An analysis of the Dynamics of Activity and Travel Needs in Response to Social Network and Life-Cycle Dynamics: a structural equation model

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ABSTRACT

In the short-term, the social network has an important role to play in discretionary activity and travel decisions of an individual. However, a social network may not stay the same in the long term. Especially, it may change in response to life-cycle events, for instance a change in job. A change in the social network in turn may have a repercussion on activity and travel behaviour, meaning that an investigation of the long term dynamics of social network is relevant for understanding activity scheduling or rescheduling behaviour. To this end, the paper explores the dynamics of social network and life-cycle events and their influence on activity–travel needs. Dynamics are assumed to be triggered by life-cycle events. For the purpose of the study an event-based retrospective survey was conducted in 2011 in the Netherlands. For this model 697 cases were selected and a structural equation model was developed. Results suggest that activity and travel dynamics are influenced by life-cycle and social network dynamics. Moreover social network and activity travel dynamics are interdependent, i.e. a change in one leads to change in the other. Furthermore, the study results confirm the general assumption that travel needs are for the most part influenced by activity needs.

Keywords: Activity-Travel Needs, Social Network Dynamics, Life-cycle Dynamics, History Dependence, Event-based retrospective survey, Structural Equation Modelling

INTRODUCTION

The activity-based approach to travel modeling came to replace traditional four-step models with the argument that four-step models take travel as an isolated incident, whereas it is related and generated from the activities one plans or needs to perform. With the progress of time-use and travel behavior research, contemporary studies in the field argue that activity-

travel models are somewhat static in nature looking at one particular moment in time whereas activity and travel demands are quite dynamic. In an attempt to capture those dynamics the focus is shifting towards dynamic modeling. Relevant to the discussion is the issue of incorporating the triggers that induce those dynamics, which in many cases are life-cycle events. A further fundamental element of activity and travel behavior concerns social activities and travel company which emerges from one's social network. The paper relates to all of these three domains, aiming towards an integrated analysis of activity travel needs, social network dynamics and life-cycle dynamics.

Individuals constantly change their daily activity schedules and decisions. Several studies advance a dynamic view on daily activity decision making process (Srinivasan and Athuru, 2005). The intra-household joint decision dynamics are also reported to be dependent on socio-demographic characteristics and car availability (Schwanen et al., 2007, Habib et al., 2008). Another stream of studies focuses on the life-cycle events and how they are interdependent triggering travel choices, such as car ownership (Verhoeven et al., 2006, Oakil et al., 2011) and activity and travel duration dynamics (Sharmeen et al., 2013). Further studies focused on the relationship between social network and activity and travel behavior (Axhausen, 2005, Dugundji et al., 2008, Ettema et al., 2011, Han et al., 2011, Van den Berg et al., 2008). It is important to incorporate the activity company (Sharmeen and Ettema, 2010) as it involves negotiation between activity and travel parties (Ronald et al., 2012), eventually causing dynamics in activity-travel scheduling. Collectively the above studies argue that activity and travel are dependent on socio-demographics, social network and life cycle events. However, individually the studies are limited to two of the three domains (i.e. life-cycle events, social network and activity-travel behavior). An integrated approach in the field is missing.

In the short-term, the social network has an important role to play in discretionary activity and travel decisions of a person. However, the social network may not stay the same in the long term. Changes would also have a repercussion on activity and travel behaviour. This necessitates investigation into the long term dynamics of social network and effects on activity scheduling or rescheduling behaviour. Similarly as one progresses through life several life-cycle events take place. These events may bring in changes in one's personal social network. For instance, a change in job means new colleagues and may have direct or indirect (via the social network) effects on activity and travel scheduling. Reversely, a change in activity and travel schedule may also introduce modifications in one's time budget. This may create possibilities or hindrance in the maintenance of social ties causing the social network to change. Therefore, we argue that social network and activity-travel schedules are interdependent and triggered by life-cycle events.

To this end, the objective of this paper is to explore the dynamics of social network and its influence on activity scheduling. Dynamics are assumed to be triggered by life-cycle events, e.g. neighbours change as one changes house. In earlier work, we argued that social networks are dynamic and developed the conceptual framework (Sharmeen et al., 2010). Later the dynamics of social interaction (Sharmeen et al., 2012) and the dynamics of activity-travel

behaviour (Sharmeen et al., 2013) in relation to particular life cycle events were investigated. The present study is in continuity of the previous works linking all life-cycle and social network dynamics with activity-travel needs in an integrated framework.

The remainder of the paper is organized as follows. Section two contains the conceptual framework. Section three explains the data and methodology used in the paper. Section four includes a detailed discussion of the results and the last section presents some concluding remarks.

CONCEPTUAL FRAMEWORK

The conceptual framework is concerned with the following three domains:

1. The life-cycle domain
2. The social network domain, and
3. The activity and travel domain

It states that all these three domains are *dynamic* and *interrelated*. Change in any one domain can have an effect on the others. For example, when a person gets married (a life-cycle event), (s)he gets new in-laws and friends, as a result of which his/her social network may change. Since the person has a partner now the household maintenance jobs (such as grocery shopping, picking up/dropping off dry cleaning etc) can be distributed between the partners. Also associated with the new social network there can be new social visits and recreational activities. These have a direct impact on the activity and travel needs of the person. The effect can also be the other way around, for instance when the activity-travel schedule changes due to a job change. Consider the three domains as three parallel lines running along with each other (figure 1). The paper analyzes the links in between.

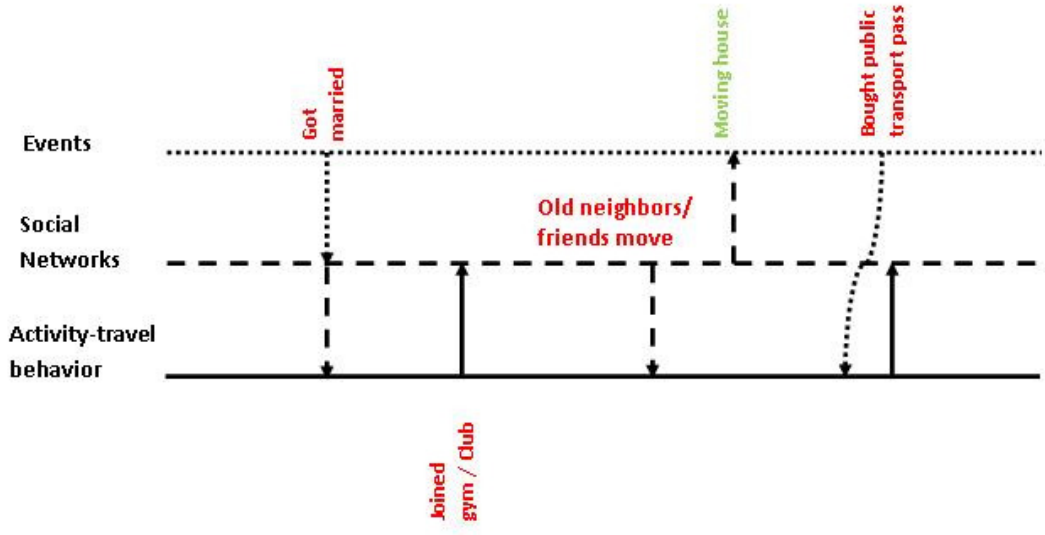

Fig 1: Conceptual framework representing three domains of interrelated dynamics.

Source and details (Sharmeen et al., 2010)

The domain definitions are given as follows:

Life-cycle dynamics is defined by the events that could bring changes in the social life of the individual and the household, categorized as change in civil status, change in residential location, change in work/study hours, starting university, starting new job and children of the household starting school.

Dynamics in social network is defined by the changes in the social network. It is measured by the number of lost contacts and the number of new contacts of the person (ego) after the latest major life cycle event took place.

Activity and travel needs are defined by means of allocation of time budget for different activity-types. Individuals have limited time to allocate to different activities. They also have varied needs to perform different types of activities. These needs differ from person to person and also within lifecycle stages of a particular person. The time budget an individual allocates to his/her activities is based on his/her need to perform that particular activity. Hence, we assume that time spent on activities can be taken as an indicator of the need for activities and travel. Dynamics are explained by taking the history of activity and travel needs into account. Activities (and associated travel) are divided into four categories:

- Work/study: work, study
- Maintenance activities: daily grocery shopping; picking up/dropping off people/goods; visit to pharmacy/barber shop/post office/dry cleaning, etc.; sport activities
- Social visit: visiting someone in the social network
- Recreation: non-daily shopping; dining out in restaurant/café/bar; going to movies/theatre/concert; organizing/attending parties; going to park/nature; social club or community activities.

To capture these notions, the conceptual model is defined as shown in figure 2). Life-cycle changes are assumed to have an effect on social networks and activity-travel needs. Events may bring in changes in individual's time budget or location status or both. For instance residential relocation includes a change of address and a modified geographical distance with all existing social network members. For some ties these changes are substantial and will cause a change in the interaction frequency (Sharmeen et al., 2012). As a result the tie may eventually disappear from the ego's social network. Similarly events may add new ties in the network. Therefore effects of event on number of lost ties and number of new ties are expected. To avoid complexity only some of these effects are shown in the figure. All of them however are tested in the structural-equation model used for analysis.

Events may also have an effect on time budget. This may bring in stress in the overall equilibrium bringing the system out of balance. Individuals then need to reschedule their activity-travel agenda (Sharmeen et al., 2013). Hence the effects of events on activity-travel needs are also taken into consideration.

The paper assumes that there is a threshold of social network size. An ego cannot keep on adding ties indefinitely. Since the time the ego needs to maintain those ties is limited, at some point some ties should fade away. With this assumption, the model tests the effect of new ties on lost ties. Furthermore, the interdependencies between social network dynamics and activity-travel needs are investigated.

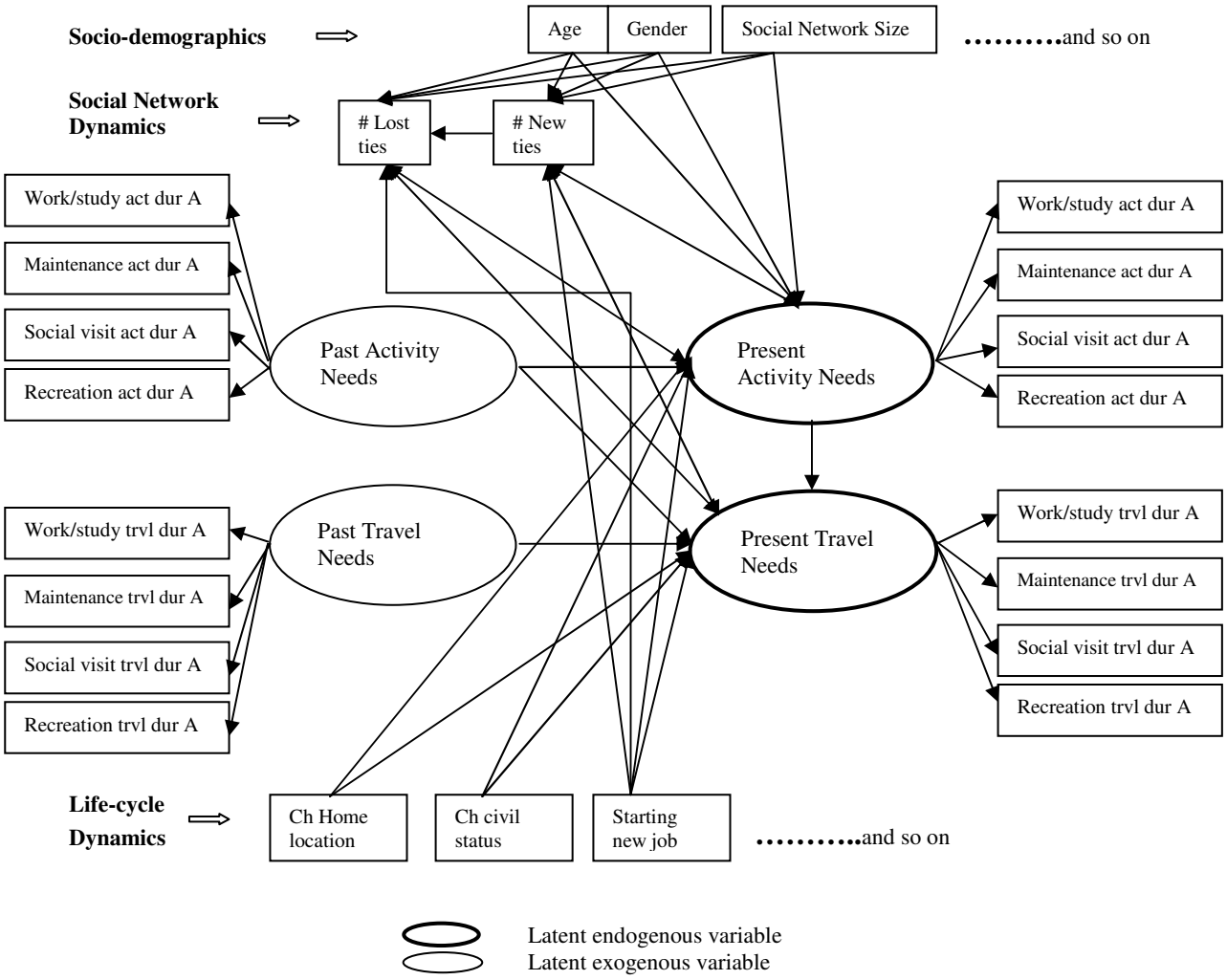

Fig 2: Conceptual model, linking activity travel needs, social network and life-cycle dynamics

DATA/METHODOLOGY

An event-based retrospective questionnaire survey has been conducted in 2011 in the Netherlands. Respondents were asked to pick any one event from a list that occurred within the past two years in his/her life. We gathered information about socio-demographics of the respondent, the present social network, the changes (if any) in personal social network and changes (if any) in the activity-travel behaviour related to the life-cycle event in question. The web-based and paper-based surveys were conducted in September 2011 and involved 697

respondents. Activity duration data were collected for out-of-home activities. The unit is hours per week in a typical working week. For details about the dataset please refer to Sharmeen (et al 2013).

Sample characteristics are presented in table 1. Young adults are overrepresented in the sample. Gender distribution is uniform. Most of the respondents are highly educated, have a paid job and have a driving license. Almost 44% of the respondents went through a residential relocation in the past two years. It is important to note that by design of the sample all the respondents have gone through one or more major life-cycle events in the past two years. In social network dynamics, number of lost and new ties averages around 0.5 per person, since there are many who did not report any change in social network due to the major life-cycle event(s) they had experienced.

Table 1: Sample characteristics

Variables	Description	Type	Mean
Exogenous variables			
Age <=20	Age of ego is less than 20 years: Young	Categorical	17.2%
Age 21-40	Age of ego is between 21 to 40 years: Young adults	Categorical	60.3%
Age 60+	Age of ego is more than 60 years: Seniors	Categorical	8.4%
Male	Ego is male	Categorical	55.1%
Highedu	Ego's highest achieved level of education is undergraduate or higher	Categorical	67.4%
#workhr	Number of working hours per week	Continuous	21.60
#child	Number of child (under 18) in the household	Continuous	0.97
License	Having car in the household and the ego has driving license (yes)	Categorical	79.6%
SNSize	Size of close social network	Continuous	29.02
Ch home location	Ego changed home location in past 2 years	Categorical	43.6%
Ch work/study hr	The weekly work/study hour of ego changed	Categorical	30.3%
Ch civil status	Ego started living together or got married or separated or divorced in past 2 years	Categorical	19.2%
Children start sc	Children of the household (under 18) started school	Categorical	21.8%
Start university	Ego joined University for higher education	Categorical	21.4%
Start new Job	Ego started a new job	Categorical	18.7%
Endogenous variables			
# Lost ties	Number of ties lost after the event	Continuous	1.44
# New ties	Number of new ties after the event	Continuous	1.62

A Structural Equation Model (SEM) was developed in this study. SEM is a very powerful tool and increasingly used in travel behaviour research. A complete SEM consists of two components: the structural component and the measurement component. They are defined by three sets of equations: structural equations, measurement equations for endogenous variables and measurement equations for exogenous variables. This study includes both the components and thus a full SEM model.

There are several measures employed to assess the goodness-of-fit in SEM. Some take parsimony into account and others do not. In most cases they do not agree (Fabrigar et al., 2010). Fit indices can be divided into general goodness of fit indices and parsimony fit indices. The first category indices show roughly speaking whether the model fits the data

better than any other model. Parsimony fit indices address the issue that the model may only be fitting the noise of the data and will not be representative for population-wide application. However chi-square is an essential statistic to report along with the Root Mean Square Error of Approximation (RMSEA) and associated p-value (Hooper et al., 2008). Given the sensitivity of chi-square to model misspecification, additionally Standardized Root Mean square Residual (SRMR) is reported. To represent a good fit SRMR should be less than 0.05 although values up to 0.08 are deemed acceptable (Hooper et al., 2008). RMSEA should be less than 0.05 to indicate a good fit (Golob, 2003, Washington et al., 2009). Given the complexity of the model we report the aforementioned two indices.

RESULTS AND DISCUSSION

The results of SEM analysis using LISREL are discussed in this section. We derived a final model by removing those relationships that were not significant on a 0.1 significance level. Figures 3 and 4 shows the final model, Table 2 presents the measurement model (composition of latent constructs) and table 3 presents the structural model. The interpretation of the results is organized in four sub-sections below. At first the influence of exogenous variables on endogenous variables is described followed by a discussion on the effect of endogenous variables on each other. The goodness-of-fit measures show that the model is acceptable. The reduced R-squares show that the explanatory power of the exogenous variables is fair. Thus, the model seems to provide an acceptable fit to the data. The parsimony indices also show that the model has a modest population-wide applicability. Since there is no established minimum acceptance value for parsimony indices it is difficult to confirm this.

Present and previous activity and travel needs are measured using four indicators, namely weekly duration of work/study, maintenance, social visit and other recreational activities. Individual's activity and travel needs are reflected through the distribution of total activity time available. Hence time spent on each activity is a good measure of individual's activity and travel needs. As a further check of reliability Cronbach's alpha values, presented at the bottom of table 2, also suggest that the concepts are measured sufficiently reliable.

From the measurement model, it is apparent that the duration of mandatory activities is the primary indicator of activity and travel needs. For activity needs the rest of the measurement parameters are fairly uniformly distributed across the indicators. As for travel needs, travel related to mandatory activities has the strongest relationship with the construct. However social travel also has a high value for measuring it. Trips associated to social purposes have a considerably stronger relationship than recreational and maintenance activity related travel with the concept. The measurement relationships of the indicators do not differ significantly between previous and present case of activity needs and travel needs, which is expected given that the concepts are the same.

Table 2: Measurement Model

	Indicator variable	Latent Variable	Parameter estimates
Variables measuring present activity needs	Work/Study act dur A	Present activity needs	2.05
	Maintenance act dur A	Present activity needs	0.46
	Social visit act dur A	Present activity needs	0.47
	Recreation act dur A	Present activity needs	0.31
Variables measuring present travel needs	Work/Study trvl dur A	Present travel needs	6.84
	Maintenance trvl dur A	Present travel needs	1.53
	Social visit trvl dur A	Present travel needs	3.06
	Recreation trvl dur A	Present travel needs	1.60
History dependence			
Variables measuring previous activity needs	Work/Study act dur B	Previous activity needs	2.50
	Maintenance act dur B	Previous activity needs	0.61
	Social visit act dur B	Previous activity needs	0.41
	Recreation act dur B	Previous activity needs	0.38
Variables measuring previous travel needs	Work/Study trvl dur B	Previous Travel needs	7.26
	Maintenance trvl dur B	Previous Travel needs	1.69
	Social visit trvl dur B	Previous Travel needs	2.77
	Recreation trvl dur B	Previous Travel needs	1.82

* p<0.1 for all the coefficients
**A represents After the event and B represents Before the event. Unit is duration per week.
***Cronbach's alpha values: 0.883, 0.835, 0.770, 0.795 respectively from the top

Effects of socio-demographics

The structural-equation model estimation results are presented in table 3. Being young (age <20) has a negative effect on new activity need in response to an event (note: given that past activity needs are controlled for the effects on current needs can indeed be interpreted as a change in needs). This suggests that young people are less susceptible to loosing ties and more likely to make new ties when a lifecycle event occurs. Young adults (age 21-40) have larger change in activity needs in response to an event. They are more likely to loose and less likely to make new ties with a life-cycle event, compared to the middle aged group (age 41-60). Seniors (age 60+) on the other hand are more likely to make new ties in comparison to the middle aged group (age 41-60). Gender has an effect on change in activity needs as well as social network changes in response to an event. Men display a higher change in activity need and are more likely to make new ties compared to women. Furthermore, being highly educated (defined by highest earned education from colleges and universities) has a positive effect on change in activity needs and number of new ties in response to an event.

Moreover, number of working hour and number of children in the household have a negative effect on activity need changes. Possession of driving licence incurs more new travel needs. Size of social network has a positive effect on new activity needs and new ties. Thus people with a larger social network tend to have a bigger change in activity needs and also are more likely to make new ties.

Effects of life-cycle dynamics

The effects of life-cycle dynamics on activity and travel needs has been investigated by means of six observed variables. Those are change in home location, change in work/study hour, change in civil status (living together/getting married/separated/ divorced), children of the household starting school, respondent starting new job and respondent starting university education. The results show that all of them have a positive effect on activity needs, except the event of change in work/study hours. The positive effects suggest that an activity need increases when the individual experiences any of these events. Among the event of starting university has the strongest effect. The size of effects of other events is fairly similar. In terms of travel needs, significant positive effects have been found for two life-cycle events, namely, change in work/study hours and respondent starting university education. Among those the latter has the strongest positive effect.

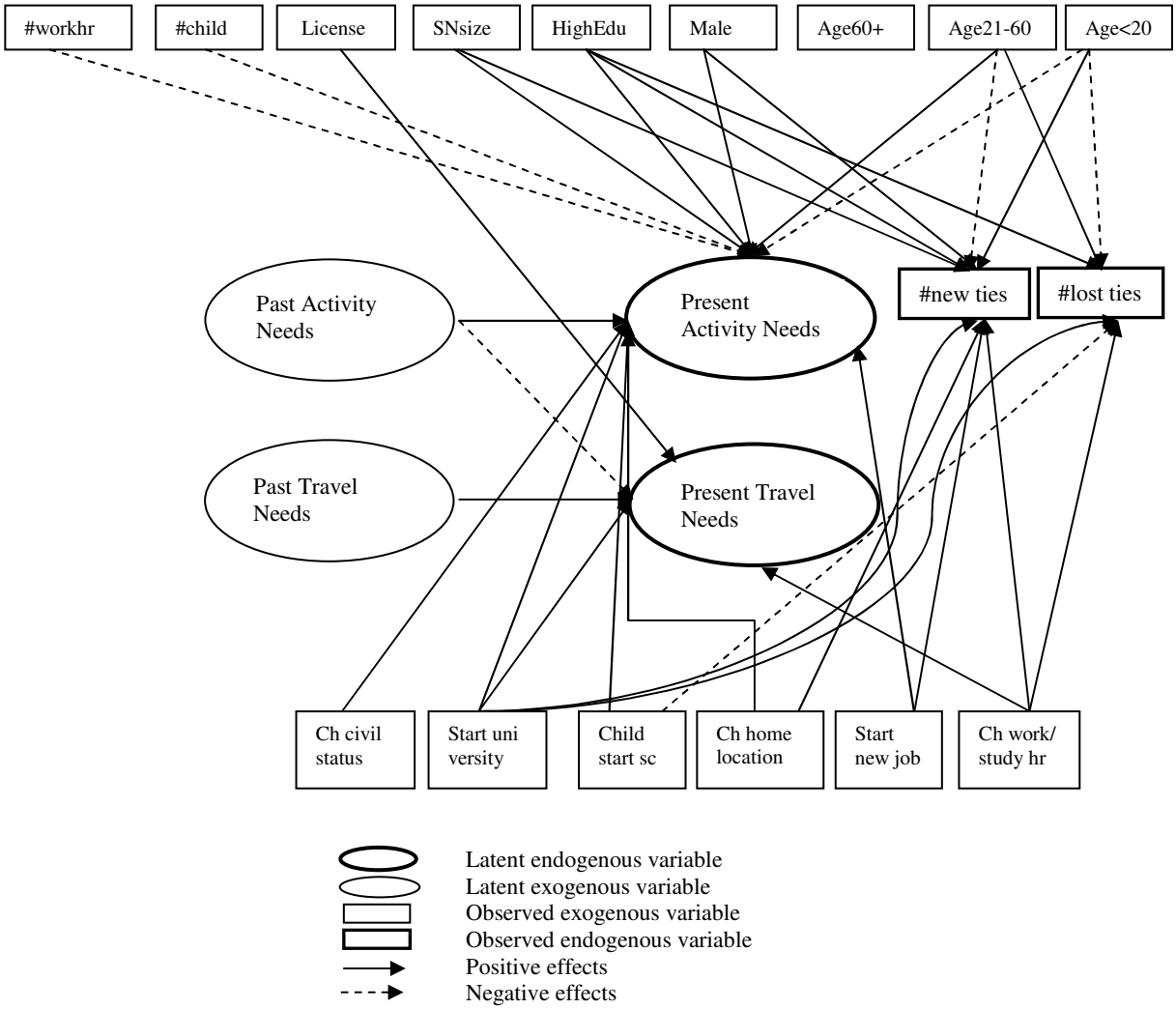

Fig 3: Structural model of dynamics of social network, life-cycle events and activity-travel needs

(Exogenous effects)

Life-cycle dynamics also have a substantial effect on social network dynamics. The number of lost ties increases when a change in work/study hours occur or the individual starts a university education. On the other hand, the event of children starting school has a negative effect on number of lost ties, suggesting that here the opposite is the case. This may be explained as that when children start school parents have more free time to interact with their peers and maintain their ties. The probability of having new ties increases with events like change in home location/work or study hours, starting new job or university. Starting university has the strongest effect. This event has the strongest effect on both the number of lost ties and the number of new ties. This seems the most significant event in terms of social network dynamics. It suggests that people make new friends but also loose their friends when they join higher studies. In the dataset, we observed that most of the students either commute on a daily basis to come to the university or move house leaving their parental homes. Hence it seems plausible that they have a major change in their social network structure. Surprisingly, change in civil status does not have any effect on social network dynamics. This may again be due to the fact that this event includes new bond as well as separation under the same variable. Thus the individual effects may have been compromised.

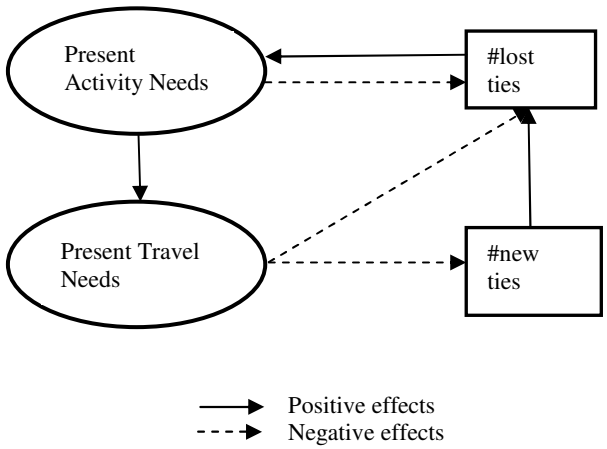

Fig 4: Structural model of dynamics of social network, life-cycle events and activity-travel needs

(Endogenous effects)

Effects of history of activity and travel

The past activity and travel schedule likely have a big impact on current behaviour. People cannot suddenly change their activity and travel schedule in a radical way. Therefore, it is important to take the history into account when analysing the present activity and travel behaviour. However in most studies, the history is not included in the analysis. In the model (as well as the survey), the previous activity (before the life-cycle event) and travel needs are measured in the same way as the present ones to maintain consistency. The results show that previous activity and travel needs have a positive effect on present activity and travel needs, as expected. Thus if previous needs were higher they would remain so. The effect is stronger for travel needs. This probably indicates that individual's travel behaviour is primarily

habitual or at least that preferences and circumstances do not change dramatically. For example, people who commute to work or travel further for recreation activities may keep on doing so, even after major life-cycle events.

However previous activity needs have a negative effect on present travel needs. It is to note that the effects hold after controlling for the history dependence of travel needs and present activity needs. The effects thus should be interpreted in terms of a change in activity needs having an effect on present travel needs. So, keeping everything else constant, a change in activity needs reduces the present travel needs.

Table 3: Structural Model

	Present Activity needs	**Present Travel needs**	**#Lost ties**	**#New ties**
Socio demographics				
Age <=20	-0.52***	-	-0.52***	1.05***
Age 21-40	0.14***	-	0.14*	-0.05*
Age 60+	-	-	-	0.30***
Male	0.09**	-	-	0.09**
Highedu	0.29***	-	0.14***	0.19**
#workhr	-0.02***	-	-	-
#child	-0.03*	-	-	-
License	-	0.09**	-	-
SNSize	0.11***	-	-	0.10
Life cycle dynamics				
Ch home location	0.24***	-	-	0.08***
Ch work/study hr	-	0.09***	0.21***	0.21***
Ch civil status	0.25***	-	-	-
Children start sc	0.24**	-	-0.17***	-
Start university	0.73**	0.12**	1.01***	0.44***
Start new Job	0.22***	-	-	0.06***
History of activity and travel needs				
Previous activity needs	0.54***	-0.33***		
Previous travel needs	-	0.90***		
Endogenous effects: Dynamics of Social network				
#Lost ties	0.23***	-		-
#New ties	-	-	0.40***	
Endogenous effects: Present Activity Travel needs				
Present activity needs		0.43***	-0.20***	0.49***
Present travel needs			-0.10**	-0.22***
R2	*0.70*	*0.86*	*0.39*	*0.55*

***p<0.01 **p<0.05 *p<0.1

Model fit statistics:
Chi square: 1201
Degrees of freedom: 398
Root mean square error of approximation (RMSEA): 0.012
Standardized root mean residual (SRMR): 0.059
Normed fit index (NFI): 0.84
Parsimony normed fit index (PNFI): 0.54

Endogenous Effects

Personal social network tends to be dynamic changing with every major life-cycle event. New ties are added and some old ties fade away. As the social network changes so would the activity and travel needs to maintain the new social network. On the other hand, if activity and

travel needs change then this may also have an impact on social network dynamics. Therefore the interrelationships between social network dynamics and activity and travel needs are also examined.

Network dynamics (i.e. number of lost ties and number of new ties) do not have an effect on travel needs. In social network dynamics, the number of new ties has a positive relation with number of lost ties. This implies that as new ties are added in the social network the number of ties that are lost also increases. This is plausible since an ego can only maintain a certain number of ties at a certain point in time, given the limited time budget.

In the activity and travel domain, the results show that activity needs have a positive relation with travel needs. The effect of travel need on activity need is not significant substantiating the general assumption that activity generates travel and not the other way around. As the need for activities increases so does the need for travel.

Activity needs have a negative relationship with number of lost ties and a positive relation with number of new ties. On the other hand, number of lost ties has a positive effect on activity needs. Travel needs have a negative relation with both of the two social network dynamics variables. This may possibly reflect an inherent attitude and personal preference. People who are active welcome new ties and yet not necessarily loose the old ones. Those with a higher travel need may restrict both loosing old ties and making new ties. Social network dynamics interaction however depicts that as you make new ties the probability of loosing old ones increases, implying a threshold concept of social network size.

CONCLUDING REMARKS

The study examined the relationships between social network dynamics and activity travel needs in response to life-cycle events. The concept of the paper is innovative; it is the first study linking the dynamics of social network and activity-travel, to the best of our knowledge.

The results of a SEM analysis confirm the expectation that activity and travel dynamics are influenced by life-cycle and social network dynamics. Moreover social network and activity travel dynamics are interdependent, i.e. a change in one leads to a change in the other. Furthermore, the study finds that travel needs are for the most part influenced by activity needs. Most of the socio-demographic and life-cycle event variables have a direct impact on activity need, which in turn generates travel needs.

The findings are coherent with the notion that activity generates travel. Travel needs do not have an impact on activity needs. We find this to be valid in a dynamic model as well. Furthermore, the findings related to social networks suggest that there is a threshold of the size of a social network. The threshold may vary among individuals and perhaps also throughout life stages. A detailed study of this concept is needed and remains in the future agenda.

To reduce errors in data we have carefully designed a retrospective survey. Studies have shown that retrospective data can be useful if carefully collected. When studying mobility

issues, panel data contain a higher risk of inconsistency and sometimes discontinuity (Solga, 2001). Keeping this in mind and given our resource constraints, we have designed and administrated a survey design to reduce respondent burden, focusing on one particular recent event and the changes associated with it to ensure respondents have a consistent mind-set when answering the questions. We organized 3 rounds of pilot testing and detailed feedback reports from respondents and academics and improved the design at each step. Applying possible and pragmatic measures, we strived to ensure that the responses have better consistency and as few errors as possible. Yet it is likely that there are errors and memory biases particularly in the area of reporting durations before the event for small activities.

The study contributes to a shift in focus by moving from short term behaviour analysis to mid term dynamics. To the best of our knowledge this is the first attempt to explore the dynamics of social network and dynamics of activity and travel needs. From a substantial point of view, the study contributes by generating insights in the dynamics of activity and travel demand.

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REFERENCES

Axhausen KW. (2005) Social networks and travel: Some hypotheses. Social Aspects of Sustainable Transport: Transatlantic Perspectives: 90-108.

Dugundji ER, Páez A and Arentze T. (2008) Social networks, choices, mobility, and travel. Environment and Planning B: Planning and Design 35: 956-960.

Ettema D, Arentze T and Timmermans H. (2011) Social influences on household location, mobility and activity choice in integrated micro-simulation models. Transportation Research Part A: Policy and Practice 45: 283-295.

Fabrigar LR, Porter RD and Norris ME. (2010) Some things you should know about structural equation modeling but never thought to ask. Journal of Consumer Psychology 20: 221-225.

Golob TF. (2003) Structural equation modeling for travel behavior research. Transportation Research Part B: Methodological 37: 1-25.

Habib KMN, Miller EJ and Axhausen KW. (2008) Weekly Rhythm in Joint Time Expenditure for All At-Home and Out-of-Home Activities: Application of Kuhn-Tucker Demand System Model Using Multiweek Travel Diary Data. Transportation Research Record: Journal of the Transportation Research Board 2054: 64-73.

Han Q, Arentze T, Timmermans H, et al. (2011) The effects of social networks on choice set dynamics: Results of numerical simulations using an agent-based approach. Transportation Research Part A: Policy and Practice 45: 310-322.

Hooper D, Coughlan J and Mullen M. (2008) Structural equation modelling: guidelines for determining model fit. Articles.

Oakil ATM, Ettema D, Arentze T, et al. (2011) Dynamics in car ownership and life-cycle events: A Longitudinal analysis. Proceedings TRB 90th Annual Meeting. Washington, D.C., USA

Ronald N, Arentze T and Timmermans H. (2012) Modeling social interactions between individuals for joint activity scheduling. Transportation Research Part B: Methodological 46: 276-290.

Schwanen T, Ettema D and Timmermans H. (2007) If you pick up the children, I'll do the groceries: spatial differences in between-partner interactions in out-of-home household activities. Environment and Planning A 39: 2754-2773.

Sharmeen F, Arentze T and Timmermans H. (2010) Modelling the dynamics between social networks and activity-travel behavior: literature review and research agenda. 12th World Conference on Transport Research. Lisbon, 11-15.

Sharmeen F, Arentze T and Timmermans H. (2013) Incorporating Time Dynamics in Activity-travel Behavior Model: A Path Analysis of Changes in Activity and Travel Time Allocation with Life Cycle Events. In Proceedings of the 92nd Annual Meeting of the Transportation Research Board. CD-ROM. Washington D C.

Sharmeen F, Arentze T and Timmermans HJP. (2012) Out of Sight, Out of Mind? Investigating Changes in Mode and Frequency of Social Interaction due to Lifecycle Events. 13th International Conference on Travel behaviour Research (IATBR). Toronto.

Sharmeen F and Ettema D. (2010) Whom to Hang out with and Where?Analysis of the Influence of Spatial Setting on the Choice of Activity Company. 12th World Conference on Transport Research. Lisbon.

Solga H. (2001) Longitudinal surveys and the study of occupational mobility: Panel and retrospective design in comparison. Quality & Quantity 35: 291-309.

Srinivasan KK and Athuru SR. (2005) Analysis of within-household effects and between-household differences in maintenance activity allocation. Transportation 32: 495-521.

Van den Berg P, Arentze T and Timmermans H. (2008) Social networks, ICT use and activity-travel patterns. Data collection and first analyses.

Verhoeven M, Arentze TA, Timmermans HJP, et al. (2006) Modeling the influence of structural lifecycle events on transport mode choice decisions using a structure learning algorithm.

Washington SP, Karlaftis MG and Mannering FL. (2009) Statistical and econometric methods for transportation data analysis: Chapman & Hall/CRC.