least smaller than 5, but preferably around 1 (Washington et al., 2003). Another goodness-of-fit measure is the root mean square error of approximation (RMSEA), which should preferably be between 0.02 and 0.05. The model's Akaike information criterion (AIC) should be close to the value for the saturated model. Finally, the value of the normed fit index is 0.997 should be close to 1 (Washington et al., 2003). Table 3 shows the goodness-of-fit measures of the model. In general, the goodness-of-fit measures of the model are adequate.

Many significant relationships were found between the exogenous and the endogenous variables. Figure 2 shows a path diagram of the significant effects between the exogenous and the endogenous variables. Males have a positive coefficient for club membership. They have fewer strong ties in their social network, and fewer telephone calls for social interaction. With respect to age we found that older people are less likely to be car owners. However, they are likely to make more car trips for social activities than average. As hypothesized (because of more free time), older people are more likely to be club members. They are more likely to have more strong ties in their social network, but fewer weak ties. The net effect on social network size is negative. As hypothesized, older people tend to have less social contact via the Internet. This indicates that older people still lag behind in adopting this communication mode.

Table 2: Path analysis model estimates

From/to	# Cars	# Clubs	Strong ties	Weak ties	Tel. contacts	Internet contacts	Walk trips	Bike trips	Car trips	Travel distance
Male		0.106	-1.566		-0.286					
t		*(2.120)*	*(-3.187)*		*(-2.834)*					
Age	-0.006	0.006	0.052	-0.151		-0.007		-0.004	0.088	
t	*(-4.313)*	*(2.925)*	*(2.831)*	*(-4.689)*		*(-2.497)*		*(-2.039)*	*(2.930)*	
Partner	0.431				-0.209			-0.109		
t	*(10.135)*				*(-1.817)*			*(-2.026)*		
Children	0.079				0.194		0.065	0.103	0.121	-2.283
t	*(2.022)*				*(1.892)*		*(2.140)*	*(2.134)*	*(1.709)*	*(-2.461)*
Full time work					-0.227		-0.096			
t					*(-1.995)*		*(-2.872)*			
Education	0.090	0.164		1.521	0.322	0.416			0.116	2.609
t	*(2.632)*	*(3.690)*		*(1.997)*	*(3.590)*	*(6.610)*			*(1.842)*	*(3.162)*
Low density	0.273	0.135	1.338	1.490					0.183	
t	*(7.650)*	*(2.862)*	*(2.871)*	*(1.835)*					*(2.779)*	
Facilities				-0.307	-0.056			0.024		
t				*(-1.707)*	*(-2.649)*			*(2.443)*		
Weekend	--	--	--	--	-0.531	-0.292	-0.068	-0.119		4.022
t					*(-5.292)*	*(-4.123)*	*(-2.276)*	*(-2.479)*		*(4.366)*
Car	--						-0.036	-0.131	0.207	
t							*(-1.824)*	*(-4.118)*	*4.387*	
# Clubs	--	--	0.798	1.576			0.037	0.096	0.092	
t			*(3.132)*	*(3.548)*			*(2.378)*	*(3.887)*	*(2.534)*	
Strong ties	--	--	--	0.793	0.014	-0.007		0.006	0.009	
t				*(17.591)*	*(2.319)*	*(-1.781)*		*(2.301)*	*(2.122)*	
Weak ties	--	--	--	--		0.008		0.004		
t						*(3.610)*		*(2.629)*		
Telephone	--	--	--	--	--	0.070			0.030	
t						*(3.882)*			*(1.682)*	
Internet	--	--	--	--	--	--				-0.584
t										*(-1.748)*
Walk trips	--	--	--	--	--	--	--		0.116	-2.785
t									*(1.903)*	*(-3.500)*
Bike trips	--	--	--	--	--	--	--	--	-0.101	1.296
t									*(-2.638)*	*(2.593)*
Car trips	--	--	--	--	--	--	--	--	--	4.661
t										*(13.749)*
R^2	0.164	0.031	0.030	0.201	0.062	0.088	0.031	0.063	0.062	0.143
R^2 reduced form	0.164	0.030	0.023	0.021	0.054	0.068	0.024	0.023	0.031	0.024

Table 3 Goodness-of-fit of the model

Degrees of Freedom	4
Minimum Fit Function Chi Square	7.678 (P = 0.104)
Chi Square / Degrees of Freedom	1.92
Root Mean Square Error of Approximation (RMSEA)	0.0248
90 Percent Confidence Interval for RMSEA	(0.00 ; 0.0513)
P-Value for Test of Close Fit (RMSEA < 0.05)	0.939
Model AIC	417.659
Saturated AIC	380.000
Normed Fit Index	0.997

As expected, people with a partner are more likely to own one or more cars. The same goes for people with children. People who live with a partner on average make fewer telephone contacts and fewer bike trips than the average. The presence of children (under 18) in the household has a positive effect on the number of telephone calls, walking trips and bike trips for social purposes, and as expected, a negative effect on social travel distance. Full time workers are found to make fewer telephone calls and fewer walking trips for social activities than the average. This may be caused by the fact that they have less free time. For people with a high level of education positive effects were found for the number of cars in the household, club membership, the number of social interactions via telephone and the Internet, and the travel distances for social activities. This suggests that high education is related to longer distance social ties.

People living in low density areas are likely to be members of clubs. They have more strong social ties than the average. This confirms our hypothesis that in low urban areas traditionally strong local networks still exist. People living in low density areas also tend to have more cars and make more car trips for social activities. These effects were hypothesized because of longer travel times, as a result of longer distances in low urban density areas. However, no significant effect was found for travel distance. The results for the number of facilities within 1 km show a negative effect on the number of weak social network ties, a small negative effect on the number telephone calls and a small positive effect on the number of bike trips for social activities.

Finally, the day of the week affects the number of contacts by telephone and the Internet as well as the social travel variables. During the weekend, people tend to have fewer mediated social interactions, and fewer walking and cycling trips. This is in line with our hypothesis that the number of social interactions is lower during the weekend. The social travel distances are found to be longer on the weekend. This can probably be explained by the fact that during the weekend people have more free time and thus more opportunities to make longer trips for social activities.

The R-squares, especially the reduced form R-squares (see Table 2) are relatively low, which indicates that the explanatory power of the exogenous variables is only modest.

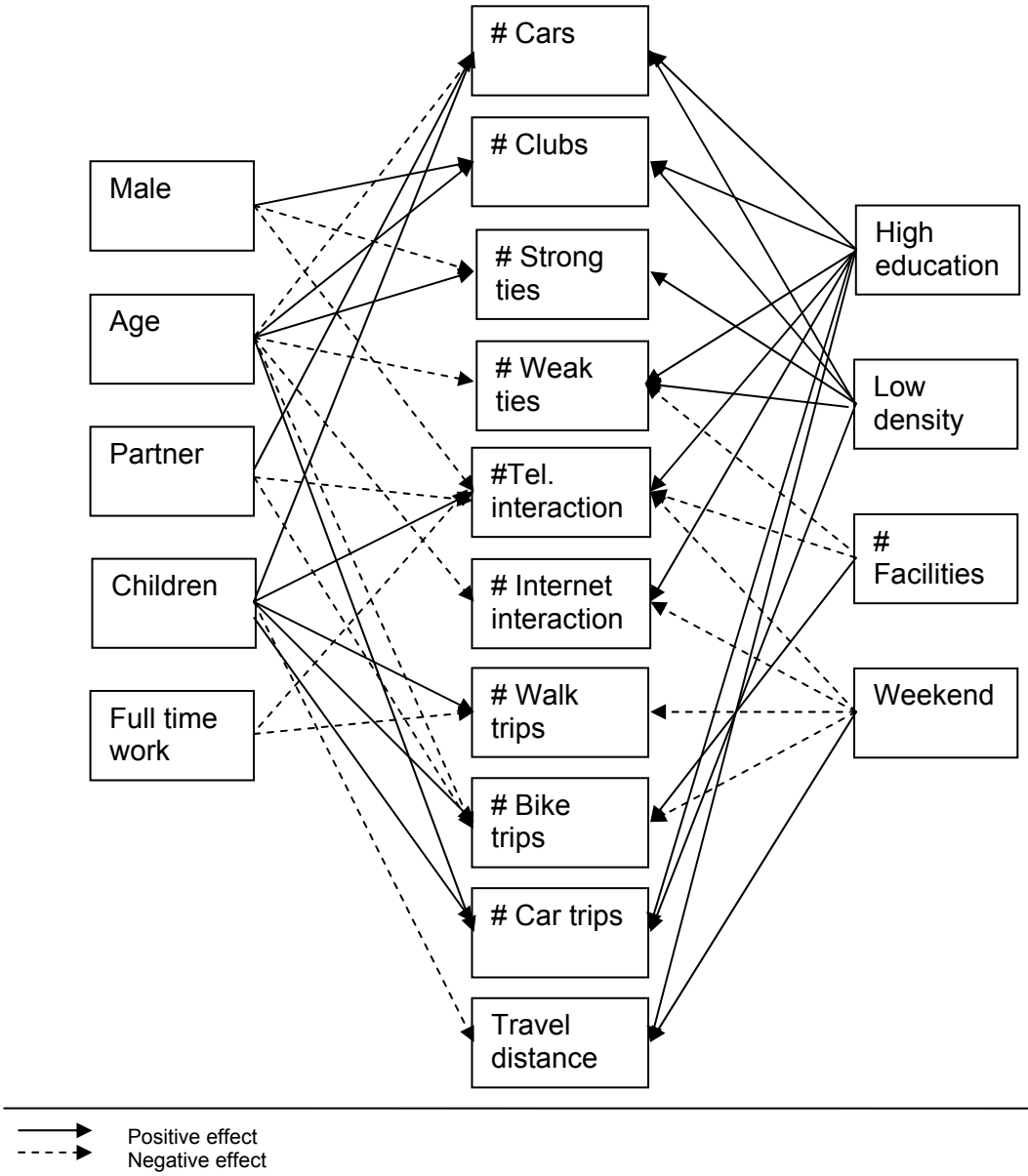

Figure 2: Effects between the exogenous and endogenous variables

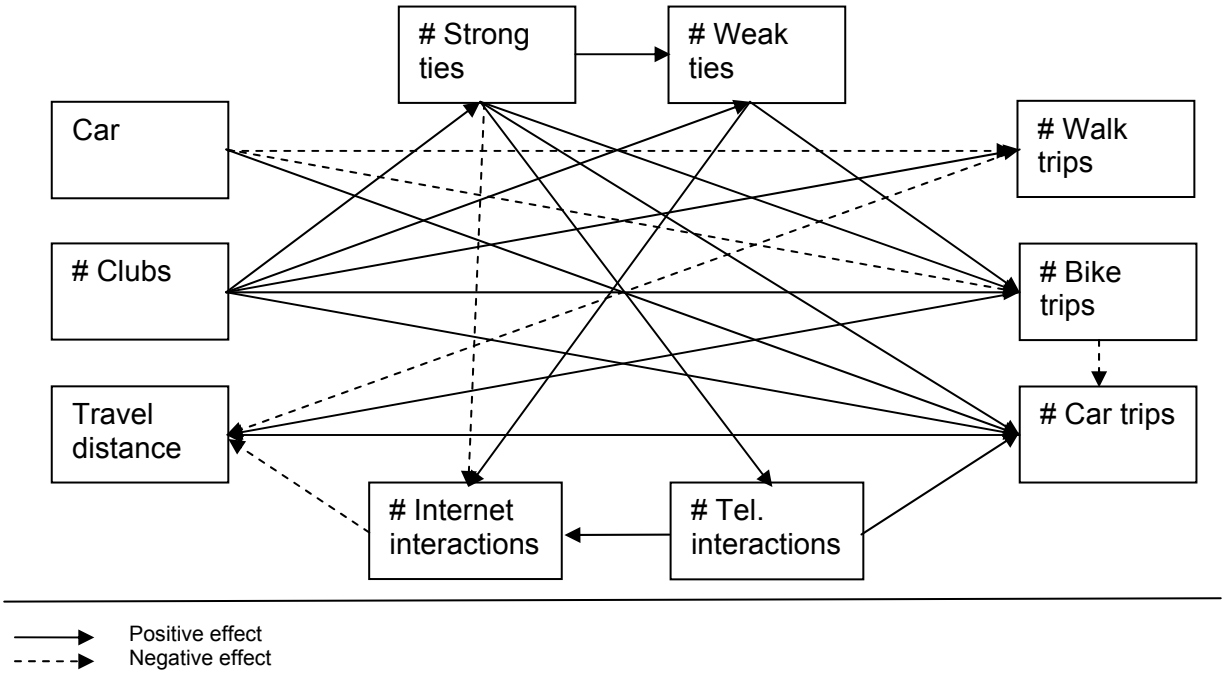

Figure 3: Effects between the endogenous variables

Figure 3 shows the significant effects between the endogenous variables in a path diagram. The results for the endogenous variables show that, as expected, the number of cars in the household has a positive effect on the number of car trips for social activities. It has a negative effect on the number of walks and bike trips. This means there is a substitution effect between these transport modes. Car ownership was not found to have a direct positive effect on the travel distance.

The number of clubs in which a person is involved, has a positive effect on the number of strong and weak ties in their social network, and on the number of walks, bike trips and car trips. This is in line with our hypotheses suggesting that clubs generate social activities. The number of strong network ties has a positive effect on the number of telephone interactions and a negative effect on the number of Internet interactions. The number of weak network ties has a positive effect on the number of social interactions via Internet. This means our hypothesis that social network size has a positive effect on the use of ICT for social contacts is only partly confirmed. Social network size also influences the number of trips with different transport modes. The number of strong ties has a positive effect on the number of bike trips and car trips, and the number of weak network ties has a positive effect on the number of bike trips for social activities.

The number of telephone interactions has a positive effect on the number of Internet interactions and a positive effect on the number of car trips. This confirms our hypothesis of complementarity. The number of Internet interactions was however found to have a negative effect on social travel distance. The number of walk trips is found to have a positive effect on the number of car trips and a negative effect on the average trip distance. The number of bike trips has a negative effect on the number of car trips and a positive effect on social travel distance. Finally, as expected, the number of car trips has a larger positive effect on the travelled distances.

6. CONCLUSION AND DISCUSSION

Based on social interaction diary data collected in 2008 in Eindhoven among 747 respondents, this paper has presented a path analysis model of the links between personal characteristics, properties of the built environment, social networks, ICT use and social activity-travel patterns. Overall, the findings are largely consistent with the literature and with our hypotheses and offer further insights into understanding social travel behavior.

The results showed many significant effects of personal characteristics that were in line with our hypotheses. For example, younger and higher educated people were found to have a higher Internet-mediated contact frequency. Older people are more likely to be club members and tend to have a smaller than average social network size. The presence of children (under 18) in the household has a negative effect on social travel distance.

The effects of the characteristics of the built environment show interesting results for urban density. Low urban density was found to be positively related to car ownership, club membership, the number of social network ties and the number of car trips. The effects of the number of facilities within a walking distance were only moderate in explaining social interaction and travel behavior. As expected, during the weekend, the number of mediated social interactions and the number of social trips (on foot and by bike) were found to be lower and the social travel distances were found to be longer than average.

With regard to the endogenous variables many significant results were found as well. Car ownership has a negative effect on the number of walks and bike trips and positive effect on the number of car trips for social activities. The number of clubs in which a person is involved, has a positive effect on the number of strong and weak ties in their social network, and on the number of walks, bike trips and car trips. Social network size was found to have a positive effect on the number of bike trips and car trips, which in turn have a positive impact on the travelled distances. The number of telephone interactions was found to have a positive effect on the number of car trips, which confirms our hypothesis of complementarity. However, the number of Internet interactions was found to have a negative effect on social travel distance.

Although the analyzed links can help to better understand social travel behavior, a number of aspects deserve further research. First, social activities could be analyzed in more detail. Apart from the number of social activities and trips, data were collected regarding the purpose of each social activity, the timing and the duration. Moreover, the model presented here uses only the number of clubs, and the numbers of strong and weak social network ties as measures for the social context. A more detailed analysis could include specific characteristics of each ego-alter relationship, such as their role relationship and their contact frequency. Addressing these issues will hopefully increase our understanding of social activity travel behavior.

REFERENCES

Aoki, R., Ohno, Y., Tamakoshi, A., Kawakami, N., Nagai, M., Hashimoto, S., Ikari, A., Shimizu, H., Sakata, K., Kawamura, T., Wakai, K., Senda, M., 1996. Lifestyle determinants for social activity levels among the Japanese elderly. Archives of Gerontology and Geriatrics 22 (1996) 271-286.

Arentze, T., Timmermans, H., 2008. Social networks, social interactions, and activity-travel behavior: a framework for microsimulation. Environment and Planning B: Planning and Design 35 (6) 1012-1027.

Axhausen, K., 2003. Social networks and travel: Some hypotheses, Arbeitsbericht Verkehrs und Raumplanung, 197, Institut für Verkehrsplanung und Transportsysteme, ETH Zürich, Zürich.

Axhausen, K., 2007. Activity spaces, biographies, social networks and their welfare gains and externalities: some hypotheses and empirical results. Mobilities 2 (1) 15-36.

Axhausen, K., 2008. Social networks, mobility biographies, and travel: survey challenges. Environment and Planning B: Planning and Design 35 (6) 981-996.

Baym, N., Zhang, Y.B., Lin M.-C., 2004. Social interaction across media: Interpersonal communication on the internet, face-to-face, and telephone. New Media & Society 6, 41-60.

Boase, J.,Horrigan, J., Wellman, B., Rainie, L., 2006. The Strength of Internet Ties. Washington, DC: Pew Internet and American Life Project.
Retrieved from http://www.pewinternet.org/pdfs/PIP_Internet_ties.pdf

Carrasco, J., Miller, E., 2006. Exploring the propensity to perform social activities: a social networks approach. Transport 33 (5) 463-480.

Carrasco, J., Miller, E., Wellman, B., 2006. Spatial and social networks: the case of travel for social activities. Paper presented at the 11th International Conference on Travel Behaviour Research, Kyoto.

Carrasco, J., Hogan, B., Wellman, B., Miller, E., 2008. Collecting social network data to study social activity-travel behavior: an egocentric approach. Environment and Planning B: Planning and Design 35 (6) 961-980.

Cho, J., Gil de Zuniga, H., Rojas, H., Shah, D., 2003. Beyond Access: the Digital Divide and Internet Uses and Gratifications, IT & Society 1 (4): 46-72.

Degenne, A., Forsé, M. 1999. Introducing Social Networks, Sage Publications, London.

Dugundji, E., Walker, J., 2005. Discrete choice with social and spatial network interdependencies: an empirical example using mixed GEV models with field and 'panel' effects. Transportation Research Record 1921, 70-78.

Farber, S., Páez, A., 2009. My car, my friends, and me: a preliminary analysis of automobility and social activity participation. Journal of Transport Geography 17 (3) 216-225.

Golob, T., 2001. Structural Equation Modeling for travel behavior research. Transportation Research Part B 37, 1-25.

Graham, S., Marvin, S., 1996. Telecommunications and the city. Electronic spaces, urban places. Routledge, London.

Haythorntwaite, C. Wellman, B., 2002. The Internet in Everyday Life: an Introduction, in Wellman, B., Haythorntwaite, C., The Internet in Everyday Life, Blackwell, Malden, MA, 3-42.

Jöreskog, K. Sörbom, D. 2001. LISREL 8.5 Scientific Software International

Kemperman, A., Arentze, T., Timmermans, H., 2006. Social commitments and activity-travel scheduling decisions. Proceedings of the 85th Annual Meeting of the Transportation Research Board, Washington D.C.

Larsen, J., Urry, J., Axhausen, K., 2005. Social networks and future mobilities, report to the Horizons Programme of the Department for Transport, Department of Sociology, University of Lancaster and IVT, ETH Zürich, Lancaster and Zürich

Lu, X., Pas, E., 1999. Socio-demographics, activity participation and travel behavior. Transportation Research Part A 33, 1–18.

Marsden, P., 2005. Recent Developments in Network Measurement, in Models and Methods in Social Network Analysis, Carrington, P., J. Scott and S. Wasserman (eds.) Cambridge University Press, New York.

Matei, S., Ball-Rokeach, S., 2002. Belonging in Geographic, Ethnic and Internet Spaces, in Wellman, B., Haythorntwaite, C., The Internet in Everyday Life, Blackwell, Malden, MA, 404-430.

Mokhtarian, P., 1990. A Typology of Relationships between Telecommunications and Transportation. Transportation Research Part A 24 (3), 231-242.

Mokhtarian, P., Meenakshisundaram, R., 1999. Beyond Tele-Substitution: Disaggregate Longitudinal Structural Equations Modeling of Communication Impacts, Transportation Research Part C 7, 33-52.

Mokhtarian, P., Salomon, I., Handy, S., 2006. The impacts of ict on leisure activities and travel: A conceptual exploration, Transportation 33 263–289.

Ohnmacht, T., 2006. Mapping Social Networks in Time and Space, Arbeitsberischte Verkehr und Raumplanung, 341, IVT, EHT Zürich

Páez, A., Scott, D., 2007. Social influence on travel behavior: a simulation example of the decision to telecommute, Environment and Planning A 39 647-665

Salomon, I., 1986. Telecommunications and travel relationships: a review. Transportation Research A 20A, 223-238.

Senbil, M., Kitamura, R., 2003. Simultaneous relationships between telecommunications and activities. Paper presented at the Tenth International Conference on Travel Behaviour Research, Lucerne

Silvis, J., Niemeier, D., D'Souza, R., 2006. Social Networks and Travel Behavior: Report from an Integrated Travel Diary, Proceedings of the 11th International Conference on Travel Behaviour Research, Kyoto.

Simma, A. Axhausen, K. 2001. Structures of commitment and mode use: A comparison of Switzerland, Germany and Great Britain. 1st Swiss Transport Research Conference Monte Verità / Ascona, March 1.-3. 2001

Simma, A., Vrtic, M., Axhausen, K., 2001. Interactions of travel behaviour, accessibility and personal characteristics: the case of upper Austria. Association for European Transport.

Van den Berg, P., Arentze, T., Timmermans, H., 2009. Size and composition of ego-centered

social networks and their effect on geograhpical distance and contact frequency. Proceedings of the 88th Annual Meeting of the Transportation Research Board, Washington D.C.

Washington, S., Karlaftis, M., Mannering, F., 2003. Statistical and Econometric Methods for Transportation Data Analysis. Chapman & Hall, Washington D.C.

Wasserman, S., Faust, K., 1994. Social Network Analysis, New York: Cambridge University Press.

Wellman, B. Hogan, B. with Berg, K., Boase, J., Carrasco, J., Côté, R., Kayahara, J., Kennedy, Y., Tran, P., 2006. Connected Lives: The Project. In: Purcell, P. (ed) Networked Neighbourhoods, Springer, London 161-216.