

Dynamics of social networks and activity travel behaviour

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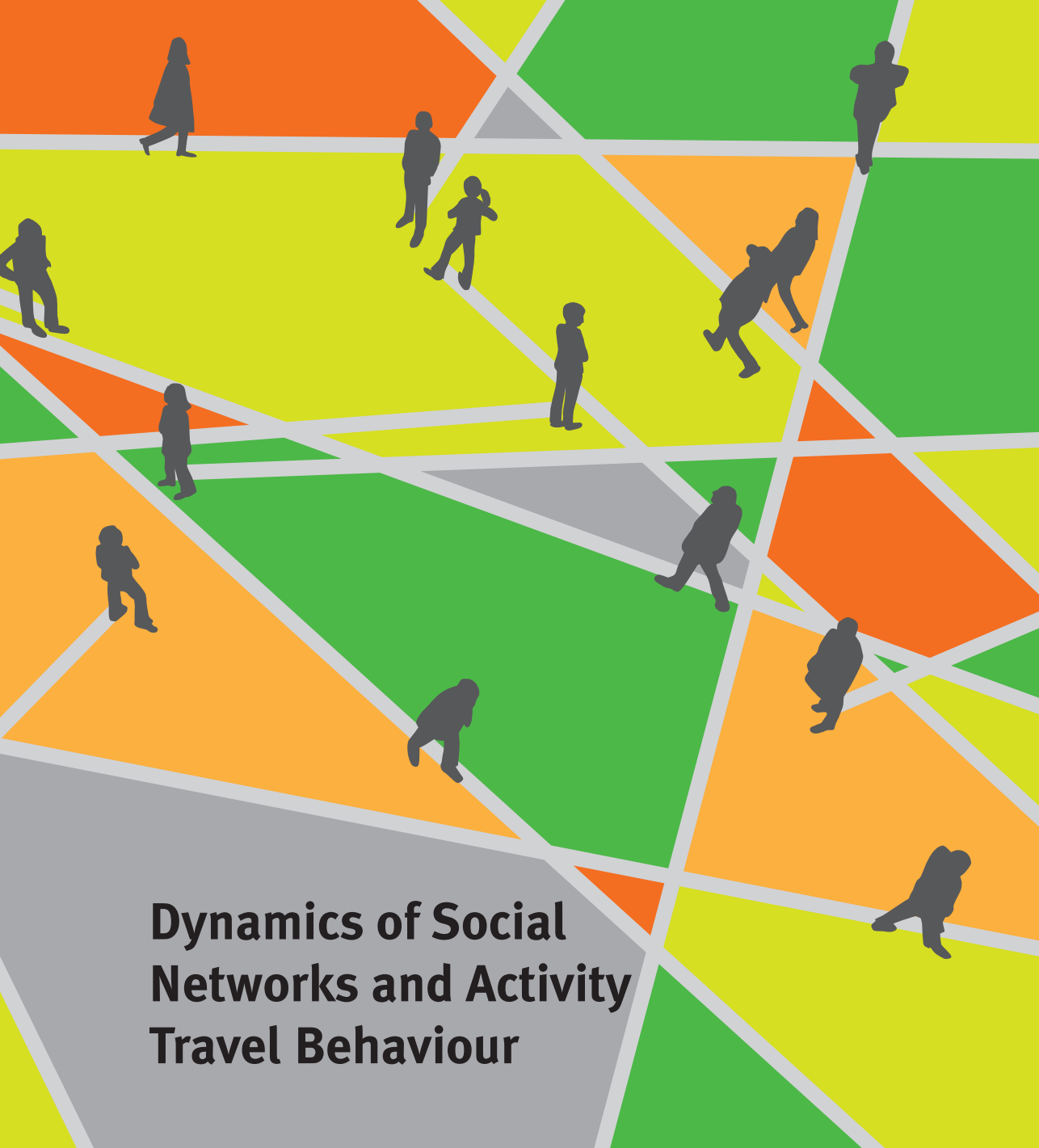
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Dynamics of Social Networks and Activity Travel Behaviour

Fariya Sharmeen

/ Department of the Built Environment

bouwstenen

199

Dynamics of social networks and activity travel behaviour

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Summary

Dynamics of social networks and activity travel behaviour

This study is based on two concepts, one is that social networks are dynamic and the second is that life trajectory events, social networks, and activity travel presumably have some level of interrelation. Relating to dynamics and evolution of egocentric social networks and activity travel behaviour, this study argues that present choices and behaviour are not independent of past actions. Empirical evidence in transportation literature show that life trajectory events act as triggers to induce long term dynamics in the system of personal activity and travel plans. Moreover social networks have an important role to play in discretionary activity and travel decisions of an individual, in the short-term.

However, social networks may not remain unchanged in the long run. They are dynamic and change constantly with new ties being added and old ties being lost throughout the life. The changes observed in social networks through time lead to changes in activity and travel behaviour. These changes call for an in depth investigation into the long term dynamics of social networks 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 employment means new colleagues and this 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 promote or hinder the maintenance of social ties causing the social network to change.

To that end, the study reports the findings of a set of analyses on the interdependency of dynamics in social network and activity travel behaviour triggered by life cycle events. It relates to three domains, viz. activity and travel, social network and life cycle events, and the interdependencies among them aiming towards an integrated analysis.

Results indicate, first of all, that social networks are dynamic. Life cycle events trigger changes in the composition of social network and in the mode and frequency of social interaction. Further analyses reveal that the modes of social interaction (face-to-face and using information and communication technology) are interdependent and that frequency of social interactions can be better predicted when history dependence and land use and accessibility indicators are taken into account. Second, life cycle events trigger changes in the time allocation for activity and travel. These changes vary in terms of existence, direction and intensity according to the type of event and the type of activity/travel. Third, the interdependencies are tested, and social network and activity travel dynamics are found to be interdependent. Finally a model of tie formation and tie dynamics was developed to estimate population wide social networks for large scale activity and travel micro-simulation.

The study contributes to a shift in focus by moving from short term behavioural analysis to mid and long term dynamics. To the best of our knowledge this is the first attempt to explore the dynamics of social networks, and the dynamics of activity and travel needs triggered by life cycle events, in a comprehensive framework. In the context of policy formulation and practical application, the study contributes to the formation and application of dynamic activity and travel behaviour models. In particular the study induces the importance of social networks in terms of how they are triggered and contextualised to the changes in life cycle events and how they can influence individual's travel behaviour.

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1. Introduction

1.1 Motivation

This PhD research is motivated by a simple notion: social networks are dynamic. A social network tends to change with time as an individual grows older. However, there are particular stages or moments in one's life when these changes are fostered. Such moments can be denoted as life cycle events. With every major event in our lives, our social networks may shuffle. Some ties are added to the network, while some may disappear from it. However, there ought to be some synergy between these lost and new ties, controlled by an optimal personal social network size. One cannot have infinite number of ties in his/her network. How many ties one would or could maintain at a certain stage of life depends on a person's preferences, and available time and money budgets for discretionary activities and trips. Social networks need to be maintained, which requires time, money and personal motivation.

Why are social networks important in travel behaviour research? The domain of activity and travel consists of several components, some of which are obligatory and some are flexible. We have to go to work and school- indicated as obligatory or subsistence activities. We need to shop, do the laundry, post our letters, get a haircut, thereby maintaining our living- denoted as maintenance activities. The rest of the time can be spent on leisure and social activities. The distinctive feature of social activities and associated travel is that they are obligatory and flexible at the same time. So there is a playing field here where an individual can actually choose. They can choose whether to travel or not, where to travel, how to travel and so on and so forth. However, the constraint and opportunity here is that one also needs to take into account the companion, because typically these activities are joint activities. Here comes the notion of personal social network. Transport planning research has, therefore, become increasingly interested in the social network studies to understand this choice process. A social network requires maintenance; maintenance may involve travel. Thus, a better understanding of social networks may lead to better travel planning and prediction.

Broadly two streams of interest can be identified in transportation research that relates to social networks. One stream follows the effects of peer influence/social norms on travel choice heuristics. Abou-Zeid et al. (2013) provide a good review of

this line of work. The second stream of research is aimed towards social interaction and travel as a function of personal social networks. This includes analyses of social travel choices, scheduling, demand prediction and simulation to feed back in population-wide large-scale activity-travel behaviour micro-simulation. The argument is that size and composition of social networks are key variables in predicting social network induced travel demand. The present research project belongs to the second stream of interest.

1.2 Background

In transportation research, traditional factors of interests are travel duration, frequency, mode, ownership of mobility resources (such as car, bicycle, discount cards, periodic travel pass), socio-demographics, personality, attitudes, etc. Gradually, the concern shifted from a trip-based to activity-based approach incorporating activity duration, location, etc. The attention also shifted from individuals to households. Consequently, joint activity scheduling, and task allocation, travel arrangement and resource allocation were incorporated in the choice models (Borgers et al., 2002; Ettema et al., 2004; Zhang et al., 2005). However, joint activities do not only involve household members, but may also include members of a person's social network. Often we negotiate with our friends and family about where to go for holidays, who should host the New Year party or what movie to go to this weekend. Each individual is part of a social network and individual behaviour may be influenced by the attitudes and behaviour of peer groups. Spatial behaviour analysis is incomplete without an understanding of this social dimension. To better understand people's activity-travel patterns, we need to understand how they organize their social space, adding a whole new dimension of transport behaviour modelling research. As Axhausen (2008) noted:

Instead of relying exclusively on the generalised costs of travel and the hedonic utility of a location as modulated by the socio-demographics of an individual and perhaps his or her values, attitudes and lifestyle, one can add as explanatory factors both the social network geography of the person and his or her biography and network-based decision making.

The relationship between social networks and travel has been subject of an increasing number of studies in recent years (Carrasco and Miller, 2005; Hackney

and Axhausen, 2006; Páez et al., 2008; Silvis et al., 2006; van den Berg et al., 2009). Most of these studies have examined the cross-sectional relationships between characteristics of social networks and facets of physical and virtual travel. However, the contemporary challenge in activity-travel behaviour analysis is to move beyond single-day approaches to dynamic activity-based models, focusing on behavioural adaptability with response to demographic, social and policy changes. This is also a research frontier in transportation as the evolving nature of social networks and corresponding activity travel agendas have not been addressed in any detail in transportation research and beyond. This dissertation proceeds with the aim to draw attention to this issue.

Social networks may induce, alter and even constrain travel. This pattern itself is not static; it evolves continuously. We do not have the same social network all our life. Our circle of friends, neighbours and contacts keeps changing as we age and life cycle events (e.g. marriage) happen. To understand long- term behaviour and decision changes, it is imperative to understand these patterns in a dynamic setting. Arentze and Timmermans (2008) conducted numerical simulations and showed that participation in social networks may lead to adaptation of aspirations and diffusion of knowledge, which in turn may trigger changes in activity-travel choice behaviour. Han et al. (2011) elaborated and extended this approach and demonstrated that the exchange of information and the formation of network-specific aspiration levels can influence choice set formation and destination choice behaviour. Páez and Scott (2004), Hackney and Axhausen (2006) also used simple simulation approaches to demonstrate the possible effect of social networks on activity choices. We discuss these works in detail in later sections. The importance of dynamic personal networks has been long pronounced in the field of sociology and demographic research (Hummon, 2000; Snijders et al., 2010; Watts, 1999), but it is not readily evident how such research can be elaborated to fit the agenda of transportation research.

To this end, in this thesis, we review contemporary researches on social networks and travel and reason the way forward, i.e. the need to explain the evolving social networks and corresponding changes in activity behaviour. We develop a conceptual framework, collect data and predict and investigate the interrelationships presented in the conceptual framework. Furthermore, we predict

social network dynamics for population-wide travel behaviour micro simulation. We conclude with the constraints and benefits of incorporating these dynamics in travel behaviour models and suggest future endeavours in this regard.

1.3 Objectives of the study

As mentioned in the previous sections, the objectives of the study are:

1. develop our understanding of the dynamics of social networks with life cycle events;
2. investigate the corresponding effects on social interaction;
3. test the effects on changes in activity and travel profiles;
4. examine the interdependencies between social network dynamics and changes in activity travel profiles;
5. predict tie dynamics for population-wide social network micro-simulation.

1.4 Outline of the thesis

The thesis is organized in nine succeeding chapters. In the analytical chapters we systematically report the long term dynamics of social network, social interactions, role of ICT and activity-travel behaviour. Then we test the interdependencies in an integrated framework. Finally we developed a model to predict for population-wide social network dynamics. Details of the chapter description are discussed below.

Chapter two summarizes the contemporary literature on social networks in transportation research. Empirical evidence and simulation models are reviewed separately. Justifying the need to investigate the interdependencies between dynamics of social networks and activity-travel needs a conceptual model is outlined in this chapter.

In chapter three, the data collection procedure will be elaborately documented. In this chapter, a stepwise procedure of data collection is delineated starting from questionnaire design via pilot studies to the final data collection. Descriptive statistics are reported.

Chapter four addresses the first objective of the study. It reports a series of models to predict the size of personal social networks and the number of lost and new ties due to a life cycle event. Further, tie dynamics will be modelled to predict the

characteristics of lost and new ties.

Chapter five and six are attributed to the second objective focusing on social interaction dynamics. In chapter five, the modes of social interaction are investigated and the trade-offs between face-to-face and ICT-based social interactions are re-visited and extended, incorporating long-term time dynamics of social interactions. Chapter six is focused on the effects of geographical features on social interaction dynamics. Apart from urban densities and accessibility indicators, the effects of geographical distance dynamics between an ego-alter tie on face-to-face social interaction were analysed. Using a stepwise ordered logit panel effects specification, it shows the model improvement when time dynamics are incorporated by means of path dependency theory.

Chapter seven turns towards the estimation of the effects of life cycle events on the dynamics of activity and travel. A set of logical hypotheses on the effect of each type of life trajectory event on the type of activity and travel profile will be developed. These hypotheses are tested using path analysis.

Chapter eight brings all three domains in an integrated model specification. It addresses the third objective and tests the inter-dependencies between social network and activity-travel dynamics with life-trajectory events. Latent variables are defined to specify activity and travel needs both before and after the life cycle events. To handle the endogenous and indirect effects structural equation modelling is used for the comprehensive representation.

Chapter nine attends to the last objective. In this chapter, we develop a model to predict tie dynamics with life cycle events for a population's leisure network simulation. Time dynamics are incorporated in the link formation model developed by Arentze, Berg, Timmermans (2012) and Arentze, Kowald, Axhausen (2013). The model can be incorporated in micro-simulation social network dynamics in large-scale operational activity-based models of travel demand forecasting.

Chapter ten summarizes the research project, discusses its limitations and delineates avenues of future research.

2. Theory, Concept and Literature

In this chapter, we will summarize a detailed literature review on social networks and their importance in travel behaviour research. We rationalize why long term dynamics of social networks are gaining importance. Based on these discussions, we sketch our conceptual framework followed by the theoretical underpinnings of the study.

2.1 Review of literature

2.1.1 Social networks

A social network consists of the individuals with whom one has an interpersonal relationship and the linkages between these individuals. The structure has two dimensions: the formal relations and the informal social relations, i.e. the social network. Social network is individuals and linkages between individuals with whom one has a (somewhat) close relation and/or affection. This means that friends and close colleagues are part of the social network, but also that one's parents or siblings are always a part of the social network' (Due et al., 1999). In this research, we are looking at the informal social network as defined above with an ego-centric approach, where each individual (called ego) has a social network, defined as a set of actors or alters who have relationships or ties with the ego, and who may or may not have ties with each other (Carrasco and Miller, 2006).

Personal social networks are important in travel behaviour research as they can induce, alter or reduce mobility in a number of ways. The spatial arrangement of social contacts generates and determines travel and communication behaviour (Ohnmacht, 2009). The key feature of social networks is social interaction through which the benefits and obligations are maintained. Social interactions are mediators or channels for the flow of information, support, social well-being and happiness. Social networks and social interactions can be divided into two dimensions, viz. spatial and a-spatial. The spatial dimension or aspect consists of the spatial features of networking and social gains, whereas the a-spatial dimension refers to the virtual features of networking and information exchange. For instance, individuals depend on their social networks as they form their social support system (spatial aspect) and a reliable information source (a-spatial aspect). The relevant literature regarding these dimensions is discussed in the following sub-sections.

2.1.1.1 Spatial dimension of social networks and interactions

The spatial dimension is related to the components that are bound to and built within spatial constraints. It includes the arrangement of support systems (physical and emotional), place attachment and physical social interactions. These components are essentially local in nature. Local social ties form our social support system. Social support systems work through local social networks (Wellman and Frank, 2001). Wellman and Frank (2001) report that the probability of giving and receiving support (and consequently travel behaviour) depends on the characteristics of local social networks. Social networks could have a significant influence on short-term mobility decisions, for example, by means of taking care of children, pets; by watching the house, car, plants, it facilitates short term activities and travel. Karsten (2007) found that migrant households in the cities (Rotterdam) have intensive relationships with their relatives, who live nearby. They engage in a variety of mutual-support activities. Grandparents care for the children when parents go to work.

Various studies in the social support literature show that for daily life problems and crises management, people turn to local social ties. Majority of those ties include family and kin. A study of Hispanic Americans, for instance, showed that kin and local ties are more important than neighbours and friends for socializing (Schweizer et al., 1998). However, in complex and large societies where people migrate for work other local ties emerge and form the support system. In Chinese cities, for example, family ties are more peripheral and issue-specific, like money issues and work-related networks are preferred over kin-networks in resolving problems (Lai, 2001). In Dutch society, varying effects of type of family relation and geographical distance was reported (Mulder and van der Meer, 2009).

The concept of place attachment is also related to social support systems as social networks do affect long-term (residential) mobility decisions along with short-term mobility scheduling decisions. Residential mobility is generally viewed as a way to adjust housing consumption to achieve the maximum attainable utility from residing in a particular residential location (Dawkins, 2006). One might expect that

compared to factors such as residential quality, life cycle, neighbourhood quality, etc. social networks would have little influence on residential mobility. This expectation is, however, 'tempered', as Connerly (1986) puts it. Existing literature suggests that proximity to relatives, friends and having good neighbourhood ties is one of the important factors in considering residential location, apart from economic and job-related issues (Connerly, 1985, 1986; Dawkins, 2006; Karsten, 2007; Mulder and Cooke, 2009).

Neighbourhood-level social ties may be conceived as either a 'push' or 'pull' factor, depending on whether such ties influence the decision to leave a given neighbourhood or choose a particular destination (Dawkins, 2006). Family ties act as a strong push as well as a persuasive pull factor (Mulder and Cooke, 2009). Myers (2000) employed measures of the presence of friends and relatives within an hour's drive and found that the presence of relatives is associated with lower rates of mobility. The effect of friends, on the other hand, is not significant (Myers, 2000). For some households, the friendly contacts in the neighbourhood apparently function as a form of self-selected kinship (Karsten, 2007).

Local social ties may also influence one's decision to move out of one's existing neighbourhood. Some scholars have referred to this hypothesized linkage between local social ties and residential immobility as the 'affinity hypothesis' (Connerly, 1986; Ritchey, 1976). This hypothesis has been applied towards an understanding of three major periods of migration in US history: the migration of African Americans from the South to the North, Japanese-American migration from internment camps during the Second World War, and migration out of Southern Appalachia between 1930 and 1960. In all three cases, those with the strongest local social ties were among the most immobile (Dawkins, 2006).

The third component of the spatial dimension of social networks is local physical or face-to-face social interaction. Social activities are in principle non-solo or joint activities. Conducting joint activities mean that the accompanying person's agenda influences the timing, location and travel modes of the activities concerned, hence affecting short term mobility decisions.

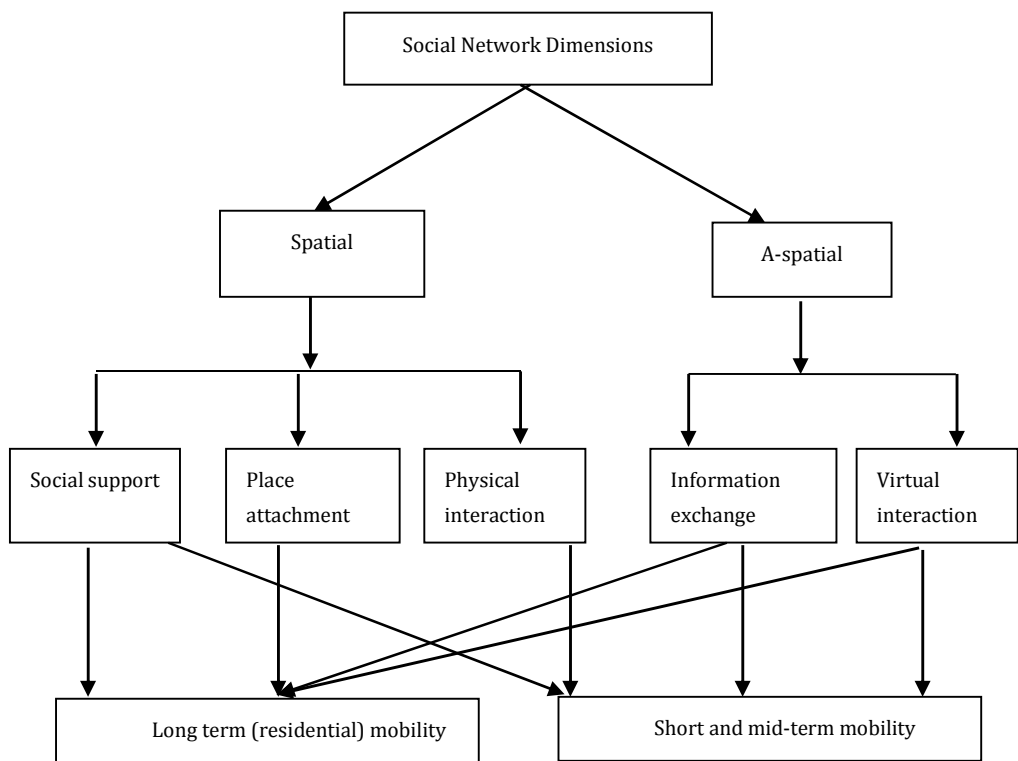


Figure 2.1 Dimensions of Social Network.

2.1.1.2 A-spatial dimension of social networks and interactions

The a-spatial dimension refers to those components of a social network that are not necessarily local but could affect our local short and mid-term mobility decisions by means of exchange of information and virtual interactions (through popular social network websites, such as facebook, skype, myspace, msn, yahoo etc.).

Social networks act as a valuable information source. We can learn about new places, faces, sources and means to bring convenience in our activity and travel scheduling, particularly in new situations. People can learn about various travel alternatives through information exchange in social networks, which might help

them in short-term mobility decisions (Ettema et al., 2007). The information exchange also assists long-term decisions. For instance, studies show that social networks are the most frequently used source in finding a home (Röper et al., 2009) and greater social diversity could assist in finding a job (Stoloff et al., 1999). Information dissemination could also change people's attitudes and perceptions leading to changes in travel behaviour decisions (Han et al., 2011; Molin et al., 2008).

Although some might argue that with modern communication technology, the whole notion of social interaction and social support has also become mobile. However, research shows that information and communication technologies (ICT) do not replace physical interaction with family and friends but provide emotional support and help to cope in difficult situations, e.g. moving to a new neighbourhood (Axhausen and Frei, 2008; Shklovski et al., 2008; Shklovski and Mainwaring, 2005). On the other hand, it has also been tested that with increasing physical and relational distances, both telephone and electronic communication frequencies tend to decline among social network members (Tillema et al., 2010). This could be examined along the lines of Wellman's 'community liberated' argument (Wellman, 1979). Nonetheless, knowledge of the effect of ICT in maintaining social contacts is limited and needs more investigation (detailed review and analysis in Chapter 5).

To summarize, social networks might be considered to have two broad dimensions (or aspects): spatial and a-spatial. The spatial dimension refers to those attributes that have a spatial component and the a-spatial dimension relates to those that operate through virtual means and are not necessarily local in nature. Components of the dimensions interrelates, for example, information exchange can be achieved by both physical and virtual interactions. The component of information exchange is not space bound but can affect and be affected by spatial components.

Social interaction dynamics and mode choice is the medium to access and maintain social network, thereby also fulfilling individual's social needs. In transportation research as well social interactions are of fundamental importance. In fact, the underlying reason to study social networks and their dynamics concern the need to better understand social interaction patterns which influence mobility decisions.

2.1.2 Social networks in travel behaviour research

Literature of social networks in the field of transportation can broadly be divided into two categories: empirical studies and numerical simulations. The former relates to data collection techniques, analytical methodologies and documentation of empirical evidence and primarily deals with egocentric social networks. The later concerns with an array of numerical simulations with partial or complete hypothetical data to demonstrate the potential effects and relevance of social networks or social influence in travel behaviour. Most of these studies focus on the definition of choice sets as influences by social networks and deals with both egocentric and global (population-wide) social networks. These two streams of literature are elaborated here separately.

2.1.2.1 Empirical studies

In the field of transportation, seminal empirical work on social networks has been documented. Notable works include by Carrasco and colleagues (Carrasco et al., 2008a; Carrasco and Miller, 2005; Carrasco et al., 2008b), Axhausen and colleagues (Axhausen, 2008; Axhausen and Frei 2008; Kowald and Axhausen 2010; 2012) and Berg and colleagues (Berg, Arentze and Timmermans 2008; 2009; 2010; 2011; 2012a; 2012b) in Toronto, Zurich and Eindhoven respectively. Most of this studies use random samples to recruit respondents and require them to report a section of their social networks, either using name generators or by using social interaction diary or both. Kowald and Axhausen (2012) on the other hand employed snowball sampling technique to capture the geographical pattern of social networks beyond the ego's known horizon. These studies were combined together to compare personal social network features in these countries (Kowald et al., 2013).

Carrasco and Miller (2005) conducted 'connected lives study' where they employed name generators to collect social network data. They focused on social activity generation explicitly incorporating social networks characteristics of each network member as well as the characteristics of the overall social structure. For better understanding of spatial distribution of social activity, they incorporated activity space anchor points such as home-based, institution-based and public space-based. Simultaneously, they characterized those places based on recurrence - whether these are regular places or not. The role of ICT on social interaction were also investigated.

Carrasco, Miller and Wellman (2008) discussed social activity generation through multi-level analysis of ego and his social network structure. While these studies explore individual's social activities patterns – with whom, how frequently and where are these done -, long-term and short-term mobility issues are somewhat limited. How social network and travel decision or social network and individual's location and its characteristics are dependent remains for further investigation.

Further, Carrasco and Habib (2009) examined the social embeddedness of activity-travel participation as a function of alters' characteristics and network degree apart from socio-economic attributes. The results show that egos tend to maintain an intense relation with a very close-circle of contacts and tend to keep in touch with those with a wider connection.

Axhausen (2008) argued that social network membership influences a person's mental map and thus logically network geography should have an impact on travel behaviour. He discussed in detail survey instruments and data requirements for social network studies. Axhausen and Frei (2008) elaborated how geographical distances in personal social networks influence travel behaviour. They found that face-to-face contact frequency decreases with increasing distance whereas email frequency increases.

van den Berg, Arentze and Timmermans (2009, 2010, 2012a) have reported a series of analyses of their social interaction diary and social network data collected in Eindhoven in 2008. The study employed a social interaction diary followed by a name generator survey to collect social network and interaction data. They (van den Berg, Arentze, Timmermans 2008; 2012b) extensively examined the impact of ICT on social travel behaviour and reported that the results differ significantly from a previous study conducted by Molin, Arentze and Timmermans (2008), who used data about social networks collected in the 1980s also in the Dutch context, implying that the inter-relations of social network and travel demand have changed over last two decades. They further investigated social travel for elderly (van den Berg et al., 2011) and the effect of club memberships on social interaction (van den Berg et al., 2012a). They report elderly being as mobile as the young population in terms of frequency of social trips. Only difference in travel mode choice were reported. They also report reciprocity in social network size and club memberships

and, as expected, involvement in clubs and voluntary organizations increases social trips.

In the studies mentioned above, social interaction diaries were commonly used. Silvis (et al., 2006) used a similar social interaction diary in Davis. Instead of collecting information about network members they provide an option for the network member to volunteer for the survey. Starting with three seed respondents, they collected information about 24 individuals over three phases of survey design. They conclude that individuals do not mind making longer trips for socializing and visiting family. Their study primarily concentrates on trip generation influence of social network. In addition, they also mapped the geography of trip frequencies.

Ettema and Kwan (2010) analysed the company of social activities among ethnic groups in the Netherlands. They argue that the purpose, direction and underlying reasons of choosing one company over another have not been addressed in the literature. They tested a number of hypotheses, contextual to social and recreational travel, and found that individuals have multiple networks (such as family, friends, associational and professional) which potentially perform multiple roles. They conclude that frequency of contact with social network members is positively correlated with the frequency of social and recreational activities, which often is not domain-specific.

In a recent study, Farber, et al. (2013) calculated a Social Interaction Potential (SIP) metric using the time geography approach. The metric estimates the potential for an individual to engage in social activities given a specific time and space window. The metric was evaluated using data from Ghent and Concepcion. It was developed to assess the relationships between spatial structure and the potential opportunities for face-to-face contacts. The study has a far-reaching applicability to assess the sociability of urban environments.

However, the interplay between social networks and travel behaviour has been explored in travel behaviour research, in a particular space and time context. These studies are focused on static concepts of social networks, whereas social networks are dynamic. We argue that to develop our understanding of network influence on individual/household's travel behaviour it is imperative to examine those in a

dynamic setting. Given the recency of including social network components in travel behaviour studies, it is understandably the forthcoming arena of exploration. As Axhausen and Frei (2008) pointed out

The investigation of local social externalities and the dynamics of the processes will be the task of later work

The major setback of investigating social network evolution is perhaps data deficiency. Ideally, a panel study would be required, which is difficult with limited resources. However, using synthetic data, some simulation studies have been conducted to account for network dynamics. In the next section, we present a brief overview of this stream of literature.

2.1.2.2 Simulation frameworks

Large scale activity-travel micro-simulation models have incorporated social interaction and travel in a minimalistic way, such as from aggregated social travel data. Recently an increasing number of social and leisure travel scholars incorporated ways to simulate personal and population-wide social networks to predict social travel and interaction, negotiation protocols, information flows and interconnectedness. Most of the studies deal with the influence of social network in definition and modification of choice set heuristics.

Dugundji and Gulyás (2008) aimed to incorporate social influence on transportation mode choice. They developed a multi-agent simulation model of household interactions looking at how they decide on transportation mode alternatives by carefully distinguishing social and spatial network interdependencies. In particular, they considered the interdependencies between individual's choice and the aggregate decision of socio-economic networks in close proximity. Using pseudo-panel micro-data, collected by the Amsterdam Agency for Traffic, Transport and Infrastructure, they extended the classic discrete choice model to account for the social influence on choice decisions in a nested logit model of mode choice. Finally, they compared the results for different assumed social and spatial networks based on similar residential location and socio-economic profile of agents. Their model, however, does not account for dynamics of social networks.

Páez, Scott and Volz (2008) described a discrete choice model to account for social influence on decision making as an advancement over auto-correlation analysis. They formulated a model on the basis of the externalities literature that takes into account the effect of other's actions on individual decisions. Simulated data was used to compare the model with social influence and without social influence in making decisions about residential location. Social network simulation was developed on the basis of the structure analysis tradition of sociology by developing an informal support network. In an earlier publication, Páez and Scott (2007) applied a similar methodology for decisions about telecommuting.

They pointed out certain limitations. First, the limited scope for empirical analysis due to scarce mobility data with social network information. Secondly, dynamics of social networks were not taken into account. For example, although changing residential location means new neighbours, schoolmates or gym mates, the social network was kept static in their model. Finally, they mentioned that they incorporate no influence from the 'rest of the world'. Yet, it is fairly difficult to incorporate that.

Han et al., (2011) presented a dynamic model that simulates habitual behaviour versus exploitation and exploration as a function of discrepancies between dynamic, context-dependent aspiration levels and expected utilities. Principles of social learning and knowledge transfer are used in modelling the impact of social networks, and related information exchange, adaptations of mutual choice sets and formation of common aspiration levels.

Dynamics on the level of evaluation of choice are drawn from the activation level and the inclination to explore depends on an individual's satisfaction with available alternatives in his/her choice set. Satisfaction depends on the individual's aspiration level, where aspiration level serves as a subjective reference point, which determines what qualifies as a satisfactory outcome for that attribute. Dynamics of aspiration levels on the other hand depend on social comparison, among many others. The outcome of a comparison between aspiration (drawn from social comparison and adaptations of mutual choice sets) and expected outcome (driven by activation level) given current beliefs marks a switch of choice mode from habitual behaviour to a conscious choice.

Dynamics in terms of short-term decision making have been studied as well opening up the scope for empirical analysis. Hackney (2009) and Hackney and Axhausen (2006) developed a multi-agent representation, incorporating dynamics of social network, by addition and deletion links, based on feedback through activity choice sets. They accounted for homophily, and associations and assume some maximum number of contacts per agent.

However the structure of the social network and its characteristics has not yet been incorporated. To that end, Arentze and Timmermans (2008) developed a theoretical and modelling framework to capture the essence of social networks, social interactions and activity travel behaviour. The core assumption was that

the utility that a person derives from social interaction is a function of dynamic social and information needs, on the one hand, and of similarity between the relevant characteristics of the persons involved, on the other.

The model is consistent with the traditional social network theories (like homophily and transitivity) developed in the social science literature. The process model has been tested using arbitrary agents. It led to the conclusion that an individual's social network has an equilibrium size dependent on several factors, and changes over time. Although this study does formulate a theory and model of social network dynamics, no empirical data was collected to estimate the parameters of the model and test their theory. This is also true for Ronald, Arentze and Timmermans (2012), which can best be seen of an extension of this line of work, focusing on numerical simulation.

An elaboration of the framework is developed in Kowald, et al. (2012). Two Swiss data sets were used to simulate connected personal networks and encounters between actors. The model investigates leisure relationships and provides insights on the connectedness between actors and the factors affecting the leisure relationships between them. More on these research is reported in Chapter 9. Illenberger, et al. (2010) conducted a similar simulation with a different approach. They tested network indicators (edge-length distribution, network degree distribution, etc.) in their model but did not account for properties like homophily.

Although these simulation frameworks are promising, most remain fairly simple. Thus, it remains a computational challenge to integrate large networks and complex social dynamics.

2.2 Towards dynamics

Going back to our basic motivation: social networks evolve over time. People do not have the same circle of friends and neighbours all their life. With age, education, job, marriage and other life cycle events, social networks keep changing. When someone first enters college or university s/he meets a whole new circle of friends, when s/he gets married, the spouse's social network adds up and maybe some old relations fall apart, when the children arrive, the nature of the social network changes again and so on.

The dimensions and components of social network (as depicted in Figure 2.1 and discussed in section 2.1.1) may affect transportation choices in a number of ways (Figure 2.2). First, social networks provide travel companions for social and leisure trips in particular. Individuals need to discuss and find agreement with their companions in decisions on the when, where and how aspects of activity and travel. Secondly, social networks are an important source of information. Not only for short term travel choices but also for long terms decisions, such as finding a new home or job (Connerly 1985, 1986; Dawkins 2006; Granovetter 1995), social networks play a key role. Thirdly, networks form an individual's primary source of social and emotional support, ranging from painting the house to child/elderly care (Lai 2001; Wellman and Frank 2001). Fourthly, peers have an influence on evaluations of choice options. Whether for novelty or approval seeking individuals tend to put value to how their alters or the society in general perceive their choice options (Abou-Zeid and Ben-Akiva 2011; Abou-Zeid et al. 2013; Schmöcker et al. 2013). ICT and social media support and shape the social interactions involved. With the growing influence of ICT in our lives, getting in touch or planning an activity is faster and easier (Mokhtarian 2002; Senbil and Kitamura 2003; Dijst 2009; Tillema et al. 2010; van den Berg et al. 2010). Despite the growing influence of ICT, face-to-face contacts and hence the geographic distribution of social contacts is still an important factor in the formation and maintenance of social relationships. If we or members of our social network move, we travel more or less, further or closer, weekdays or weekends to socialize with them. When social networks change it

potentially brings changes in any or all of the ways, eventually changing individual's activity and travel patterns.

In the field of sociology, demography, health studies and anthropology the need for constructing a dynamic social network has been realized a number of times (Hummon 2000; Snijders et al. 2010; Watts 1999). A series of studies on social network evolution has been well documented in leading journals such as Social Network (a special issue was featured in 1997). However the documentation is rather fragmented and focused on specific groups or life cycle event. These, predominantly qualitative, studies report that with age and life cycle events the size and diversity of social networks change (e.g. Wellman, et al., 1997; Bidart and Lavenu, 2005). However, there are contradictions about the pattern of these changes. Empirical studies contradict whether it is somewhat U shaped or the changing pattern of social networks with life cycle can be explained by an inverted-U shaped curve (Kan, 2007).

Perhaps the most relevant (to this thesis) study was conducted by seminal scholar Wellman and colleagues (Wellman et al., 1997) in Toronto based on the information collected from 33 residents a decade apart. They report a complete turnover in the network composition to those who got married during the study period. However they did not find any association with other life cycle events, such as, childbirth, residential relocation or employment transition. Further they report that continued telephone interaction and social support positively influence tie maintenance. In a similar attempt of qualitative study in three waves Bidart and Lavenu (2005) found

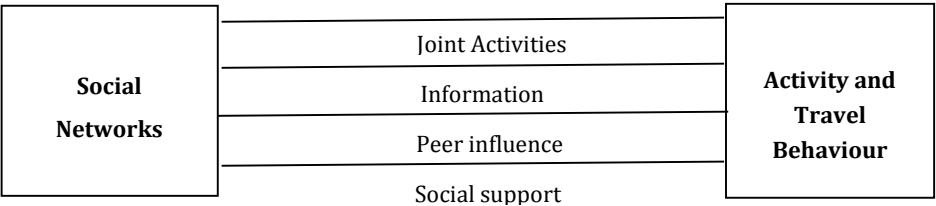


Figure 2.2 Interactions between social networks and activity-travel behaviour

patterns of social network maintenance due to entry to o market, start of a romantic relationship, childbirth and geographic mobility. Social interaction and relations to activity and travel scheduling, however, remain largely unexplored. Furthermore it is not readily evident how such research can be elaborated to fit the agenda of transportation research

Evidently personal social networks do evolve with socio-demographic status and life cycle events. Some ties get stronger and intertwined while others fade away due to either changes in priorities or changes in individual's/household's time budget. These changes in social networks are most likely to affect long-term mobility and short-term activity-travel decisions. Individuals alter and update their choices under social influence or at specific points in life. Those points or life cycle events apparently act as triggers to deliberate alternative choice decisions. Therefore to understand the choice processes related to activity and travel it is imperative to incorporate social contexts and life cycle events in transportation models. These arguments are conceptualized in the following section.

2.3 Conceptual framework

As stated above, social networks, life cycle events and activity and travel are presumably interconnected. Accordingly 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

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. 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 2.3). The thesis analyses the links in between.

Certainly causality relationships may also be in reverse direction. For instance, marriage and conjugal relationships and new jobs can be mediated through social networks, changing activity and travel behaviour may necessitate relocation, etc. However, the scope of the study is limited to investigate, firstly whether social networks change with life cycle events and secondly if they do, whether this has any effect on activity and travel needs. Investigating the causalities of life cycle events is beyond the scope of the study. Given this focus, the data collection is aimed at changes in social networks. The purpose of figure 2.3 is just to convey that these three domains are interrelated. This is an area not put forward before in the literature. Although all three domains can influence each other, the present study focuses on social network changes occurring after a particular life cycle event.

The domain definitions are given as follows:

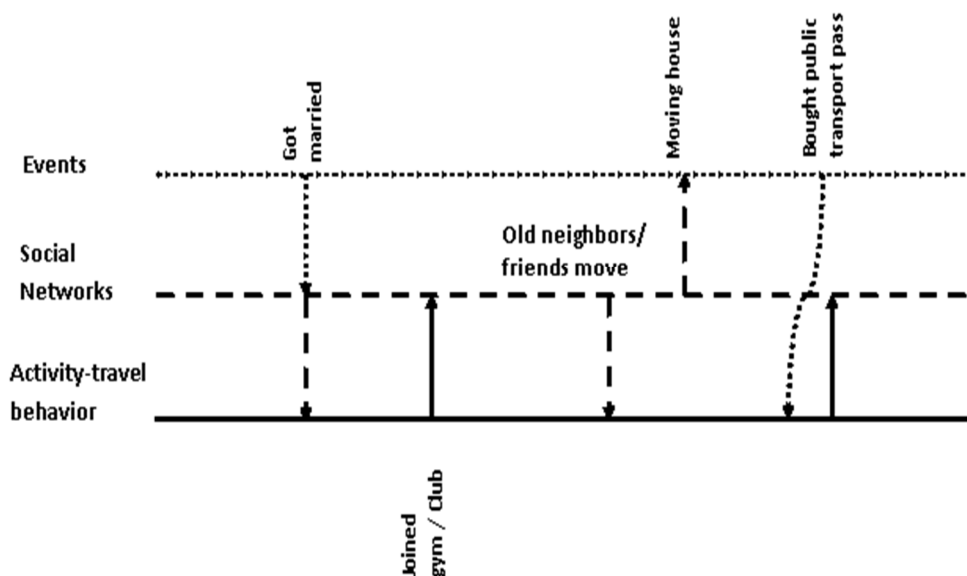


Figure 2.3 Conceptual framework representing three domains of interrelated dynamics.

Life cycle dynamics is defined by the events that could bring changes in the social life of an individual and 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 life cycle 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.

Life cycle events 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., 2012a). 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 2.3. 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. Hence, the effects of events on activity-travel needs are also taken into consideration.

With socio-demographics and life cycle events, social network changes having an impact on activity-travel behaviour, both direct (frequency and duration of contact, use of ICT) and indirect (exchange of information). The concept includes three parallel phenomena, events (including socio-demographics and life cycle events), social networks and activity-travel behaviour. All three of them are interdependent. Any change in one could result in change in the other two or any one of them. For instance, the event of 'getting married' could mean that the spouse's (partial) social network is now included, resulting in a change in social network and could eventually lead to a changed activity-travel behaviour. On the other hand, new activity-travel behaviour, such as joining a new gym or club may possibly result in a change in social networks and so on.

2.4 Theoretical Framework

This study is based on the theories of life course, homophily, accessibility and path dependency.

2.4.1 Life course theory

The life course theory stems from evolutionary human geography and anthropology and has been widely applied in social science research (O'Rand and Krecker, 1990). It has a number of interpretations in the fields of economics, psychology, history, sociology and demography. It is defined as 'a sequence of socially defined events and roles that the individual enacts over time' (Elder, 1985). From a networked society perspective, it can be explained as the interdependency of lives that are socially connected. Individuals and households experience the influence of the relationships between individuals (Elder, 1998; Elder Jr, 1994). For instance, demographic events affect the family; relocation events may affect the neighbours;

employment transitions may affect colleagues, school transitions may affect childhood friends, and so on. These effects are likely to vary with the age of the event. A recent event may have a different impact than an old one.

In activity-travel behaviour research, the life course approach has been used in a number of studies to predict mode choice (Oakil et al., 2011a; Scheiner and Holz-Rau, 2013; Verhoeven et al., 2007), car ownership (Oakil et al., 2011b; Prillwitz et al., 2006), commute distance (Prillwitz et al., 2007) and duration and travel time dynamics (Sharmeen et al., 2013). Particularly in predicting social network and social activity dynamics, empirical evidence suggests a significant impact (Sharmeen et al., 2013). Naturally, these effects vary according to the type of event.

2.4.2 Homophily

The study draws from the concept of homophily that defines that individuals are more likely to have ties based on the degree of similarity between them. Similarities may be in terms of socio-demographics, race, ethnicity, attitude, behaviour, beliefs and aspirations (McPherson et al., 2001). Based on this concept, we assume that the same principle applies to the maintenance of the ties. Joint social activity and interaction frequency can be taken as a measure of network maintenance with alters. Social interaction frequency might also follow the principle of similarity in the sense that people who are similar will more frequently interact with each other.

2.4.3 Accessibility and geographical distance

Another significant determinant of social activities is accessibility and opportunities offered by the surrounding environment. Handy (Handy, 1996) defined accessibility as the potential of opportunities for human interaction. In the field of geography, accessibility is explained by 'the pattern of activities; their quantity, quality, variety, and proximity; and the connectivity between them as provided by the transportation system' (Hansen, 1959). Therefore, the concept of accessibility provides a measure of the choices available in the surrounding. Particularly in terms of social interaction and activity frequency, accessibility measure is important because social and joint recreational activities are flexible and take place in a variety of locations depending on the socio-demographics of the actors and their preferences.

Recent studies have adopted from the concepts time geography to extend individual level accessibility measure to joint accessibility measures (Neutens et al., 2008; Soo et al., 2009). Neutens (et al., 2008) considered individual's activity schedules to devise space-time anchor points to dictate the space and time of joint discretionary activities. Essentially the consideration of intra-household negotiation, time budget and space-time windows come into play here. Eventually maps of joint accessibility can be simulated to evaluate joint discretionary activity scenarios. The results can be validated and extended using social network data in a dynamic setting. Empirical studies on joint activity and travel suggest that opportunities for group activities offered by places are important in explaining the frequency and pattern (Handy, 1996). Thus, we argue that social activity and travel does not only depend on the time, money and other resources available to the ego and the willingness to maintain contact with an alter, but also on the facilities and opportunities inherent in the geographical context they reside in.

Further, in social network studies, spatial proximity has been identified as a key source of social contact/tie. Empirical evidence in transportation research suggests that geographical distance between ego and alter influences face-to-face contact frequency between them (Carrasco et al., 2008b; Tilahun and Levinson, 2010b; van den Berg et al., 2009). Carrasco et al. (2008) suggest that geographical proximity has a positive effect on social interaction frequency. Life cycle events, such as, residential relocation may bring changes in geographical distance with alters. We argue that these dynamics induced by life cycle events on geographical proximity might impact social activity and travel (Carrasco and Miller, 2009b; Tillemma et al., 2010). Sharmeen and Timmermans (2011) report that change in geographical distance with kins caused by residential moves has a moderate effect on contact frequency and relationship strength with close family members. They note that the effects may intensify for non-family members. In terms of travel demand dynamics, these effects provide important insights that we address in this study.

2.4.4 Path dependence

The concept of path dependence is widely used across social and economic geography, which we adopted to explain the background of the research. We argue that activity and travel choices are path dependent. Path dependence is generally

defined as the tendency that a previous movement in a specific direction induces further progress in the same direction (Frenken and Boschma, 2007; Mahoney, 2000; Martin, 2010). Path dependence defines a general characteristic of human choice behaviour. Path dependency has been used as a central concept to analyse historical inference in decision-making processes of institutions (Greener, 2002; Mahoney, 2000; Martin and Sunley, 2006; Pierson, 2000). The notion is widely used in political and economic geography. It was first explained by Noble Laureate Douglas North in his seminal book on institutional change and economic performances (North, 1990). He noted that path dependency is a way to narrow down the choice sets and to link decision-making over time. In other words, it is a process that constraints future choice sets.

The utilization of the concept in this context might be different from where it originated, although the trends it seeks to capture are comparable (figure 2.4). Individuals may differ in terms of their reactions to life cycle events. Some may adapt faster with the life-course flow and rapidly change their networks and interaction patterns. Others may be more conservative and display a steady transition. Still others with a more change-averse attitude may prefer a stable equilibrium lock-in. Nevertheless, be it rapid or steady transition or a stable equilibrium, all sorts of evolution are likely to be path dependent. Because first of all habitual traits are inherent in human nature and secondly social ties and their maintenances have a trail likely to influence what follows, owing to loyalty towards ties and inertia of choice adaptations.

Path dependence is often linked to positive feedback and self-reinforcement, and it is then thought to stem from either 'increased returns' according to scholars of history, economics and politics (Pierson, 2000), or to 'network effects' according to the theorists of economic geography (Boschma and Martin, 2010; Martin, 2010; Martin and Sunley, 2006). In other writings path dependence is understood in terms of 'reactive sequences', that is, sequences that are 'temporally ordered' or 'causally connected' (Pierson, 2000). Whether self-reinforcing or reactive, social interaction history between an ego-alter tie might be influenced by life cycle events. From a behavioural perspective, the notions can be interpreted as individuals tending to repeat their behavioural sequences (increased returns) or to react in a way that

reflects their behavioural experience at the preceding point of time or similar past event (reactive sequences).

Following explanations in political sociology (Pierson, 2000), we locate the source of path dependence in increasing returns, which refers to the tendency of actors walking the similar path as before. Once positive feedback of a product/technology is disseminated through network effects, it may get 'locked in' and thereby exclude competition. From a human behaviour perspective, the notions can be inferred as individuals react and respond towards a particular choice set which are associated with their choices at a preceding and/or similar incident. Economics and technology policy evaluation studies refer to the notion of increasing returns as the cost to revert from a path usually is very high (Pierson, 2000). Although cost might not always be the factor, habits and constrained choice sets may overtake decision-making processes. A classic example in this regard was reported by Greener (2002), is the use of QWERTY keyboards. Despite the fact that efficient alternatives exist and that the cost of a path divergence in this case can be recovered in just ten days by the increased efficiency achieved, the QWERTY still continues to be the standard version. This phenomenon was described as inheritance overtaking choice (Rose, 1991) and shows the centrality of inheritance and familiarity to human behaviour. Habits, familiarity, inheritance and sense of belongingness therefore are of prime importance and could better explain the decision-making process. Particularly in maintaining social life and social communication the habitual behaviour, sense of familiarity and loyalty towards peers are likely to play an even more significant role.

Nevertheless, there remains room for competition as argued by scholars in evolutionary economic geography (Martin, 2010). Actors may take the path of ongoing change with time and life events (e.g. preference to Google+ when Facebook is already operational for years) or the path of resurgence as opposed to a state of lock-in or equilibrium. Similarly, in social networks and social psychology it is widely recognized that personal social networks (social support and interaction) are re-organized with time and life cycle events (McPherson et al., 1992; Paykel, 1994). We argue that a change in the social network of a person could induce changes, for instance, in social interaction frequencies, either because the person has more or fewer ties to maintain or because his/her need for social contact and

aspiration level have been altered. The decision to maintain a past meeting frequency or not is partially dependent on the changes in the cost of social maintenance. Changes in cost of maintenance can be caused by changes in time and money budget (caused by, for instance, changes in geographical distance) or changes in need and aspiration level to conduct social activities as frequently as before (consequence of life cycle events such as change in marital status). Eventually these changes are likely to induce dynamics in overall activity and travel demand.

To summarize, history influences all aspects of decision making, a notion that is particularly relevant to social relationships and their maintenance but rarely addressed in social interaction studies. Individuals might tend to be in touch with those they have a history of regular interactions with. However, the intentions also have to be in line with possible changes in geographical distance and personal time budget. The notion is similarly applicable to choices in other traits of activity and travel, such as, mode choice, duration, location, etc.

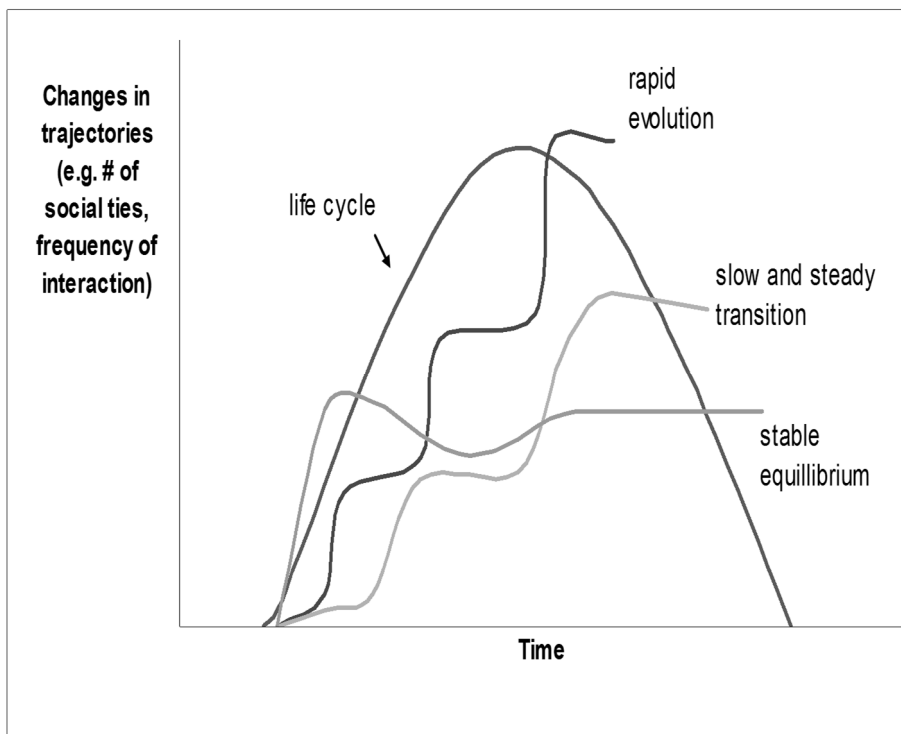
However, one should be careful in making assumptions or deriving too simplistic conclusions based on path dependency effects only, particularly when testing new technologies. In those scenarios, it is also important to understand the common sense and reasoning behind them. In a related study (Chen et al., 2009) examine history deposition effects in choice of residential neighbourhoods. In explaining the underlying process, they note that history influences choice in two ways. Under adaptive human behaviour perspective either individual becomes more tolerant to the negative attributes or more appreciative to the positive attributes associated with the choice that similar attributive features are chosen at a next stage. Under alternative hypothesis, one may become fatigued with a welcoming attribute or become rigid to an unwelcoming one. As a result, soothing with a different or opposite set of attributes is chosen in the subsequent stage. They found evidence towards the first hypothesis towards adaptive human behaviour.

In this study, however, without making any prior assumptions, we will investigate activity-travel needs and social interaction profiles considering effects of path dependence. The underlying motivation is explained here and the aspiration is that

by incorporating path dependence effects we can better explain the choice heuristics.

2.5 Concluding remarks

The need to expand the recent studies on social networks in the transportation research community to include the *dynamics* of social networks has been argued in this chapter. The summary of a literature review on the current state of the art have shown that the vast majority of current studies have examined cross-sectional relationships between social network characteristics and travel demand. Thus, social networks have been investigated mainly from the perspective of how the maintenance of these networks influences travel demand.



(Based on Martin 2010)

Figure 2.4 The concept of path dependence: alternative paths of social traits

However, social networks, especially the network of friends, are not static but change with particular life cycle events. As a consequence, individuals and households will need to adapt to these changing social networks and perhaps reconsider how to organize their social activities in time and space. The extent of such behavioural change will depend on the nature of the change in the social network. If new friends live in the same neighbourhood and have similar schedules, adaptation may be limited in the sense that the timing, duration, distance, mode of communication may remain the same. On the other hand, more substantial changes in the social network may trigger more dramatic changes in activity-travel patterns.

Our contention, therefore, is that the study of the dynamics of social networks should be comprehensively undertaken by the transportation research community to better understand and model the dynamics of activity-travel patterns. Maintenance of social networks is an important contributor to travel. The expected increased importance of social support in aging societies will increase travel demand. All are good reasons for intensifying our research efforts into the dynamics of social networks.

To realize these plans, it is crucial to first collect empirical data on the nature of changes in social networks, triggered by life cycle events. These data can then be used to model the probability of particular dynamics in social networks, which in turn can be linked to activity-travel schedulers and choice models. The following chapters describe the data collection and analytical findings based on this concept.

3. Data Collection

3.1 Motivation and objective

The main objective of this study is to analyse the dynamics of social networks in reaction to life trajectories. We assume that personal social networks vary throughout an individual's life, particularly in response to life cycle events. With respect to travel behaviour modelling, this is quite relevant because social networks need maintenance and, therefore, require planning of social activities and travel. We argue that the concept is dynamic. Life cycle events may trigger dynamics in social networks and activity travel planning (Figure 3.1). A change in social network would essentially mean an altered social activity and travel need, which would also have an impact in the overall activity-travel budget. For example, if an ego reduces the frequency of meeting with an alter due to a lifecycle event posing restrictions in time budget (new job) or increase in geographical distance (relocation), he may try to compensate it with increased frequency of ICT contact. To empirically examine all these dynamics, we need information about social network dynamics, social interaction changes and activity travel dynamics triggered by different types of life cycle events.

As discussed in the conceptual framework of Chapter 2, the three domains, viz. activity travel, social network and lifecycle events are interrelated. To fulfil the study objectives (Chapter 1), we need information regarding these three domains and how they influence each other. The primary and most direct link between social networks and activity travel domain would be social interaction (Figure 3.1). Therefore detailed information of social interaction dynamics is also warranted. Unfortunately, to the best of our knowledge, such data is not available for the Netherlands. Therefore, the only way to obtain these data is to collect primary data. However, secondary sources were consulted to validate our assumption as stated in the first paragraph and to design the questionnaire (discussed below). Apart from the literature review we aimed at getting some resource to fit our specific concept. Our search led us to the Netherlands Kinship Panel Survey (NKPS) data (For details of the survey, see Dykstra et al., 2005a and 2005b). This is a nationally representative multi-actor multi panel study on kinship in Netherlands. The panel survey had three waves and records social interaction patterns, relationship quality and relocation information of both ego and alter. Analysing the data we found evidence of key life cycle events, such as relocation has an effect on face-to-face and ICT interaction with kin and have an impact on the relationship quality with them

as well (Sharmeen and Timmermans, 2011). The study concluded that the effects may get stronger for non-kin ties. The findings validated our assumption that life cycle events do influence social networks and social interactions (therefore activity and travel patterns).

To summarize, the aim of data collection was to collect information about Network size dynamics (expansion or reduction), social interaction dynamics (changes in mode, distance and Activity-travel dynamics (changes in the planning of activity and travel). Life cycle events were considered as triggers to induce these dynamics.

3.2 Survey Design

In this section, we will summarize all components of the survey design in a step by step manner under separate headings.

3.2.1 Data Considerations

The data requirements for this study can be divided into three segments, viz. socio-demographic and household information, activity and travel dynamics data, and social network dynamics data. The following socio demographic and household data were collected:

1. Age, gender, education and income level of the respondent and his/her partner (if any)
2. Number of household members (adults and minors)
3. Household composition

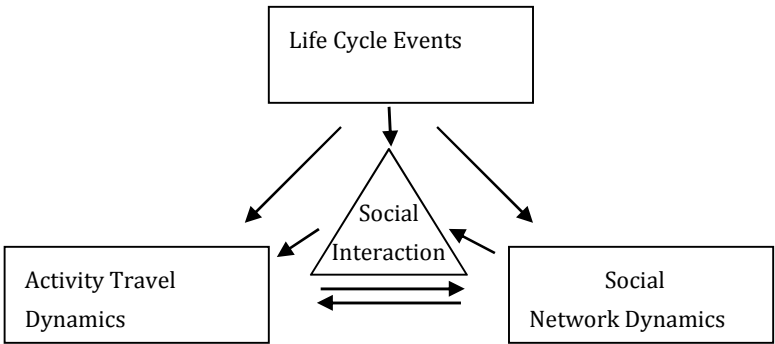


Figure 3.1 Conceptual domains and their interdependence

4. Information regarding the residence (type and of residence, postcode)
5. Automobile and bicycle ownership and availability
6. Size of personal social network according to relationship type
7. Membership to club and voluntary associations

Information regarding activity and travel dynamics were sorted in a rather straightforward manner. Fourteen activity types were selected: work, study, grocery shopping, fun shopping, visiting family and friends, attending party, dining out, going to movies/theatre/concert/cultural show, going to park/green areas, active sport/fitness/wellness centre, visiting post office/bank/hair dresser, activities in clubs and voluntary organizations, surfing on the internet, other activities. In addition, data were collected about activity frequency and duration; travel mode, frequency and duration for each of the activity types, and the number of participants in each activity.

The central and the most crucial part of the survey concerns social network dynamics. We summarized the following three set of information about social networks that were crucial to understand social network dynamics.

- Information about network size dynamics (expansion and reduction)
- Information regarding network composition (life-cycle of social relations, how fluid are those, transitional arrangements, support networks)
- Learning about key informants. Do people prefer to maintain contacts with people with a central position in society?

All these three components require the information about the tie between ego and alter, whether it is about lost or new ties, ties that provide social and emotional support or act as a valuable information source. This is the most crucial requirement for our study. We initially listed the alter information requirement as follows:

1. Age of the tie
2. Type of relationship
3. Geographical distance (and change in distance) between ego and alter.
4. Social distance (and change in distance) between ego and alter: defined by frequency and type of meeting/communication (face-to-face and ICT) and relationship strength (how close and important the alter is to the ego?)

5. Socio-economic status of alter.

3.2.2 Survey instrument

Two options were considered for collecting the data.

- a) Activity/interaction diary
- b) Questionnaire to collect information about alters and retrospective data on dynamics of Social networks and activity travel scheduling.

Approach a is rich in information but demands significant time and money budgets. Approach b, on the other hand, may be associated with memory biases causing respondent burden. However, studies have shown that retrospective data can be useful if carefully collected (Behrens and Mistro, 2010). Moreover, we argue that when systematically structured with reference points (life cycle events in this case) these errors can be reduced.

Moreover, research shows that when studying mobility issues, panel data contain a higher risk of inconsistency and sometimes discontinuity (Solga, 2001). It may also assist respondents to have one mind-set while answering all the questions as they all dwell around one specific life cycle event. People rarely forget about major life cycle events. Therefore, given the available resources, time frame and the specific advantages of retrospective surveys, we decided to choose approach b.

To reduce errors in the data, the survey was carefully designed. Moreover, to reduce respondent burden, a respondent focused 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 (discussed in section 3.2.4).

3.2.3 Sampling

According to Lee et al. (2006), there are three ways by which we can sample alters:

1. Node sampling: certain nodes of the network are randomly selected and the rest of the nodes are discarded.
2. Link sampling: certain links of the network are randomly selected and the associated nodes are included.

3. Snowball sampling: at first a single node is selected and all nodes (and respective links) directly linked to it are selected. Then all the nodes connected to those picked are selected. The process continues until the desired number of nodes is sampled. In some cases, hubs (nodes with many links) are picked (Song et al., 2005).

Based on four measures (average path length, betweenness centrality distribution, assortivity and clustering coefficient), it was proved that in general, node and link sampling gives fairly accurate and reliable results (Lee et al., 2006). Since our goal was to investigate tie dynamics and maintenance, link sampling was more suitable.

Reiterating the scope of this study: it is based on social network and activity travel dynamics induced by life cycle events. Therefore we sampled based on life cycle event. Events were selected based on a literature review (Wellman et al., 1997; Bidart and Degenne, 2005). Presumably, all these events have an impact on social network and social interaction patterns because time and money budgets and social needs are changed.

The screening criterion (presented in the introduction page of the questionnaire) used to select respondents was that they must have experienced one of the following life cycle events within the past two years:

1. Residential relocation: change of residence
2. Getting married/divorced/cohabitation: change in civil status
3. Children starting school: any of the children of the household started school, who was not going to school before.
4. Starting new job: the respondent started a new job that involves a change in the workplace.
5. Starting University: respondents who have joined the University for higher education

In cases of when multiple events were experienced by a respondent, s/he was asked to choose the most recent one to answer the questionnaire. If they qualified, respondents were forwarded a set of questions related to the event, otherwise the questionnaire ended for them. A total of 733 (out of 1246) respondents did not experience any event.

The selection rate, therefore, is 58.1%¹. We carefully chose (based on respondent's feedback, discussed in the next section) the period of two years so that respondents would have a new settled activity-travel plan comparable to their pre-event agenda.

During sampling, we aimed to have an equal representation of each type of life cycle event. We designed separate questionnaires for each event type including event definitions and additional questions, such as, year of marriage, leaving parental home after starting university, etc. related to the corresponding events. When the response (completed questionnaire) to a life-cycle event reached 150, the questionnaire was closed. However, after correcting for non-response and eliminating incomplete questionnaires, we obtained comparable responses for each life cycle event (between 18% and 21%). The average response rate of the survey was 56%. Table 3.1 presents a summary.

3.2.4 Pilot study

Based on the objectives, research questions and concept we designed a questionnaire to collect data about all the variables necessary to develop the model. The initial version of the questionnaire had six sections:

Part I: Personal and household information

Part II: Dynamics of social networks

Part III: Present social network: details about alters

Part IV: Dynamics of Social support arrangements

Part V: Dynamics of activity and travel behaviour

Part VI: Lifestyle and personality

We organized 3 rounds of pilots to test the options:

1. The study design was presented in a workshop organized by NETHUR (Netherlands graduate school of Urban and Regional research). The audience (constituted of colleagues from Urban and Regional research field) were asked to fill out the social network part of the questionnaire. According to the feedback, the survey was too long. In the next round we

¹ Note that the last event (starting university) was not accounted for in the selection rate calculation. We invited university students to participate in this questionnaire who obviously have experienced this event.

- decided to drop section VI to make it more concise,
2. Incorporating these experts' remarks, the questionnaire was modified and the next version was developed. This version was distributed among 17 respondents. The key criteria for choosing participants were:
 - a. He/she has been living in the Netherlands for at least past 20 years, so that they have a history of social network dynamics in the Netherlands.
 - b. He/she have limited or no prior knowledge of the research.
 3. A feedback page was incorporated for the respondents to tell us their views, difficulties and time requirement to fill out the questionnaire. The questionnaire was still long and respondents were not willing to disclose names and postcode of their alters and personal income details. In the second round, we eliminated ego's income and alter's postcode related questions and used numbers instead of names of alters. About the length of the survey we decided to part IV since it is of the least priority given the study objectives.
 4. Considering the suggestions and difficulties, we designed the next version of the questionnaire, divided into four parts (eliminating part IV and VI and 8-10 from variable list) discussed in the next section. The questionnaire was further refined and tested by distributing to 60 respondents. Until this stage these were paper-based questionnaires.

During pilots runs of the survey a query was included to investigate the time frame that would allow a the responded to report the new settled social network after a life cycle event and to minimize the memory biases. The qualitative discussions reveal that 2 years is a good time to optimize the above two objectives.

Moreover, the list of life cycle events is not comprehensive. Important events such as childbirth was left out owing to budget limitations. The event of childbirth was incorporated in the initial design. As was mentioned earlier, we designed separate questionnaire for each life cycle event and aimed at obtaining comparable responses. At the implementation stage, we had to adjust the number of questionnaires to distribute due to budget limitation and had to compromise on the number and type of events to be included. We decided to drop the event of childbirth as our pilot run showed that the event of children starting school has a more prominent effect on social network dynamics.

The questionnaire has been finalized and translated in Dutch. Then, the web version of the questionnaire was designed by a consulting agency named Marketing Bytes and labelled MoveLab. The panel was administered and provided by a survey organization PanelClix. The Dutch version of the questionnaire is attached in appendix 1. Data from the last pilot (60 questionnaires) was included since they were compatible. The survey, therefore constitute a combination of web and paper based questionnaires.

The survey was administered among 703 respondents. The majority of these respondents were recruited by a survey organization having a dedicated panel, representative of the Dutch population. In addition, for the fifth event (starting university), a number of University students were sent out invitations, using the list of newly admitted students at the Eindhoven University of Technology.

3.3 The questionnaire

Information about socio-demographics, social network and ego-alter tie characteristics, and social interaction dynamics were collected using an event-based questionnaire survey. Respondents were asked to choose one recent event from the event list provided at the beginning of the survey.

Table 3.1 Summary of survey responses

Type of life cycle event	# of Total participants	# of Completed questionnaires	# of Incomplete questionnaire	% of Completed questionnaires	% of Total completed questionnaire
Relocation	231	135	96	58.4	19.2
New job	244	150	94	61.4	21.3
Change in civil status	194	134	60	69.0	19.1
Children starting school	351	153	198	43.6	21.8
Starting university	226	131	96	57.9	18.6
Total	1246	703	543	56.4	100

Recent events were defined as events that took place within the past two years. The web-based and paper-based surveys were administered in September 2011 in the Netherlands.

The final survey questionnaire was divided into four parts seeking information about socio-demographics of the respondent, changes and new contacts (if any) in the personal social network in response to the life cycle event, the (then) existing or present social network, and changes in activity-travel behaviour in response to the life-cycle event in question. The first part collected socio-demographic details of the respondent including an estimate of the size of their present social network) according to type of relationships (family, friends, neighbours and others; excluding the members of own household). In the second part, respondents were asked whether any change in the social network occurred as a result of the event. If yes, they were forwarded to a table where they had to list existing ties where a change occurred and new ties that were formed. Furthermore, for each listed tie they had to fill out the type of change (geographical distance, frequency of contact per mode both before and after the event), the socio-demographics of the alter, information about the tie (strength, length known) for each of the alter where a change occurred, regardless to the tie being close or not and a member of the household or not. They also reported new ties and lost ties here. Therefore an account of all changes in the personal social network was recorded.

The third part asked details about their (then) present social network defined as close ties. Close ties were defined as those individuals with whom important information is shared, personal problems are discussed, help during emergency or daily necessities is asked and with whom regular contact exist. Respondents could mention up to 25 ties. Details include socio-demographics of the alter, geographical distance, frequency of interaction, relationship strength (on a five point scale) and length (in years). The fourth part of the survey asked about changes in activity-travel schedules before and after the event.

3.4 Sample characteristics

Sample characteristics are presented in Table 3.2. Age was classified into five categories, viz. 0-19, 20-29, 30-39, 40-59 and 60+ years. In the Dutch education system secondary and tertiary education is divided into several levels that students

can choose based on merit and personal goals (UNESCO-UNEVOC, 2012). The education levels are categorized in six groups, viz. primary, general secondary, vocational, post-secondary, undergraduate, graduate and higher. The sample is relatively homogenously distributed across education levels and age groups, except that the elderly group is under represented. Male are slightly over represented. The average number of working hours per week is 21 and the average number of children in the household is 1. The majority of the respondents have a driving license and the average size of the social network is 29.

The average number of ties lost is 1.44 and average number of new ties is 1.62 per respondent in response to life cycle events. A detailed analysis and discussion on the social network dynamics is reported in the next chapter.

Table 3.2 Sample characteristics (703 cases)

Observed Variables	Description	Mean or Proportion (%)
Age <=20	Age of ego is less than 20 years	20.2
Age 20-29	Age of ego is between 20 to 29 years	28.2
Age 30-39	Age of ego is between 30 to 39 years	24.9
Age 40-59	Age of ego is between 40 to 59 years	23.1
Age 60+	Age of ego is more than or equal to 60	3.50
Male	Ego is male	54.6
Primary	Highest education level is primary	8.40
General Secondary	Highest education level is secondary	28.0
Vocational	Highest education level is secondary	18.7
Post-secondary	Highest education level is post-secondary	22.0
Undergraduate	Highest education level is undergraduate	11.7
Graduate and	Highest education level is graduate or	11.2
#workhr	Number of working hours per week	21.6
#child	Number of child in the household	0.97
Driving License	Having car in the household and the ego	79.6
Social Network Size	Size of close social network	29.0
# Lost ties	Number of ties lost after the event	1.44
# New ties	Number of new ties after the event	1.62

3.5 Conclusion

The data collection procedure used a novel approach to serve the specific objectives of the study. It was a successful venture and we obtained significantly high response rate. We believe several factors accounted for that. For instance, the survey was completely anonymous and we had informed the respondents upfront about the nature, purpose of the survey, who will own and handle the data and the demands (time, level of concentration) of the survey. We offered some reward to the respondents upon completion. Students that we recruited received 10 euro upon completing the questionnaire. The rest of the reward was administered by PanelClix. Moreover following the feedback from pilot survey we excluded information related to income and name and address of alters, as they were noted as personal and sensitive information. We believe the three rounds of pilot survey have improved the design and response rate of the survey. For replication purposes we strongly recommend to take local socio-cultural issues into account.

Designing the survey around one specific and recent life cycle event and pre-screening of respondents based on that have proven to be effective for the purpose of the study. As was mentioned in the beginning of the chapter, the purpose of the study was to investigate social network dynamics related to life cycle events. This also means respondents self-reported changes in their social network and activity travel pattern before and after the event. Therefore if they reported a tie as lost it was actually lost. With panel data this could be particularly difficult as some sort of identification or name recall system is needed to be implemented, which was not welcomed by our pilot study group, in particular.

Nonetheless, it seems that individuals still remained protective of disclosing their social network related information. It is also probable that they had lack of knowledge about their alters or found it too demanding to disclose those information. In several occasions data suffered from incomplete and missing information. Particularly the details of alter information were missing or left incomplete. Missing or incomplete cases were not excluded from the dataset completely. For instance, alter information for lost and new ties when missing were not possible to incorporate in analysing homophily effects, but they were included wherever possible, in the descriptive statistics to indicate average number of lost

and new ties, for instance.

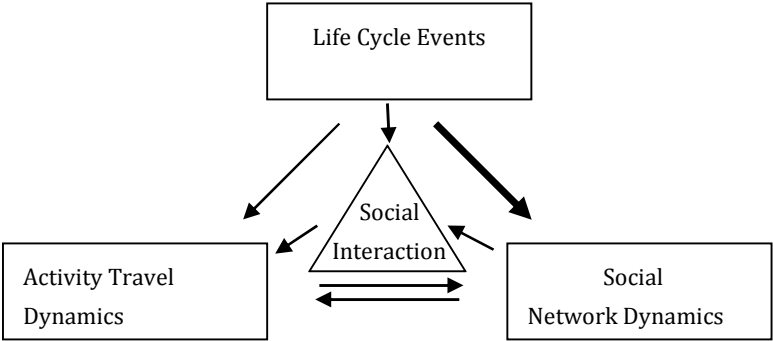
However there were some limitations in design and definition of the variables. For instance, the definition of the event of change in civil status could have been altered to focus specific aspects instead of including both marriage and separation. In the next chapter we reported the analyses. Some specific limitations were discussed in relevant sections and summarized in the last chapters furthermore.

Sampling of the study was done by two separate ways. One by the dedicated panel of PanelClix which was nationally representative and the other by student recruitment of one local university. The second set of respondents might exactly represent the population. However Netherlands is a concise country with very good public transport system. Commuting to university or temporarily relocating for higher studies is a common practice. Therefore it was not entirely a local sample.

We had to compromise with certain information to reduce respondent burden. For instance we collected weekly activity travel information instead of activity and travel episodes. Recalling each episode before and after an event is not possible. This can be better achieved by panel survey using activity travel diary or GPS technologies. However to link those with social network dynamics would be a challenging task as how to ensure a consistent time frame that belongs to both the changes in social network and activity travel pattern. It can be claimed with certainty that we achieved that exact consistency with regard to time frame of changes in social networks and activity travel agenda with our survey. However the entire survey was prompted and centred around one specific life cycle event and the changes associated to it, thereby ensuring certain level of consistency.

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. Nonetheless, the survey presents a first approach of its kind fitted to the unique nature of the study.

4. Dynamics of Personal Social Networks



4.1 Introduction

Seminal studies on the evolution of personal social networks has been conducted in the fields of sociology, demography and health geography. Wellman et al. (1997) gathered personal network data from qualitative surveys among 33 Torontonians a decade apart. In 1968 they surveyed 845 adults, then re-interviewed 33 of them during 1978-1979. While the first survey was large in sample the second was rich in details on personal networks. They report that only 27% of the intimate ties were retained as intimate ties. Majority (two-thirds) of them has an intimate network with newly made ties. The relation between social interaction and tie maintenance was found to be rather complex. Telephone contacts were found to be positively influencing tie maintenance whereas daily face-to-face contacts were not. Daily contacts were made with co-workers and neighbours which were rather involuntary (contrary to telephone contacts) and therefore were more vulnerable in the face of life cycle events, such as, relocation and employment transition. They report a complete turnover in network composition to those who got married during the study period. However they did not find any association with other life cycle events, such as, childbirth, residential relocation or employment transition.

Bidart and Lavenu (2005) reported changes in personal network of young adults focusing on four life cycle events, viz. entry to labour market, geographical mobility, setting up house with a partner and childbirth. The qualitative studies identified trends of social network evolution. For instance, with entry to labour market, individuals assign more value to homophily and less value to weak ties. Right after involvement in a romantic relation network size increases but drops with cohabitation. Conversely network size increases with separation and divorce. Residential relocation relates to an initial count of lost ties followed by resurgence of new ties with time. For fresh University students the number of lost ties is rather limited. They stress the necessity to distinguish life cycle events as some may act as transitions while other pose a break in the network. Pahl and Pevalin (2005) found complementary evidence of large changes in social network size after separation, divorce or the death of partner. Degenne and Lebeaux (2005) studied network evolution during entry to adult life and report effects of the events of being a couple, childbirth and starting to work. In line to the findings of Wellman et al. (1997) they report disappearance of ties that are dependent in the context of daily life,

particularly in case of geographical mobility.

However, the evolution of social networks through different life stages of an individual has not been systematically investigated in transportation studies. How the evolution of personal networks can be incorporated to predict dynamics in travel demand is rather unexplored. One of the reasons may be that such analysis requires social network data over the life course. Understandably, obtaining such data is a difficult task given the commitment and resources that are required to collect such data. The importance of gathering this empirical evidence has been expressed several times in transportation literature (Axhausen, 2008; Carrasco and Miller, 2009a; Kowald and Axhausen, 2012). With the gradual shift towards dynamic modelling, the significance of incorporating social network evolution in activity and travel behaviour modelling has become more prominent in recent years. When the whole research community is being increasingly challenged about modelling long-term dynamics of activity and travel choices, considering social networks as stationary is inapt and may lead to erroneous prediction of social and leisure travel in particular.

Scholars conclude that independent of the size and context personal social networks do change over time (van Duijn et al., 1999), which is the core argument of this thesis. A systematic investigation of the effects of lifecycle events on the size of social network is rare. What are the effects of lifecycle events on personal social networks? What are the number of lost and new ties after an event? Does it depend on the event type, time or the locational attributes? Which ties are retained and which are dissolved? These questions are rarely addressed in empirical studies. With this motivation, we investigate the size of personal social networks and their dynamics (size of lost and new ties) in this chapter. Since the data collection instrument was designed to allow respondents to self-report lost and new ties in relation to specific events, the analyses presented in this chapter essentially predict social network dynamics with respect to lifecycle events. Additionally, we investigate the tie characteristics that are lost and made based on theories of homophily and the effects of life-cycle events.

This chapter explores the size of personal social networks, the size of lost and new ties after a lifecycle event, and the characteristics of lost and new ties after a lifecycle

event. Five models are estimated. The first model predicts the size of social networks after the event. Next, two models report predictions related to the number of lost ties and the number of new ties after a lifecycle event.

Since the dependent variables of these models are count data, Poisson and negative binomial regression models are candidate options. Since the standard deviation was not equal to the mean, in the end the negative binomial regression was selected. It can solve the problem of over-dispersion and allows the variance to differ from the mean. In these two models, explanatory variables were ego's personal and household characteristics. However, lost and new ties also depend on ego-alter tie characteristics (such as homophily, strength and length of relationships). To predict the characteristics of a tie that is new or lost, two models were estimated as a function of the characteristics of ego and alter. For these two models, the binary mixed logit specification was used.

4.2 Descriptive Statistics

The number of lost and new ties and ratio statistics were calculated to understand social network dynamics with respect to network size (shown in Table 4.1). The ratio statistics divide the total number of lost and new ties for each ego by its size of social network. The mean and Coefficient of Dispersion (COD) were calculated for each type of lifecycle event. The COD statistic measures variability. Thus, the greater the value of COD, the higher the variability. The lost ties ratio is less than that of new ties. Further, if we look at the ratios according to the type of event we discover some interesting distribution. Residential relocation as a standalone event yields less lost and new ties than when residential relocation both as a separate event and a secondary decision as a consequence of other events (such as, starting University and leaving parent's house). This is plausible since there is the added effect of the primary event on the number of lost and new ties, i.e. social network dynamics.

The event of children starting school has the lowest ratio for lost ties, but it has a considerable ratio (however more variable) for new ties. This indicates that this event is more likely to bring more ties than losing them, either by bringing exposure to new people or by posing less pressure on the personal time budget.

Table 4.1 Ties lost or new - distribution according to homo (hetero)phily between ego and alter

Homophily Variables	Tie lost (yes)	New tie (yes)
Same age	57.4	92.3
Different age	42.6	7.70
Same gender	61.8	59.2
Opposite gender	38.2	40.8
Same education level	1.50	0.90
Different education level	98.5	99.1
Relationship strength: weak	91.2	62.6
Relationship strength: strong	8.80	37.4
Change in geographical distance: decrease	11.8	-
Change in geographical distance: no change	51.5	-
Change in geographical distance: increase 0-10km	29.4	-
Change in geographical distance: increase 10+km	7.40	-

Starting university has the highest ratio for new ties. This is also plausible since this is the age and time to make new friends. Starting a new job has the lowest ratio for new ties and the variability is also low. Further, Table 4.1 shows the aspects of homophily/heterophily in the making or losing of ties. This is a tie level analysis. The numbers represent the percentage distribution of lost and new ties across the socio-demographics of ego and alter.

We observe that 92.3% of new ties were made among same age groups, only 7.7% among different age groups. On the other hand, 57.4% of the ties that were lost also belong to the ego-alter of same age group. The majority of both lost and new ties are among ego and alter of the same gender. However, in terms of education we observe that difference in education level has a landslide share. Weak and average ties constitute the major proportion of lost ties. On the other hand, new ties are mostly indicated as weak ties (rated 1, 2, 3 on a 5 point scale), which is plausible since closeness takes time to grow. However, 37.4% of the new ties were reported as strong ones. Interestingly, 51.5% of the lost ties did not have any change in geographical distance and in 11.8% cases there were a decrease in distance. Apparently geographical distance is less crucial in losing ties when life-cycle events are considered.

The proportion of ties lost per type of life cycle event is shown in Figure 4.1. The differences between types of life cycle events are remarkable. Residential relocation has a larger impact on lost ties than on new ones. The opposite is true for the event of children starting school. Change in civil status (defined by the start or end in cohabitation, wedding, separation and divorce) has a more equal impact in terms of lost and new ties. The proportions are among the highest, compared to other types of life-cycle events. The proportion of new ties is the highest for the event of new job or study.

Table 4.2 Comparison of the ratio of number of lost and new ties with social network size and according to type of event

Ratio statistics	Mean	Coefficient of dispersion
# of Lost ties/Social Network Size	0.06	4.39
# of New ties/Social Network Size	0.09	1.68
# of Lost ties/Social Network Size for Event: Residential relocation (only)	0.06	0.89
# of Lost ties/Social Network Size for Event: Residential relocation both as a standalone event and followed by other event	0.08	1.89
# of Lost ties/Social Network Size for Event: Getting married/divorced/cohabitation	0.06	0.58
# of Lost ties/Social Network Size for Event: Children starting school	0.00	0.02
# of Lost ties/Social Network Size for Event: Starting University	0.08	1.70
# of Lost ties/Social Network Size for Event: Starting new job	0.02	0.04
# of New ties/Social Network Size for Event: Residential relocation (only)	0.02	0.16
# of New ties/Social Network Size for Event: Residential relocation both as a standalone event and followed by other event	0.10	1.14
# of New ties/Social Network Size for Event: Starting University	0.12	1.29
# of New ties/Social Network Size for Event: Getting married/divorced/cohabitation	0.07	0.11
# of New ties/Social Network Size for Event: Children starting school	0.05	3.61
# of New ties/Social Network Size for Event: Starting new job	0.01	0.03

4.3 Model estimates

4.3.1 Size of Social Network

The first model (Table 4.3) predicts the size of social network of an individual after the life cycle event. As was discussed earlier, a negative binomial regression model was used to estimate the model. A total of 701 valid cases were used in the analysis. Goodness of fit statistics show that the model has a good fit.

The model parameters show that young (less than 30 years) and old (more than 50 years) are likely to have a larger social network compared to the middle-aged group (30-60 years). Gender has no significant effects. Van den Berg (2012) reported similar findings related to gender and young age.

On the other hand, the primary and highly educated group have a smaller social network. For the secondary educated group, the effects were not significant. The base category was vocational education level. Molin et al. (2008) have found similar results, except for highly educated individuals. Their prediction reports larger social networks for highly educated persons.

With regard to household composition, the only significant effect was found for families with young children. Families with children on an average have a larger network. Similar findings were reported in previous studies (Kowald and Axhausen, 2010; Molin et al., 2008). Working people tend to have a larger social network than the unemployed (and those looking for work or on pension). This finding could be of concern as it indicates social stigmatisation of the jobless population, further reducing their possibilities to find work (Morris, 1992; Russell, 1999), particularly with regard to the recent economic recession (Rubery, 2010).

We did not have information about household income in our survey. Therefore, we tested two sets of variable as a proxy to income and wealth; one is the type of house and second is the neighbourhood quality (wealth). For the house typology, the only significant effect was that of row house; a negative coefficient implying a comparatively smaller network for those living in a row house. People living in wealthy neighbourhood areas tend to have a smaller network than middle income neighbourhoods.

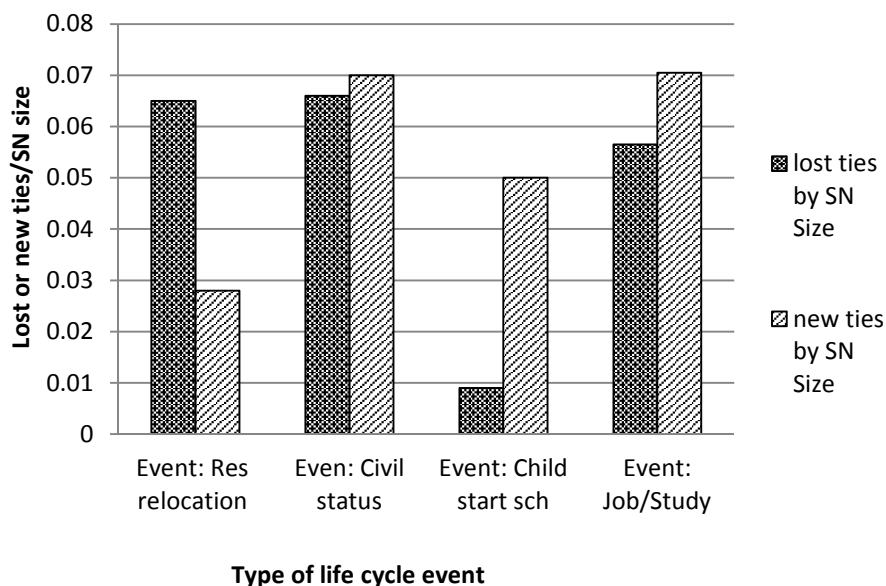


Figure 4.1 Social network dynamics according to life cycle events

Household car ownership has a positive association with size of social network. Having one car in the household has a positive effect relative to no car availability. Two or more car ownership, however, do not have a significant coefficient.

Urban density positively influences social network size. Those living in high and very high urban density have larger social networks on an average. This imply that people living in high density areas report larger social networks. Other scholars have reported similar findings (Korte, 1980; Wahba and Zenou, 2005; Wellman, 1979). The strength of those ties however is debatable. Scholars have argued that density influences the quantity of weak ties more than the number of strong ties (Wahba and Zenou, 2005). They report that individuals in cities might have fewer strong ties than those living in the rural areas. This might be the reason why different effects were reported in van den Berg (2012). She used name generators to find close and somewhat close ties whereas the respondents were asked to report the size of their social network regardless the tie strength.

Table 4.3 Modelling size of social network with the effects of life cycle events

Parameter estimates	β	t
Constant	3.16	8.39
Age less than 30	0.25	2.60
Age more than 50	0.22	2.28
Male	0.10	1.16
Primary or no education	-0.41	-3.12
Bachelor or high education	-0.19	-1.70
Secondary education	0.10	0.70
Full time work	0.29	2.54
Part time work	0.28	2.56
Live with parents	0.06	0.44
Live with roommates	0.04	0.16
Couple without children	0.12	0.96
Family with young children	0.36	3.15
Live in apartment	-0.39	-1.61
Live in row house	-0.46	-1.91
Live in detached house	-0.16	-0.67
Has driving license	-0.11	-1.08
One car in the household	0.20	2.57
Two or more car in the household	0.08	0.54
Member of a club	-0.26	-3.44
Medium urban density (1000-1500 addresses/km ²)	0.11	0.93
High urban density (1500-2500 addresses/km ²)	0.44	4.45
Very High urban density (>2500 addresses/km ²)	0.22	2.06
Wealthy postcode area (mean yearly mortgage >10k€)	-0.62	-3.92
Middle income postcode area (mean yearly mortgage 5-10k€)	0.43	2.68
Old residents (>5years in present house)	-0.36	-3.04
Event: relocation	0.04	0.36
Event: new job	0.36	3.29
Event: change in civil status	-0.13	-1.03
Event: starting university education	0.68	3.55

Parameter estimates	β	t
Event time: more than 18 months	0.07	0.88
Event time: less than 6 months	0.11	1.15
Dispersion parameter, α	0.83	15.94

Model Summary

# Observations	701.00
Log likelihood function	-3057.59
Restricted log likelihood	-14549.26
Chi squared	22983.35
Significance level	0.00
McFadden Pseudo R-squared	0.79
Inf.Cr.AIC	6183.20
AIC/N	8.82

One important aspect of the analysis is to investigate whether passing through a life cycle event recently had an effect on the size of social network. Two events (viz. starting new job and stating university education) positively influence social network size. This implies that if someone has recently experienced any of these two events, their social network size would probably increase. The other event types and timing of the event did not have a significant effect. On the other hand, if an individual is living in the current residence for five years or more he/she might have a smaller social network as opposed to new residents. This may indicate that right after relocation the networks get bigger but with time gets settled and more concise. The coefficient for the event of residential relocation also has similar indication yet not significant.

4.3.2 Number of new and lost ties

The next two models predict the number of lost and new ties as a function of personal, household and urban density characteristics. Similar to the first case, the dependent variable is a count variable, hence negative binomial estimation was used here as well. Both the models (Table 4.4 and 4.5) have a high R-square value indicating a good fit.

Table 4.4 Predicting number of new ties with life cycle events

Parameter estimates	β	t
Constant	1.83	1.94
Age less than 30	0.11	0.56
Age more than 60	1.21	2.04
Male	-0.07	-0.44
Basic or no education	1.67	3.66
Secondary education	1.69	3.84
Bachelor or high education	0.37	1.61
Full time work	-0.01	-0.02
Part time work	0.01	0.10
Live with parents	0.27	0.88
Live with roommates	0.79	2.87
Couple without children	0.69	2.18
Family with young children	-1.04	-2.16
Live in apartment	-1.98	-3.82
Live in row house	-2.16	-4.30
Live in detached house	-1.16	-2.82
Has driving license	-0.41	-2.07
One car in the household	-0.15	-0.96
Two or more car in the household	-0.13	-0.80
Member of a club	-1.86	-4.91
Medium urban density (1000-1500 addresses/km ²)	0.09	0.32
High urban density (1500-2500 addresses/km ²)	0.83	3.22
Very High urban density (>2500 addresses/km ²)	0.34	1.26
Wealthy postcode area (mean yearly mortgage >10k€)	-0.24	-0.71
Middle income postcode area (mean yearly mortgage 5-10k€)	-0.16	-0.65
Old residents (>5years in present house)	-0.18	-0.71
Event: relocation	-1.69	-2.46
Event: new job	-9.11	-0.00
Event: change in civil status	-2.41	-2.83
Event: starting university education	-0.79	-1.17
Event time: more than 18 months	0.04	0.19
Event time: less than 6 months	0.26	0.60

Model Summary

# Observations	701.00
Log likelihood function	-207.63
Restricted log likelihood	-850.65
Chi squared	1286.05
Significance level	0.00
McFadden Pseudo R-squared	0.76
Inf.Cr.AIC	481.30
AIC/N	0.69

For older people the probability of both gaining and losing a large number of ties is higher². It is natural to lose ties at later life. Also older people have more time at their disposal and, therefore, might be more open to making new ties. Gender effects show that men are likely to lose more ties compared to women. In terms of new ties the effects are not significant. Lower education levels have a varied influence on tie dynamics. Individuals with basic or no education are likely to make a higher number of new ties. On the other hand, for those with secondary or pre-University education to the probability of both making and losing a larger number of ties is higher. Working status has an impact on losing more ties. Full time workers are more likely to lose a larger amount of ties compared to non-workers.

Household composition was modelled relative to single person households. Individuals living with roommates and with partners (couples) are more likely to both making a larger number of new ties as well as losing more ties, whereas families with young children are less likely to make a lot of new ties or lose a larger number of existing ones.

Housing type, number of cars and residential postcode can be taken as a proxy to income and wealth. Possession of one or more cars does not have any effect on number of new and lost ties. Wealthy postcode areas were identified by the top 25 percentile of monthly mortgage payments in the Netherlands. Living in wealthy

² The findings were reported as probabilities to avoid complications and clumsiness. Please note that the model though predicts a number not a probability.

postcode areas do not seem to have any effect on the number of new ties but seem to have a positive effect on the number of lost ties with life cycle events.

Joining university for higher education may lead to losing a higher number of ties on an average. This event type was dominated by young respondents. Therefore, it is a relevant finding since at the young age social networks might change dramatically and may stabilize at a later age. On the other hand, change in civil status has a negative effect on the number of new ties. This finding is difficult to interpret as this event definition includes marriage, separation and divorce. Timing of life cycle events do not have any significant impact on number of new and lost ties.

4.3.3 Adding and deleting ties

The following two models predict the characteristics of making a new tie and losing an existing one. The unit of observation is a tie between an ego and alter. For the first model predicting making a new tie (Table 4.6), if the tie was newly made after the event the observation is yes otherwise (if the tie is old or lost) no. Similarly for the second model predicting deleting a tie (Table 4.7), if the tie was deleted after the event the observation is yes, otherwise (if the tie is retained) no. The models were estimated using binary logit model specification. The constants for both the models are negative, as expected, indicating that all being equal the probability of making or losing ties are negative. Model summary show the models fit well. Additionally, we calculated rho squares based on the constant only log likelihood, which show that the explanatory variables explain addition (0.666) and deletion (0.493) of ties sufficiently.

New ties compared to existing ties are characterized by a high probability of age and gender homophily as the probability that the tie is new increases when the alter is of same age/gender. Education level on the other hand has a negative effect implying the opposite effect than age and gender homophily. Same age and education level also positively affect the probability of losing ties. This is an intriguing finding indicating that individuals are likely to keep ties based on heterophily and make new ties based on homophily parameters compared to existing ties.

Table 4.5: Predicting number of lost ties with life cycle events

Parameter estimates	β	t
Constant	-3.70	-1.98
Age less than 30	0.04	0.16
Age more than 60	1.75	1.93
Male	0.55	2.35
Basic or no education	0.96	1.36
Secondary education	1.69	2.64
Bachelor or high education	0.41	1.48
Full time work	1.94	2.81
Part time work	0.01	0.09
Live with parents	0.55	1.43
Live with roommates	0.75	2.45
Couple without children	0.61	1.77
Family with young children	-1.53	-2.37
Live in apartment	-0.84	-1.11
Live in row house	-1.23	-1.67
Live in detached house	-0.63	-1.05
Has driving license	-0.91	-3.98
One car in the household	-0.02	-0.11
Two or more car in the household	0.24	1.25
Member of a club	-0.90	-1.91
Medium urban density (1000-1500 addresses/km ²)	0.04	0.15
High urban density (1500-2500 addresses/km ²)	0.83	2.66
Very High urban density (>2500 addresses/km ²)	0.17	0.54
Wealthy postcode area (mean yearly mortgage >10k€)	0.83	2.23
Middle income postcode area (mean yearly mortgage 5-10k€)	0.13	0.43
Old residents (>5years in present house)	-0.11	-0.35
Event: relocation	-1.01	-0.64
Event: new job	-0.24	-0.19
Event: change in civil status	-1.35	-0.90
Event: starting university education	3.32	2.17
Event time: more than 18 months	-0.22	-0.95

Parameter estimates		β	t
Even time: less than 6 months		-1.15	-1.70
<u>Model Summary</u>			
# Observations	701.00		
Log likelihood function	-162.75		
Restricted log likelihood	-667.79		
Chi squared	1010.07		
Significance level	0.00		
McFadden Pseudo R-squared	0.76		
Inf.Cr.AIC	391.50		
AIC/N	0.56		

However, looking into the type of ties, we observe that family and friends are less likely to be lost from individual's social networks. Similarly strong ties are less likely to be lost but weak ties are more likely, indicating rational behaviour. On the other hand less known ties have a negative effect on losing ties, meaning that less known ties are less likely to be erased from social networks. We would like to note that this is after controlling for the tie strengths.

Geographical distance and changes in geographical distance promotes the ties being retained. We observe that a decrease in geographical distance negatively effects losing a tie, meaning that the probability is higher of the tie being in the network. Similarly a tie that was always close (within 1 km of distance both before and after the life cycle event) is less likely to be erased from the network. These parameters were only calculated for losing existing ties, as these information were not relevant for making new ties.

For types of life cycle events we observe that new job and change in civil status positively affects losing ties. None of the events have significant effects on making new ties. If the event took place 18 months before or more the probability of making new ties is lower yet the probability of losing ties is higher. Immediately after a life-cycle event it is rather difficult to identify if a tie is lost. Perhaps the frequency of interaction is reduced and after a while diminishes completely. Therefore, after a while the life cycle event has passed ties are recognized as being lost by individuals.

Table 4.6 Predicting the probability of making a new tie

Parameter Estimates	β	t
Constant	-15.4	-5.69
Same age	3.94	2.14
Same gender	4.11	5.15
Same education level	-3.07	-2.96
Age less than 30	2.63	1.37
Age more than 60	7.27	2.20
Male	-4.21	-4.74
Bachelor or higher education	0.65	0.62
Size of social network	0.02	2.04
Event: relocation	-0.48	-0.42
Event: new job	-8.33	-0.40
Event: change in civil status	-8.35	-0.39
Event: starting university education	10.0	0.00
Event time: more than 18 months	-9.20	-4.82
Event time: less than 6 months	-0.30	-0.26
Std deviation random effects	3.04	5.88

Model Summary

# Observations	1109.00
# Individuals	266.00
# Halton draws	1000.00
Null log-likelihood	-768.70
Constant only log-likelihood	-671.68
Final log-likelihood	-223.69
Rho square	0.68
Rho square (based on constant only model)	0.67

4.4 Conclusion

In this chapter we summarize five models predicting all about size and dynamics of personal social networks with life cycle events. All the models show a good fit and the selected variables explain the variability of the respective social network parameters well.

Table 4.7 Predicting the probability of losing a tie

Parameter Estimates	β	t
Constant	-15.7	-5.43
Same age	0.98	1.93
Same gender	0.84	1.17
Same education level	3.57	2.12
Alter is family	-3.18	-2.06
Alter is a friend	-4.49	-4.76
Alter is a neighbour	0.14	0.20
Strong tie (>4 in a 5 point scale)	-3.18	-3.98
Weak tie (<2 in a 5 point scale)	2.84	3.47
Alter is less known (<2 years)	-1.76	-1.93
Alter is long known (>10 years)	1.22	1.58
Decrease in geographical distance	-1.91	-1.58
Increase in geographical distance	0.10	0.14
Always close (before and after event <1km)	-1.74	-1.95
Now far (before event<1km after event>1km)	-0.63	-0.51
Old residents (>5years in present house)	6.56	4.00
Event: relocation	1.26	1.26
Event: new job	2.28	2.01
Event: change in civil status	2.16	1.92
Event: starting university education	-1.62	-1.51
Event time: more than 18 months	2.40	2.53
Event time: less than 6 months	0.07	0.09
Age less than 30	-2.39	-1.89
Age more than 60	-9.51	-7.76
Male	-2.16	-2.35
Bachelor or higher education	-0.16	-0.19
Std deviation random effects	-3.02	-5.28
Model Summary		
# Observations	1109.00	
# Individuals	266.00	
# Halton draws	1000.00	

Null log-likelihood	-768.70
Constant only log-likelihood	-255.71
Final log-likelihood	-129.54
Rho square	0.79
Rho square (based on constant only model)	0.49

Size of social network was modelled with socio demographics, life cycle events and neighbourhood characteristics and results are comparable to previous empirical studies.

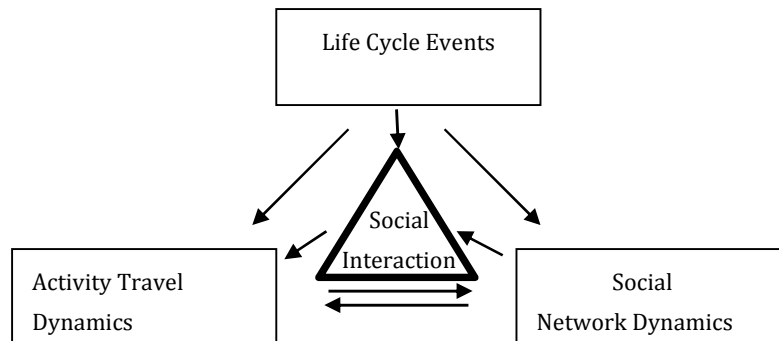
The number of lost and new ties were modelled in the similar way. The first three models were based on ego-level variables. However, given the novelty of the approach and data structure, it is difficult to compare the results. In the next stage we predicted losing or making a tie based on ego-alter level characteristics, where we observe that homophily plays a role in making new ties whereas heterophily effects are in play when keeping existing ties.

The findings are a novel addition to the empirical studies on the dynamics of social networks. It reports the effects of life cycle events on size of social networks, number of lost and size of new ties. Moreover, we investigate the probability of making and losing ties with life cycle events based on dyad characteristic of tie between the pair of ego and alter. This is a first study of to account for the effects of life cycle events on social networks. We observe there are significant effects that vary according to the type and timing of events. Extensions along this line are imperative to overcome the limitations of this study. For instance, the definition of change in civil status is difficult to interpret. In the next stage, careful attention should be given in this regard.

5. Social Interaction

Dynamics:

Face-to-face Vs ICT³



³ Reproduction from Sharmeen, F., Arentze, T. and Timmermans, H. (2013) A Multilevel Path Analysis of Social Network Dynamics and The Mutual Interdependencies Between Face-to-Face and ICT Modes of Social Interaction in The Context of Life-Cycle Events Chapter 18, pp. 411-432. In: Roorda, M. J. & E.J., Miller (eds.) *Travel Behavior Research: Current Foundations, Future Prospects*. Lulu Press, Toronto, ISBN 9781304715173

5.1 Introduction

Personal social networks evolve as one passes through important stages of life. Not all childhood friends become friends for a lifetime and people tend to gain and lose colleagues as they change jobs. Moreover, with increasing popularity and introduction of ways to keep in touch with one's social world, the mode and frequency of social communications might change over time as well. With this concept in mind, in this chapter, we investigated how social communication patterns change among the various modes of communication with evolving social networks.

To investigate the dynamics of social interaction patterns, it is important to know the history of social interaction between the ego and alter. By doing so, we can account for the dynamics in social interaction modes and the effects of social network dynamics and secondary effects of life-cycle events. Life-cycle events bring about changes in individual's activity and home locations, thereby increasing the probability to meet new people and expand the social network. Similarly, some old contacts may get less communication owing to changes in time budget or perhaps geographical distance. Further, to compensate for lost social and emotional needs, caused by the network members with whom the ego lost touch, an ego might become eager to communicate with more new friends. Presumably, there will be changes in the social network and social communication pattern.

The relationship between face-to-face contact and use of ICT (Information and Communication Technology) modes of contact has been a popular research theme for quite some time now. Research shows that ICT contacts, first of all, are not independent from face-to-face interactions (Dijst, 2009; Kwan et al., 2007; Tillemma et al., 2010). There may be four possible ways by which ICT can interact with leisure activities and travels: substitution, complementary, neutrality and modification (Salomon, 1986). Further, researchers found that social travel and ICT communication are complementary to each other (Mokhtarian, 2002; Senbil and Kitamura, 2003; van den Berg et al., 2010). However, in most contemporary research, only one-way interaction from ICT to face-to-face communication has been assumed and modelled. Evidently, increasing ICT contact would trigger new face-to-face contacts and also enable additional face-to-face interactions as people

would have increasing virtual space to schedule and plan new social events. We argue that the effects might also be the other way around. Increasing face-to-face communication with an alter may lead to more ICT communication with him/her as well. Further, we argue that these communication options and particularly the company of social interaction, however, is dynamic and changes with spatial context (Sharmeen and Ettema, 2010) and over lifetime (Sharmeen et al., 2010; Sharmeen et al., 2012b).

In that context, the objective of this analysis is to investigate the dynamics of social interaction with the dynamics of social networks and test the causal interferences between the modes of social interaction.

5.2 Theory and Literature Review

5.2.1 Theory and Concept

Drawing from previous literature (Mokhtarian, 1990; Salomon, 1986) the interaction between ICT (virtual) and physical travel behaviour can be defined into four categories:

1. Substitution: ICT replacing travel
2. Complementary: this could be either enhancement (ICT stimulating trips) or improving operational efficiency (ICT facilitating more efficient travel)
3. Neutrality: ICT and travel having no interaction effects
4. Indirect: ICT may influence land use which will further affect travel

We assume these interaction effects between ICT and face-to-face communication, being the primary reason of social travel. Mokhtarian (1990) concluded that the most important impact of ICT on travel behaviour might be the flexibility it brings in deciding the time, place and mode of travel. The impact is of key importance particularly in social activity-travel behaviour, comprising mostly non-mandatory activities.

The direct interaction effects between ICT and travel is illustrated in Figure 5.1. We extend the concept presented by Salomon (1986), where he illustrated the interaction between modes of communication across time, assuming an

exponential growth. The total communication pattern can be divided into three distinct areas:

- The share of transportation - lower section of the graph
- The interaction zone - middle section
- The ICT communication zone - upper section of the graph

The interaction zone is divided by the 'no interaction' line. The area above the no interaction line represents 'enhancement' and the area below the line defines 'substitution' effects of interaction between ICT and travel. When at a certain point of time an important life-cycle event is introduced the communication patterns might get modified. There might be an increase (upward shift) of the graph, a decrease (downward shift) or there might be no change at all. The modifications are represented by introducing dotted lines in the interaction zone of the graph.

With respect to social interaction, contemporary research shows that the effects between ICT and physical travel are complementary. However, in a dynamic context, life trajectory events, when they occur, may change physical or social distance between ego and alter. The ego might also make new contacts and has to adjust the social travel schedule accordingly.

There could be the following three scenarios:

1. There might be no influence of the event on some (ego-alter) ties.
2. The ego might decide to either substitute travel or enhance the communication with existing contacts using ICT to accommodate new contacts or adjust to the new time/money budget.
3. The ego might decide to reduce communication with some alters because the social network has expanded or the time/money budget has shrunk down. An ultimate reaction might be that the total communication declines and the alter gradually disappears from the ego's social network.

We hypothesize that the third scenario is probable for weaker ties and with stronger ties either of the first two scenarios are realized. The hypothesis was confirmed in Sharmeen et al. (2012a) by means of empirical data analysis.

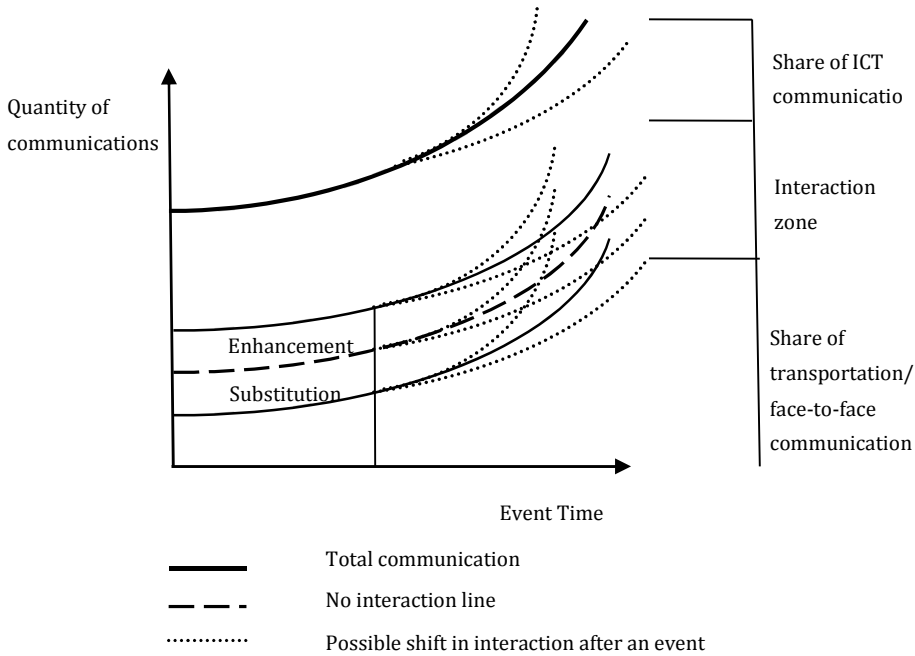


Figure 5.1 Dynamics of social communication with life cycle events (based on Salomon, 1986)

Moreover, we argue that the relationships between face-to-face and ICT are interdependent. In other words, any of them can substitute or complement the other. The causal direction is not only from ICT to face-to-face as assumed in most of the contemporary studies. We, therefore, redefine the dynamic interaction effects between ICT and social travel behaviour as:

1. Substitution: a decrease in one mode of communication is compensated by the other
2. Complementary: this could be enhancement (e.g. ICT stimulating trips), improving operational efficiency (e.g. ICT facilitating more efficient travel) or decline (e.g. decline in face-to-face contact with an existing alter would result in a decline in ICT communication).

3. Neutrality: ICT and travel having no interaction effects
4. Indirect: e.g. ICT may influence land use which will further affect travel

The objective of the chapter is, hence, twofold:

- Firstly, to investigate the effects of changes in ego's social network due to a life-cycle event on the changes in social interaction frequency with alters and
- Secondly, to test the interdependencies between the modes of social interaction given the changes due to life-cycle events.

The concept is presented in Figure 5.2. The effects of dynamics of social network and associated travel have not been explored in transportation research yet. To that end, we contribute by developing a conceptual framework and exploring the effects.

5.2.2 Review of Empirical Literature

Social activities and associated travel are not an individualistic but rather a collective phenomenon. It involves a number of aspects to consider, for instance, time, place, duration, travel/communication mode, and most importantly negotiation on these aspects with the travel/activity company, i.e. the social network member. Recent empirical evidence strongly suggests that an understanding of social networks is imperative to explain discretionary travel behaviour. In this section, we will review this research.

There have been quite a few studies in the travel behaviour research community to explore the relationship between social interaction and travel behaviour. Carrasco, et al. (2006) in their research analysed social network data collected in Toronto. They concluded that the propensity to perform social activities has a strong association with the activity-travel behaviour process. He noted that the overall propensity to perform social activities suggests a complementary and not a supplementary effect on travel, with the exception of instant messaging. Kowald, et al. (2010) explored social interaction modes and the relation with geographical distance and leisure travel. They noted that face-to-face contacts are of high importance for each distance class, yet phone and e-mail contacts become more important as distance increases, in particular between 20 to 70 km. They also noted

that the findings are similar to those of Axhausen and Frei (2007). However, they did not state the nature of the relationship between interaction modes.

Van den Berg, et al. (2010) presented their analysis on the role of ICT in social interaction using social interaction diary data collected in the Netherlands. Using a path analysis, they tested the links between ICT use and face-to-face interaction frequency and found that social travel is mediated by ICT and effects tend to be complementary. Larsen, et al. (2006) conducted exploratory research using detailed analysis of qualitative data collected in the UK. They noted that mobile phones and e-mails are becoming increasingly necessary to arrange social meetings. They used the terms 'flexible punctuality' and 'perpetual coordination' to explain that social meetings are increasingly flexible and that young adults constantly change their plans on the move. Their theoretical explanation to explain the dynamics in the short term also applies to the mid and long term and they argue that social meetings are indeed flexible and for coordination/compensation people frequently use different models of interaction.

Dijst (2009) used a Tripartite Situatedness framework to analyse the relationship between ICT and social network. He extensively reviewed the literature and analysed ICT use data from a number of countries. He reports a complementary relationship between ICT and frequency of contacts yet a substitutive relationship prevails between ICT and the time budget spent on social ties. He also shows that with increasing geographical distance ICT communication declines, with an exception of e-mail. This might be associated with the low cost of maintaining e-mail contact.

Using bi-variate correlation analysis, Tillema, et al. (2010) showed a positive correlation between the frequencies of ICT and face-to-face contacts. Further, they conducted ordered probit analysis of a two-day travel diary of 662 respondents. The results demonstrate that both face-to-face and ICT communication frequencies decline with increasing physical and relational distance to the network members. Although this was a cross-sectional data analysis, we assume a similar effect when physical and social (relational) distance increases among the same ego-alter tie as a result of a life cycle event. Therefore, we find it important to include the effect (decline) in the theoretical construct (section 5.2.1).

All these studies strongly suggest that the social network and the analysis of social interaction frequencies are important to understand and explain travel behaviour. They also explore different dimensions of social interaction patterns and the corresponding associations at a certain point in time and individual state. We argue that these interaction patterns are dynamic and change with changes in social networks triggered by lifecycle events. In this paper, we explore these dynamics.

5.3 Data and Methodology

In this chapter, we analysed the data collected about any change in the ties after the stated event (collected in section two of the questionnaire, see Chapter 3). The question this chapter addresses concerns the effects of changes in social network on social interaction and the interrelationships between the modes of communication. We investigated the nature and the relation between possible changes in ICT and face-to-face contact frequencies.

For the purpose of the chapter, we re-structured the data according to ego-alter tie so that each case represents one tie where a change occurred. Thus, the data constitutes new ties, lost ties and ties where there were changes in terms of social interaction or geographical distance or both. The unit of analysis is, therefore, tie not ego. Table 5.1 presents the number of cases (ego-alter ties where a change occurred) according to the type of event as used in the analysis. The event of starting the University is over-represented in the sample of ties where a change occurred. The respondents in this case were young students who reported more ties where a change occurred than others. Also this may be due to the fact that at young age a personal social network is more flexible (Degenne and Lebeaux, 2005). After re-structuring the data and removing missing cases, we had 1012 cases (ties) for the analysis.

Structural Equation Modelling (SEM) is a powerful tool to model complex causal associations. We had a number of endogenous variables in two separate levels of variable sets. Hence, SEM seemed the most appropriate method for the analysis. SEM constitutes two components: a measurement and a structural model. In the study, we were only modelling causal relationships among directly observed variables. Thus, the model has only the structural component, also known as the

path analysis. The results of path analysis using LISREL are discussed in the next section. We modified the final model and removed those relationships that were not significant on a 0.1 significance level. Figure 5.3 shows the structure of the final model and Table 5.2 presents the results. The interpretation of the results is organized in four sub-sections below. First, the influence of exogenous variables on endogenous variables is described followed by a discussion on the effect of endogenous variables on each other.

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.

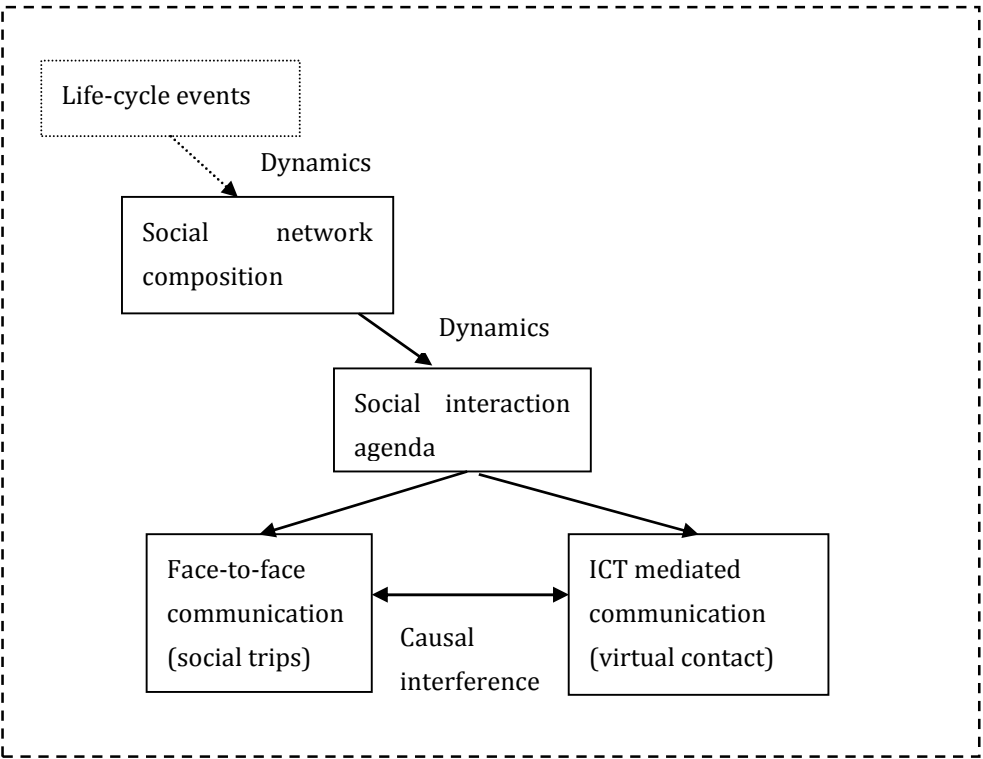


Figure 5.2 Causal inferences to and between social interaction modes

The first category broadly states if 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, although has many difficulties associated with it, is an essential statistic to report along with the Root Mean Square Error of Approximation (RMSEA) and associated p-value (Hooper et al., 2008). The value of Chi-square divided by the degree of freedom is an acceptable measure of model fit, which should be less than 2. Also the 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 stated two indices. The measures show that the model is acceptable. The reduced R-squares show that the explanatory power of the exogenous variables is fair.

Since each of the respondents had multiple alters to report, we opted for a multi-level structural model. There are two levels in the structure, namely the person level and the tie level. The person level represents the characteristics of the ego. The tie level represents the characteristics of the ego-alter tie. The main endogenous variables viz. the social interaction frequencies belong to the tie level. The model accounts for history dependence to take the dynamics of social interactions over time into account. Hence, there are also two variables representing the history of social interaction at the tie level defined as exogenous ones.

Moreover, the model takes the dynamics of social networks into account. Therefore, it includes the measure of the lost and new social network members. They are defined as the contacts that the ego lost touch with or gained associations with after the particular life-cycle event that the ego experienced in recent past. The number of network members that are lost or gained depends on ego's socio-demographic characteristics. Hence, they are also endogenous but at the person level. Thus, the model has endogenous and exogenous variables at both the levels. A detailed distribution of the variables is presented in Table 5.1.

Sample characteristics show that the data is over represented by young (age less than 30 years) and male. Average working hour per week is 13 (approximately). Since more than 70% of the respondents had a driving license, a combined variable

of car availability and driving license was calculated. Approximately 63% of the respondents have a driving licence and also at least one car available in the household. For 38% of the respondents, the event is fairly new (took place less than a year ago) and approximately 39% have a close social network of less than or equal to 25 members. The average number of lost ties, due to the said event, is 2.39, and the average number of new ties due to the event is 3.40.

At the tie level, comparative variables are formulated to better represent the relationship and homophily between ego and alter, for instance, age difference instead of age. Since these variables are about the relationship between ego and alter, such formulations are more informative. In the sample, 42% of the ties are of different age group and approximately 53% are of different gender. Approximately 19% of the ties are weak (rated 1 and 2 on a scale of 5) and 44% (rated 4 and 5 on a scale of 5) of the ties are strong. 40% of the ego and alters know each other for less than two years and 20% of them know each other for a long time (more than 10 years). Relationship status of 75% of the ties are friends or family, as opposed to neighbours, colleagues, acquaintances and miscellaneous other types.

Geographical distance between the home locations of ego and alter is represented by comparative measures before and after the event. Social network studies also show that when an ego moves, those alters who were geographically close previously are more likely to disappear from the network of important relationships than those who are already distant (Degenne and Lebeaux, 2005). Thus, two variables were computed to characterize change in geographical distances, namely, recently distant and already distant. Recently distant means the home locations of an ego and alter were within 15 km before the event, which has become more than 30 km after (30% of the cases). On the other hand, already distant ties were always more than 30 km away (14% of cases). For the remaining cases, either there are no changes in geographical distance or the ego and alter were always within 15 km apart. Interaction frequency was measured both before and after the event in terms of number of times of face-to-face and ICT-contact per month. The 6-level categorical variable, with which frequency was measured, was transformed by taking mid points of the categories as follows:

- Daily : 30
- 2-3 times a week: 13.5

- Once a week: 4.5
- 2-3 times a month: 2.5
- Once a month: 1
- Less: 0.5
- Not at all: 0

The study is about dynamics or changes in social network and social interaction due to a lifecycle event. The sample constitutes of ties that have changed (new, lost or change in interaction frequency or geographical distance) or is affected due to a lifecycle event. A comparison to existing data is difficult and unrealistic partly because of the distinctive sample, and partly because the structure of the data (organized on tie level based on homophily among ego-alter). Only some attributes of the sample are comparable with the national sample and similar studies. Ego's socio-demographic characteristics are biased in terms of age and gender. The alter sample characteristics are in line with previous research (van den Berg, 2012). For example, in their sample, friends and family constituted 78% of the social network of the ego.

5.4 Results and Discussion

The model presents the causal relationships among the variables by means of a path analysis (Figure 5.3). The objective of the study is to investigate the dynamics of social interaction with the dynamics of social network and to test the causal interferences between the modes of social interaction. Parameter estimates are presented in Table 5.2.

5.4.1 Effects of Socio Demographics

Face-to-face communication frequency has a positive relationship with young individuals. For males, the probability of both face-to-face and ICT communication frequency is positive, with ICT having a larger coefficient. Working hours has a negative association with face-to-face interaction. This is plausible because the more hours one works the less time one has for social activities. Number of young children in the household has a negative effect on ICT communication. People having the car mobility option (car in the household and driving license) have a positive probability to engage in both face-to-face and ICT communication. Having a small close social network increases the probability of ICT communication.

Table 5.1 Sample characteristics

Variables	Description	Type	%
Exogenous variables			
<i>Between level (person characteristics)</i>			
Age	Age of ego less than 30 years	Categorical	72.2
Male	Ego is male	Categorical	61.8
#Working hr	Number of working hours per week	Continuous	12.7
#Child in HH	Number of child (under 18) in the household	Continuous	0.62
Car+License	Having car in the household and the ego has driving license (yes)	Categorical	62.6
New event	Event took place <= 12 months ago	Categorical	38.3
Small SN	Size of close social network < 25 persons	Categorical	38.5
<i>Within level (tie characteristics)</i>			
Age difference	Ego and alter of different age group (yes)	Categorical	42.1
Gender difference	Ego and alter of different gender (yes)	Categorical	52.6
Tie strength: Strong	Relationship strength between ego and alter (strong)	Categorical	44.4
Tie strength: Weak	Relationship strength between ego and alter (weak)	Categorical	18.7
Less known	Alter known for less than two years	Categorical	40.5
Long known	Alter known for more than ten years	Categorical	20.2
Friends or Family	Alter is a friend or a family member	Categorical	75.7
Recently distant	Home locations close before event (<15km away) distant after (>30km away)	Categorical	30.0

5. Social Interaction Dynamics: Face-to-Face Vs ICT

Variables	Description	Type	%
Already distant	Home locations were always distant (>30km away)	Categorical	14.0
F2F frequency before	Face-to-face communication frequency per month before the event	Continuous	10.0
ICT frequency before	ICT communication frequency per month before the event	Continuous	5.83
Endogenous variables			
<i>Between level (person characteristics)</i>			
#Lost ties	Number of ties lost after the event	Continuous	2.39
#New ties	Number of new ties after the event	Continuous	3.40
<i>Within level (tie characteristics)</i>			
F2F frequency after	Face-to-face communication frequency per month after the event	Continuous	9.29
ICT frequency after	ICT communication frequency per month after the event	Continuous	6.86

Young people have the probability of both losing ties and making new ones. The probability of making new ties is, however, stronger. This implies that young people are more responsive to social network dynamics. Males also have a positive probability of making new ties. Working hours and having children in the household both reduce the probability of both the number of lost ties and new ties. This is plausible since having young children in the household and longer working hours pose a restriction on an individual's social activity time.

5.4.2 Effects of Life-cycle Events

The data was designed and pre-selected with a sample that has experienced a major life-cycle event in recent years. It was assumed that the effect of those events would be reflected in social interaction changes. In the initial model, the effect of type of events was controlled. However, those events became insignificant, implying that

the type of events do not have substantial influence on social interaction. Yet, the timing of the event has an effect. If the event is fairly new, the probability of losing ties and making new ties increases. Based on a descriptive analysis, Sharmeen, et al. (2012a) found that right after the event there is a big change in social interaction frequency. This suggests that a change in social network is also probable. Having a small close social network has a negative effect on the number of new ties. This may reflect a preference of people to have a selective social network. They do not make new friends readily.

5.4.3 Effects of Social Network

Social networks are represented at the tie level in the model. For the ego-alter relationship, we considered the difference and similarity in socio-demographics. The model shows that difference in age has a positive effect on face-to-face communication and a negative effect on ICT communication. On the other hand, opposite gender has a negative probability of keeping in touch with ICT mode of communication with each other. Differences in education level do not have any effect perhaps because the distribution is highly skewed for this attribute (Table 5.1). ICT frequency decreases in both newly distant and already distant ties, with already distant ties having a higher coefficient. This implies that distance in general has a negative effect on ICT communication frequency.

Increase in geographical distance with existing ties makes decrease in ICT communication more probable. Previous research has reported similar results (Tillema et al., 2010). In terms of relationship strength, stronger ties have a negative effect on face-to-face frequency and a positive effect on ICT communication, implying a substitution effect. If the tie is strong and because of a lifecycle event the face-to-face contact has become infrequent, individuals might compensate for it by communicating through other modes. Studies on the effect of technology in transportation have shown that people use multiple modes of communication for strong ties (Haythornthwaite, 2005). Thus, plausibility suggests that when face-to-face interaction decreases due to an event, people reach out to other means to keep in touch with strong ties. Long known ties, on the other hand, show an opposite effect, which is counter-intuitive. However, this is after controlling for the effect of tie strength. Similarly, an opposite effect on ICT-contact can be observed for weaker ties and less known ties. Similar effects were found by Haythornthwaite (2005),

who studied the dynamics of ICT. It reports that a change in ICT media makes weak ties more vulnerable. Also, if the tie is friend or family as opposed to neighbours, colleagues and other relations, the probability of ICT communication decreases. To sum up, ICT communication decreases unless the tie is strong and if the tie is between individuals of opposite gender.

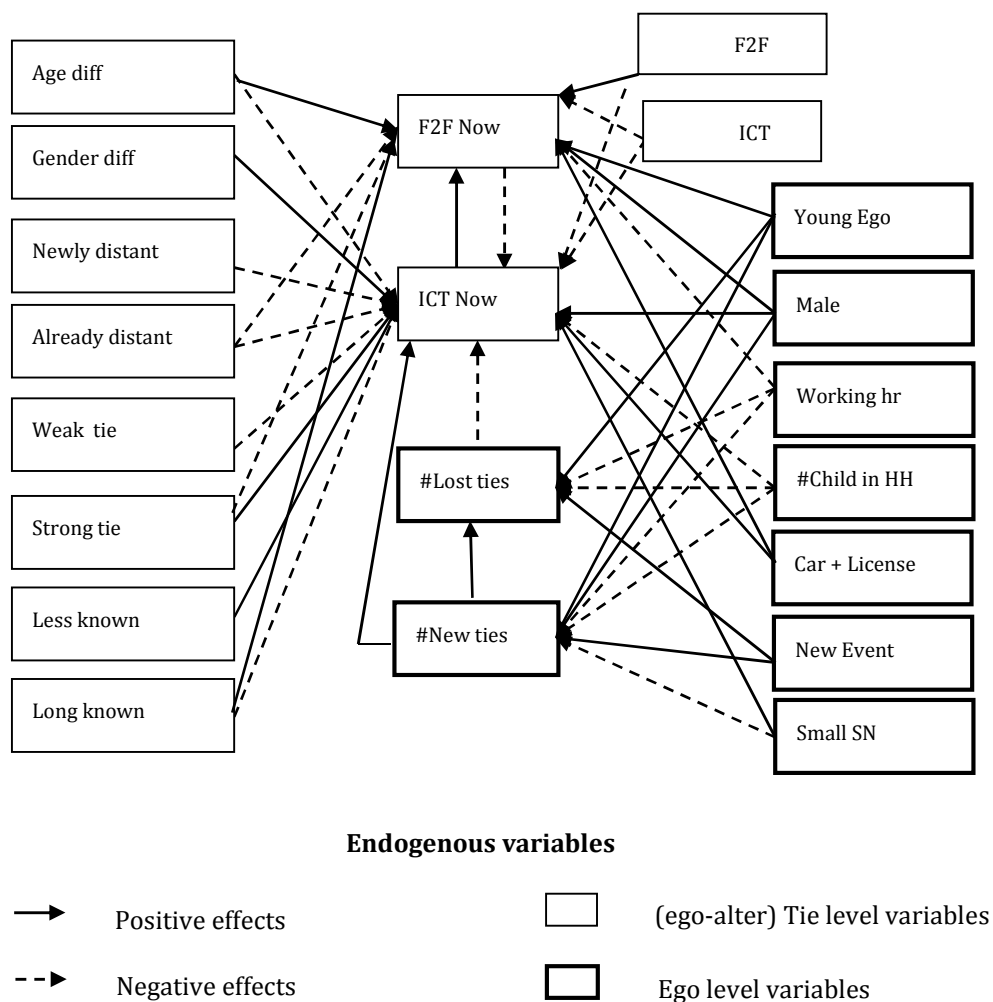


Figure 5.3 Path analysis of social network and social interaction dynamics

Table 5.2: Results from Multilevel Path Analysis

	F2F freq now	ICT freq now	#Lost ties	#New ties
Intercept	8.61*	6.47*	1.25*	1.81*
<i>Between Level</i>				
Exogenous				
Young	2.31*	-0.43	0.71*	1.93*
Male	2.52*	3.18*	0.30	0.65*
Working hour	-0.04***	-0.02	-0.02*	-0.06*
Nr child in HH	0.26	-0.73*	-0.23*	-0.47*
Car + licence	1.55**	1.56**	-0.02	-0.30
New event	1.15	0.93	0.42**	0.61**
Small SN	-0.64	1.60*	-0.31	-1.18*
Endogenous				
#Lost ties	-0.65*	-	-	-
#New ties	0.66*	-	0.36*	-
R ²	0.24	0.20	0.33	0.39
<i>Within Level</i>				
Exogenous				
Age diff	1.36***	-3.44***		
Gender diff	0.58	2.57***		
Newly distant	0.84	-15.19*		
Already distant	-5.14	-28.10*		
Weak tie	2.32	-12.55**		
Strong tie	-25.99*	48.28*		
Less known	-2.84	41.03*		
Long known	9.48*	-17.97*		
Friends or Family	1.30	-39.43*		
F2F freq before	0.90*	-1.00*		
ICT freq before	-0.94*	-0.70*		
Endogenous				
F2F freq now	-	-6.52*		
ICT freq now	4.51*	-		
R ²	0.28	0.22		

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

Goodness of fit statistics:

Chi-square/Degrees of Freedom: 1.14

Root Mean Square Error of Approximation (RMSEA) = 0.012

90 percent confidence interval for RMSEA = (0.011; 0.013)

P value for a test of close fit (RMSEA < 0.05) = 1.00

5.4.4 Path Dependence and the Effects of Network Dynamics

The history of face-to-face communication (variable 'F2F freq before') with the alter has a positive effect on face-to-face interaction and a negative effect on ICT communication. Thus, if the ego had a high number of social meetings with an alter, it still remains high after the event, whereas the ICT communication may go down. On the other hand, history of ICT communication (variable 'ICT freq before') has a negative effect on both face-to-face and ICT communication frequency, implying that if an ego had a high ICT interaction frequency with an alter, both face-to-face and ICT communication decrease after the event. The latter may represent more social-media based ties, though cannot be interpreted conclusively.

Interestingly, the number of new or lost ties does not have an effect on ICT communication frequency. However, the number of lost ties has a negative effect on face-to-face interaction frequency and number of new ties has a positive effect.

These findings imply that if one has more new friends he or she has more social trips. In contrast and quite naturally, if one has more friends that one lost touch with, he or she has less social trips.

5.4.5 Inter-dependencies between Endogenous Variables

We hypothesize that a mutual causal relationship between face-to-face and ICT communication frequency exists. The results are in line with this hypothesis. Face-to-face communication has a negative effect on ICT communication. On the other hand, ICT has a positive effect on face-to-face communication. The results, therefore, comply with existing empirical evidence that ICT has a complementary effect on social trips. In addition, the study provides evidence that face-to-face communication has a substitution effect on ICT. This is probable since face-to-face communication potentially makes ICT communication redundant. However, we do not have information about changes in attitude, availability or use of ICT of the Ego or Alter, which may also have an impact on these results. Furthermore, it is difficult to distinguish between the motives behind the social interactions, whether it is pure socialization or daily interactions or multi-tasking combining with shopping, etc.

However, this is the first attempt investigating effects of life-cycle events on social

interaction dynamics. Further enhancements of the model should be conducted. Given the limitations we have found, some significant effects to accept the hypothesis. Those cannot be taken as definite or conclusive though.

Another important finding is the relationship between number of lost and new ties. Number of lost ties has no effect on number of new ties. In contrast, number of new ties has a positive effect on number of lost ties, implying that the more new ties one makes, the higher the probability of losing a tie. This is plausible since one can maintain a certain number of relationships at a given point of time. Hence, if more new ties are being added to the social network, the probability of losing more of the existing ties becomes higher.

5.5 Conclusion

The purpose of the study was to develop an understanding of the effect of social network dynamics on modes of communication with social network and to test the interdependencies between the communication modes. We investigated the dynamics of interaction between physical and virtual modes of communication in social networks. The results provide a direct input to the dynamics of social travel and activity behaviour. The paper contributes to the understanding of the relationship between the dynamics of social networks and travel. Prior research in transportation research has already examined the relationship between discretionary activity and travel behaviour. This paper has added to this body of literature.

The relationship between face-to-face and ICT contact frequency was found to be of a complementary nature in previous researches. However, in most of the studies, it was found or assumed that ICT use has an effect on face-to-face communication. In this study, we found evidence that the effects could also be in the other direction. In compliance with the contemporary researches, we also found that ICT has a complimentary effect on face-to-face communication. Adding to it, we found that face-to-face communication has a substitution effect on ICT interaction frequency, in a dynamic context.

Moreover, the study provides some important findings regarding the dynamics of social network due to life-cycle events. The most intuitive one is that the number of

new ties has a positive effect on number of old ties. As more and more new members are added to one's personal social network, the loss of existing ties becomes more probable. However, it is to note that the sample is over-represented by young and male population and the event of starting University. There can be potential biases attached to it. In this case, young respondents recorded more changes in social ties and social interaction than that of the older respondents. Perhaps social network at the young age is more prone to changes due to life-cycle events than at the older ages, when personal social network gets more stable. This cannot be conclusively reported and would be subject to further investigation. Nonetheless, this indicates that there might be a threshold size of social networks, which may certainly vary between individuals.

Some measurement errors might have been induced in the data due to conversion of the main dependent variables from categorical indices. The model fits the data effectively but does so at the cost of parsimony. Moreover, data is about egocentric social network and not all ties in each ego's network were included. The population wide application of the model is thus an issue that needs further attention.

Further, the definition of the social interaction did not make a distinction of the motives behind it, i.e. whether for socialization only or combining with other activities, such as shopping, etc. Also, we do not have information about changes in attitude, availability or use of ICT of the Ego or Alter, which may also have an impact on these results. The effects of these attributes are subject to future investigation.

Analysis of social network dynamics and social interaction modes (face-to-face and ICT) is not new. However, linking them with life-cycle events and testing the co-dependencies is a novel addition that the chapter brings. This, we believe, is an emerging field in transportation research in particular. The conceptualization and theoretical understanding is, therefore, befitting. The empirical results are intuitive, yet need further investigation for the purpose of generalization and definite conclusions.

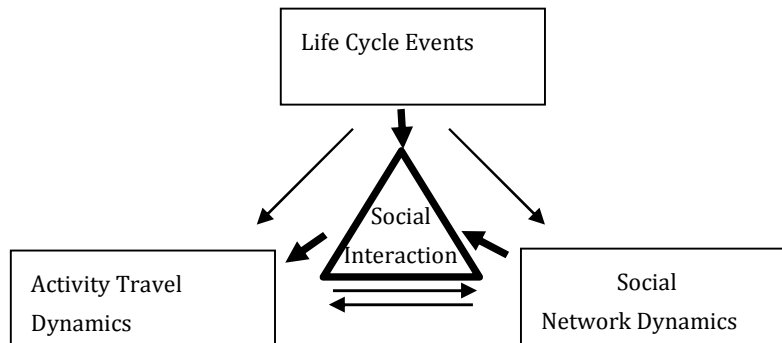
The decision of activity partner is a key factor on other aspects of activity and travel, whether it is location, duration, timing, mode or choice of other partners. All these

decisions are interconnected and dynamic. These aspects are inevitable and pivotal in comprehending travel behaviour and seek considerable attention in advanced travel demand models. Incorporating these issues in a dynamic context would facilitate pragmatic policy formulation and practical applications. The policy makers cannot only better comprehend the social contexts of individuals and households but also how those contexts change affecting their modes of communication and travel. All these issues are interrelated and should be treated as such in order to target the intended audience and to deploy through the proper channel (social media or other means).

6. Social Interaction

Dynamics:

Role of Geography⁴



⁴ Reproduction from Sharmeen, F., Arentze, T. and Timmermans, H. (2014) Dynamics of Face-to-face Social Interaction Frequency: Role of Accessibility, Urbanization, Changes in Geographical Distance and Path Dependence. *Journal of Transport Geography* 34: 211-220.

6.1 Introduction

Social networks are embedded in a spatial setting. People cannot go beyond a certain distance to maintain contacts that are important for their social and emotional needs. Studies on social networks recognize distance in geographical space as a determinant of distance in network links in terms of tie strength between an ego and alters. How far one lives and how far one is willing and is capable to travel for socializing depend on the resources and constraints available to him/her. Studies reveal that more effort and energy is required to maintain contacts with network members living outside a threshold distance (Campbell and Lee, 1992; Gans, 1968).

Several studies in social network and transport studies have looked into the effects of geographical distance and social interaction frequency (Carrasco et al., 2008b; Mok et al., 2010; van den Berg et al., 2009). For long the effects of 'distance decay' and 'community liberated' theories have been studied to reflect distance effects on social interaction patterns. However, these effects of geographical distance again are subject to change in the long term, particularly in response to life cycle events. During the life course people may change their residence and social activity places. Life trajectory events may have an impact on social interaction frequency in one of two ways, depending on the type of event. First, these events may change the geographical distance between ego and alter. For instance, proximity to alters may change after residential relocation. The nature of correlation between the distance in geographical space and tie strength can be modified by life cycle events. The motivation for this investigation stems from this assumption. Second, these events may impose new time and other resource constraints that hinder or facilitate social interaction frequency and network maintenance. Time constraints can partially be compensated by means of information and communication technology. Trade-offs between the modes of interaction were reported in Chapter 5.

In addition to the catalyst of proximity, social activity and meeting frequency can be influenced by the accessibility to and variety of social and recreational facilities. Variety of choices might also partially counterbalance the need of having destination choices at close distances (Handy, 1996). Scholars (Ettema and Schwanen, 2012) contend that opportunities and facilities offered by places are

more important for joint activities. Therefore, inclusion of accessibility indicators to facilities in the analysis would make the model predictions more comprehensive. Studying social interaction and travel frequency in isolation of spatial aspects would only partially explain travel demand. We argue that accessibility and variety of facilities in a neighbourhood and degree of urbanization may play an important role in determining social interaction dynamics. With this view, we explore (face-to-face) social interaction patterns as a function of accessibility indices and degree of urbanization, in this chapter.

In addition, research in joint activity and travel contextualizes and explains other crucial aspects of travel behaviour, such as the unit of measurement. Studies argue that joint activities and interaction should be investigated at the tie level taking dyad characteristics into account instead of ego's socio demographics only (Ettema and Zwartbol, 2013). Furthermore, since social activities are joint in nature, activity and travel parties are likely to have a history of interaction and travel, which may explain the interaction at a certain point of time. Thus, only by incorporating the history of interactions we can fully encompass the frequency of social activity and travel. Therefore, a test of path dependence before and after the life cycle event is also taken into account in this chapter.

Hence, the chapter addresses the following research questions:

1. To what extent are social interaction/activity frequencies path dependent?
2. Does a change in geographical distance with alters influence social interaction/activity frequency?
3. What are the effects of urbanization and accessibility to social/recreational facilities on social interaction/activity frequency?
4. What are the effects of life cycle events on social interaction/activity frequency?

To the best of our knowledge, these aspects are rarely explored in activity and travel behaviour research. To that end, in this chapter, we examine the role of geographical proximity, accessibility and urbanization density on the dynamics in social interaction frequency. Data on accessibility and urbanization density were collected from the Central Bureau of Statistics of the Netherlands.

This study is based on theories of life course, homophily, accessibility and path dependence (discussed in Chapter 2). The actors in social interaction and the theoretical underpinnings are presented in figure 6.1, as conceptualized in this research.

6.2 Survey, Data and Variables

Data in this chapter is again organized according to ties. Therefore cases here are not individuals but ties. Also we re-organized the events into four groups, aggregating the events of starting new job and starting university into one group (group 2). The reorganization was done to define and categorize the events so as to explain their effects on social activity frequency in a structural way. The events are:

1. Events affecting geographical distance with alters: Residential relocation
2. Events affecting mandatory activity and travel: Change in work or study hours per week
3. Events affecting maintenance activity and travel: Children starting school

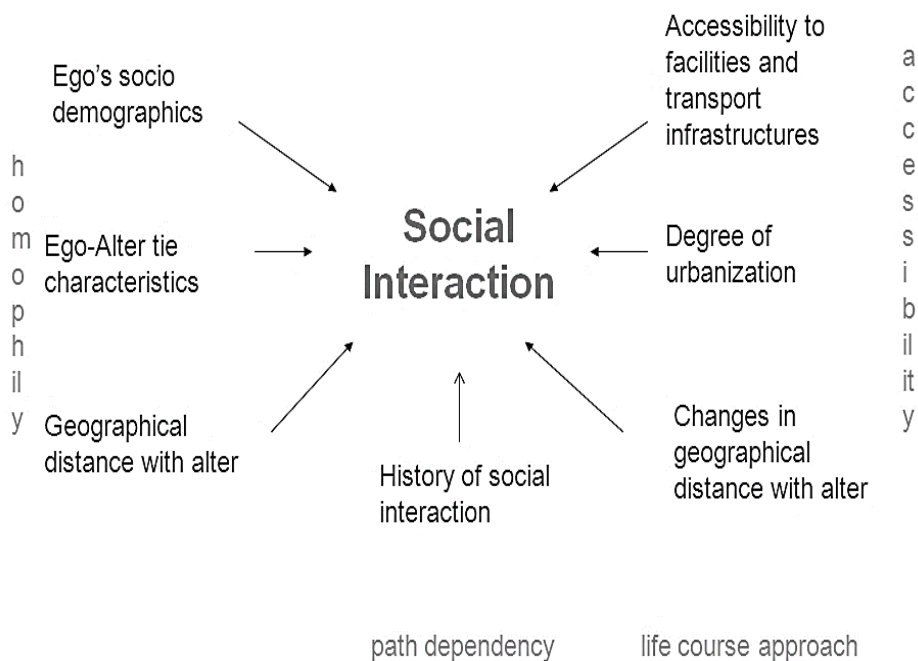


Figure 6.1 Social interaction paradigms

4. Demographic events: Getting married/divorced/cohabitation
In the model the last event (demographic events) was taken as base event type.

Additional information of urbanization and accessibility were collected from two dataset. A second dataset was compiled from the Centre Bureau of Statistics (CBS) Netherlands, to collect information about degree of urbanization and accessibility to social and recreational facilities in the neighbourhood, in the year 2006.

Accessibility is defined by the distance of a certain facility and the quantity of a certain facility within a certain distance (Table 6.1). Those facilities were chosen which may serve as a potential destination of social and recreational activities, such as non-grocery shopping, restaurants, amusement parks, zoo etc. Postcode (4-digit postcode instead of the detailed 6-digit version) was taken as the unit of surrounding neighbourhood to derive accessibility and degree of urbanization. A third dataset was created using open street maps to calculate distance from the city/town/village centre in 2013.

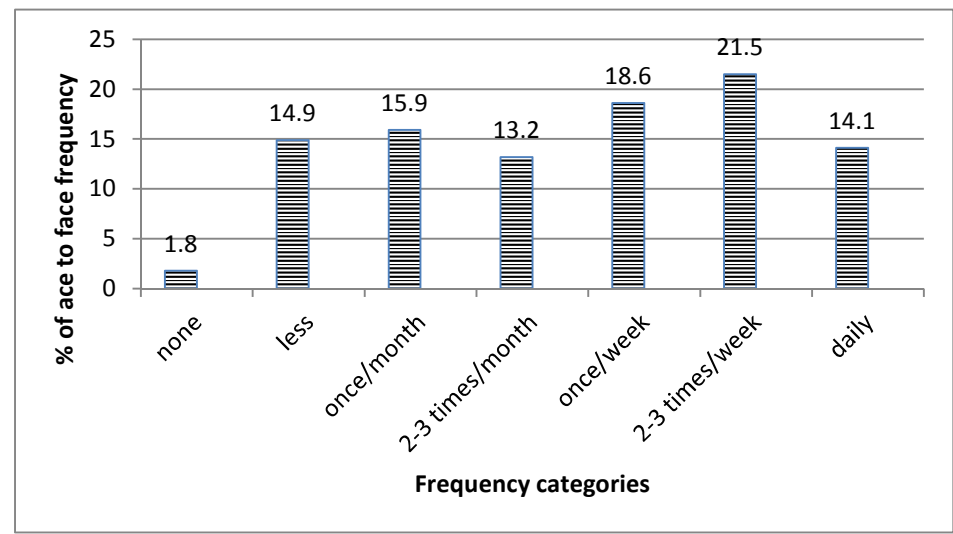


Figure 6.2 Distribution of face-to-face interaction frequency between ego-alter after an event (% of 8458 ties)

A total of 8458 ties are reported that are used in the analysis. In 77% of the cases face-to-face interaction frequency did not change. Sample characteristics are presented in Table 6.1 and the distribution of the dependent variable is shown in figure 6.2. In the survey, the dependent variable (face-to-face interaction frequency after the event) was coded into seven (0 to 6) categories of gradually increasing frequency of social interaction. Distribution of the dependent variable (Figure 6.2) shows that weekly frequencies of face-to-face interactions have the largest share. History of interaction frequency (face-to-face interaction frequency before the event) distribution (presented in table 6.1) is also concentrated in the weekly and monthly categories.

Age and gender distributions are representative of the Dutch population. Two-third of the respondents has a driving license. Almost 42% of the households has young children and 23% does not have any car. Almost 31% of the respondents went through a residential relocation in the past two years. It is important to note that the design of the sample was such that all respondents have gone through one or more major life cycle events in the past two years.

More than half of the tie members belong to the same gender and nearly half of them belong to the same age category. On the other hand only 10% of the ties have the same education level. Relationship strength is medium (rated 2-3 in a five point scale) for 42% of the ties and 39% are reported as friends. In terms of geographical distance, 18% of the tie members live within 1km and 70% of them live within 30km.

In this chapter, we investigate the effects of changes in geographical proximity with alters on the social activities with them. To serve that purpose, two variables were used. One is NOWFAR that categorizes those alters who were within 1 km before the event and more than 1 km after the event. The counter category is NOWCLOSE, which is defined as alters that live within 1 km after the event and was further than 1 km before. Since the focus of this chapter is to investigate the role of geography and accessibility (unlike Chapter 5 where the role of ICT was explored) and since we assumed neighbourhood being a 1 km radius of the neighbourhood, we created these variables consistent to the other neighbourhood accessibility indicators. The fractions in these two categories are really small, around 1-2%. Yet, we included those to test the effects of dynamics in geographical distance with the same alter.

Table 6.1 Sample characteristics (8458 ties)

Explanatory variables	Type of variables	Mean or %
AGE21-30	Categorical	21.60
AGE more than 30	Reference category	78.40
Gender: men	Categorical	53.70
Gender: women	Reference category	46.30
0 car in the HH	Categorical	23.40
1 or more car in the HH	Reference category	76.60
Driving license: yes	Categorical	78.20
Driving license: no	Reference category	21.80
HH with children	Categorical	42.30
HH without children	Categorical	18.60
HH with friends	Categorical	8.30
HH single person and other type	Reference category	30.80
Work hr per week	Continuous	20.80
Size of Social network	Continuous	26.00
# club membership	Continuous	1.40
Event - change in work/study	Categorical	31.70
Event- children start school	Categorical	23.00
Event- change in residence	Categorical	31.10
Demographic event	Reference category	14.20
Event time - 6-12 months	Categorical	23.40
Event time - 0-6 months	Categorical	32.50
Event time - more than 12 months	Reference category	44.10
Same gender	Categorical	60.60
Different gender	Reference category	39.40
Same age group	Categorical	48.60
Different age group	Reference category	51.40
Age difference upto 2 category	Categorical	10.30
Age difference more than 2 category	Reference category	89.70
Same education level	Categorical	10.60
Different education level	Reference category	89.40

Explanatory variables	Type of variables	Mean or %
Education level difference upto 2 category	Categorical	11.40
Education level difference more than 2 category	Reference category	88.60
Relation family	Categorical	24.20
Relation friend	Categorical	39.00
Relation neighbour	Categorical	10.20
Relation colleague and others	Reference category	26.60
Relationship strength weak	Categorical	12.60
Relationship strength medium	Categorical	42.50
Relationship strength strong	Reference category	44.90
Distance 0-1 km	Categorical	18.40
Distance 2-5 km	Categorical	23.20
Distance 6-30 km	Categorical	28.60
Distance more than 30 km	Reference category	29.80
F2F before daily	Categorical	9.500
F2F before weekly	Categorical	31.20
F2F before monthly	Categorical	25.50
F2F before less than monthly	Reference category	33.80
NOWFAR: >1 km now, before<1km	Categorical	1.80
NOWCLOSE: <1 km now, before >1km	Categorical	1.30
Distance to city centre (km) : city, town or the village centre	Continuous	4.27
Distance to train station (km)	Continuous	4.64
Distance to highway (km)	Continuous	1.82
Distance to public green area (km)	Continuous	0.63
# of shopping facilities (non grocery) within 1 km	Continuous	2.74
# of café, restaurants within 1 km	Continuous	21.01
# of public attractions(amusement parks, zoo) within 10km	Continuous	3.68
Suburban area (density between 500-1500 addresses/km2)	Categorical	28.70
Rural area (density less than 500 addresses/km2)	Categorical	37.90
Urban area (density more than 1500 addresses/km2)	Reference category	33.40

Accessibility indicators are considered by means of five variables related to distance and quantity of facilities around ego's residential postcode area. Mean distance to city centre and nearest train station are around 4 km, whereas mean distance to nearest highway is 1.82 km. It can be observed that average distance to highways is much less than distance to railway stations. This is due to the fact that Netherlands is a densely populated country with small numerous relatively small cities and the nearest highway is not that far. Public green areas such as parks, playgrounds and wood are fairly close (0.63km). It is to be noted that in the model all distance variables were converted using natural log transformation. Average number of café/restaurants and non-grocery shopping facilities within 1 km are 21 and 2.74 respectively. On the other hand, average number of public attractions within 10 km is 3.68. Density indicators show that majority of the respondents live in less urbanized areas.

6.3 Methodology

6.3.1 Basic model

An ordered logit model was used to explain social interaction frequency. The basic ordered logit model for the present case can be defined as latent regression model as follows (Greene, 2012):

$$y_{ijt} = \sum_{k=1}^n \beta_{itk} x_{itk} + \varepsilon_{ijt}$$

where,

i = an index for ego.

j = an index for alter.

t = an index of time of observation.

k = an index of explanatory variable.

y_{ijt} = a latent variable of the relationship between ego i and alter j at time t ,

x_{itk} = set of explanatory variables

β_{itk} = the parameters related to the effects of x_{itk}

ε_{ijt} = a random error term that is assumed to follow a logistic distribution across observations.

The observation mechanism results from a complete censoring of the latent dependent variable as follows:

$$\begin{aligned}
 y_{ijt} &= 0 \text{ if } y_{ijt} \leq \mu_0, \\
 &= 1 \text{ if } \mu_0 < y_{ijt} \leq \mu_1, \\
 &= 2 \text{ if } \mu_1 < y_{ijt} \leq \mu_2, \\
 &\dots \\
 &= k \text{ if } y_{ijt} > \mu_{k-1}.
 \end{aligned}$$

The ordered logit model results from the assumption that ε has a standard logistic distribution instead of a standard normal. The model is extended to capture the effects of unobserved heterogeneity (random effects model) and path dependence in the next sections respectively.

6.3.2 Extension 1: Random effects model

The model presents the social activity frequencies between an ego and his/her alters. To capture the unexplained heterogeneity in the interaction frequency between the ego, a random effects model is defined by adding a random error term (α_i) as follows.

$$y_{ijt} = \sum_{k=1}^n \beta_{1itk} x_{1itk} + \sum_{k=1}^n \beta_{2ijtk} x_{2ijtk} + \sum_{k=1}^n \beta_{3itk} x_{3itk} + \alpha_i + \varepsilon_{ijt}$$

x_{1itk} = set of variables explaining socio demographics characteristics of ego i .

β_{1itk} = the parameters related to the effects of x_{1itk}

x_{2ijtk} = set of explanatory variables explaining the tie characteristics between ego i and alter j .

β_{2ijtk} = the parameters related to the effects of x_{2ijtk}

x_{3itk} = set of explanatory variables indicating the density and accessibility features available to ego i .

β_{3itk} = the parameters related to the effects of x_{3itk}

α_i = an error term that explains the variance between egos.

α_i is assumed to be independent with a zero mean and a variance of one. The parameters are added gradually (group-wise) to note the changes in model performance.

6.3.2 Extension 2: Path dependence model

Further, the ordered logit model is extended to include path dependence effects, as follows

$$y_{ijt} = \sum_{k=1}^n \beta_{1itk} x_{1itk} + \sum_{k=1}^n \beta_{2ijtk} x_{2ijtk} + \sum_{k=1}^n \beta_{3itk} x_{3itk} + \sum_{k=1}^n \beta_{2ij(t-1)k} x_{2ij(t-1)k} \\ + y_{ij(t-1)} + \alpha_i + \varepsilon_{it}$$

$y_{ij(t-1)}$ = observed behaviour between ego i and alter j at time $(t-1)$ [before event]

$x_{2ij(t-1)k}$ = set of explanatory variables between ego i and alter j at time $(t-1)$ [before event]

$\beta_{2ij(t-1)k}$ = the parameters related to the effects of $x_{2ij(t-1)k}$

6.4 Results and Discussion

Findings are reported by means of five incrementally hierarchical model specifications. In each hierarchical step, effects of specific indicator variables were added. They were grouped into six categories for interpretation purposes (Table 6.2). In the first step, data were fitted to a pooled model (model 1) with ego's socio demographics (I1), ego-alter tie characteristics (I2) and the life cycle events (I3) variables. Then, it was extended to random effects model (model 2) to capture unexplained heterogeneity in the interaction frequency of ego's by means of a random error term (α_i). The third model was extended by including density and accessibility parameters related to variables in I4. History of social activities and dynamics of geographical distance (I5) with the same alter before and after event was taken into account in model 4. Further, in model 5, interaction among life cycle

events and geographical distance were captured by estimating interaction effects (I6).

Model fit shows a gradual, but significant improvement for subsequent models. In addition to the log likelihood function and chi-square estimates, we also include the Akaike Information Criterion (AIC). The AIC caters for the information loss in model selection. Generally, in modelling practice, model selection uncertainty is ignored. AIC responds to these uncertainties. Since AIC is sensitive to sample size, a relative likelihood measure (Δi) is calculated which is the difference between the minimum AIC and the AIC of the model of concern. This measure provides an estimate of information loss in each step of model selection (Akaike, 1974, 1998; Burnham and Anderson, 2004). In other words, Δi represents the information loss if we choose the model instead of the best model (with the lowest AIC). From the results, we can observe the significant improvement in the models. For data inference, model 1 to 4 perform poorer than model 5. Therefore, we can conclude that model 5 can predict social activity frequency better than the other models. In other words, inclusion of geographical attributes reduces model uncertainty and information loss in predicting social activity frequencies.

6.4.1 Effects of socio demographic characterises of ego (I1)

Young egos between 21 and 30 have a higher social activity frequency than the rest as opposed to the other age groups. Gender, however, do not have significant effects. Having a driver's license increases the level of face-to-face social interactions. Absence of car in the household also has a positive effect, which is counter-intuitive. However, it should be noted that other modal choices such as bicycle and public transport passes could not be taken into account. Negative effects can be observed for both households with and without young children, relative to singles. However, households with children have a comparatively lower coefficient. Size of social network has a negative effect on social activity frequency, indicating that the larger the social network, the lower the level of face-to-face social interaction frequency with ties. The number of club memberships has a positive effect, indicating that involvement in social/recreational clubs increases the probability of frequent social activities.

6.4.2 Effects of ego-alter tie characteristics (I2)

Homophily has a positive effect on social interaction frequency, except for age. When members are of same gender and education level, frequencies increase. However, a negative effect can be observed for members of the same age groups. Weak and medium tie strengths have negative effects compared to strong ties. The level face-to-face interaction frequency is higher for strong ties, as expected. Family, friends and neighbour relationship categories have positive effects on face-to-face interaction frequency, and decrease monotonically. Distance plays a role in face-to-face interaction frequency. We can observe significant higher coefficients for alters living within 1 km. Within 2-5 km and 6-30 km we also observe a positive effect as opposed to distance further than 30 km.

6.4.3 Effects of life cycle events (I3)

Life cycle events become insignificant in the final model. The only significant effect is the effect of residential relocation, which influences face-to-face interaction frequency negatively, implying relocation reduces face-to-face interaction frequency, compared to demographic events (base category). This represents intuitive and rational behavioural patterns. Event timings have negative effects as well, with very recent events (0 to 6 months) having a slightly higher influence. Our early investigation show similar trends (Sharmeen et al., 2012a).

6.4.4 Effects of density and accessibility indicators (I4)

Distance to city/town/village centre can be taken as a proxy of the hub of social cultural facilities. It has a negative effect on face-to-face social interaction frequency implying the further the city centre the less frequent face-to-face social interaction frequency is probable. Number of shopping facilities within 1 km of ego's home positively influences face-to-face social interaction frequency. The opposite is the case for the number of café/restaurants (within 1 km) and attractions (within 10 km), which is counter-intuitive. However, this effect is in addition to the effects of distance to city centre. Distances to transport infrastructures have opposite effects on face-to-face social interaction frequency. Distance to train station has a negative effect, whereas distance to highway has a positive effect.

Table 6.2 Ordered logit model of face-to-face interaction frequency

Dependent variable face-to-face interaction frequency (0=none, 1=less, 2=once a month, 3=2-3 times a month, 4=once a week, 5=2-3 times a week, 6=daily)

	Model 1: Basic model			Model 2: Random effects model			Model 3: Random effects with land use & accessibility indicators			Model 4: Random effects with state dependence			Model 5: Random effects with interaction variables		
	β	t		β	t		β	t		β	t		β	t	
Constant	1.87	***	28.12	2.25	***	29.56	2.34	***	28.98	1.37	***	16.42	1.37	***	15.68
I1: Ego's socio demographics															
AGE21-30	0.32	***	7.62	0.34	***	7.28	0.29	***	6.01	0.35	***	7.10	0.35	***	7.00
Gender: men	0.06	**	2.37	0.01		0.57	0.03		1.29	-0.00		-0.17	-0.00		-0.25
No car	0.04		1.08	0.05		1.61	0.07	*	1.94	0.32	***	8.1	0.32	***	7.91
Driving license: yes	0.06	*	1.83	0.12	***	3.8	0.11	***	3.38	0.16	***	4.55	0.14	***	4.19
HH with children	-0.03		-0.7	-0.14	***	-4.06	-0.16	***	-4.54	-0.09	**	-2.39	-0.08	**	-2.17
HH without children	-0.09	**	-2.38	-0.19	***	-4.62	-0.21	***	-4.88	-0.15	***	-3.78	-0.151	***	-3.67
HH with friends	-0.06		-1.13	-0.05		-0.97	-0.01		-0.26	-0.07		-1.57	-0.08		-1.6
Work hr per week	0.002	***	2.89	0.00	***	2.89	0.00	**	2.49	0.00		1.14	0.00		1.33
Size of Social network	0.004		-1.16	0.00	***	-2.61	0.00	***	-2.94	-0.53	***	-0.63	-0.10	***	-7.45
# club membership	0.05	***	3.33	0.04	**	2.03	0.05	**	2.19	0.08	***	3.49	0.08	***	3.45
I2: Ego-alter tie characteristics															
Same age group	-0.08	***	-3.04	-0.07	***	-3.21	-0.08	***	-3.33	-0.12	***	-4.57	-0.12	***	-4.57

Model 1: Basic model		Model 2: Random effects model		Model 3: Random effects with land use & accessibility indicators		Model 4: Random effects with state dependence		Model 5: Random effects with interaction variables	
		β	t	β	t	β	t	β	t
Same education level		0.08	**	0.14	***	0.14	***	0.22	***
Same gender		0.09	***	0.07	***	0.07	***	0.17	***
Age difference: upto 2 category		0.04	*	1.85	0.04	*	1.83	0.01	0.48
Education level difference: upto 2 category		0.01		0.27	0.01	0.34	0.02	0.53	-0.61
Relation: neighbour		-0.12	**	-2.39	-0.18	***	-4.80	-0.18	***
Relation: friend		-0.18	***	-6.11	-0.25	***	-11.25	-0.26	***
Relation: family		-0.12	***	-3.68	-0.19	***	-6.47	-0.19	***
Relationship strength: weak		-1.02	***	-13.86	-1.05	***	-23.47	-1.06	***
Relationship strength: medium		-0.43	***	-17.34	-0.45	***	-20.16	-0.46	***
Distance: 0-1 km		1.33	***	33.33	1.48	***	47.86	1.47	***
Distance: 2-5 km		0.72	***	22.29	0.75	***	27.72	0.75	***
Distance: 6-30 km		0.57	***	18.49	0.58	***	21.29	0.59	***
I3: Life cycle events									
Event: change in work/study		0.05		1.52	0.01		0.21	-0.01	
Event: children start school		0.10	***	2.7	0.13	**	2.03	0.11	*
Event: change in residence		0.08	***	2.68	0.04		1.26	0.02	
Event time: 6-12 months		-0.10	***	-3.64	-0.14	***	-4.75	-0.14	***
Event time: 0-6 months		-0.09	***	-3.32	-0.09	***	-3.11	-0.09	***

	Model 1: Basic model			Model 2: Random effects model			Model 3: Random effects with land use & accessibility indicators			Model 4: Random effects with state dependence			Model 5: Random effects with interaction variables		
	β	t		β	t		β	t		β	t		β	t	
I4: Density and accessibility indicators															
Distance to city centre (log)				-0.01	-0.11	-0.05		-0.74	-0.01	*	-1.68				
Rural area				0.10	***	0.06	*	1.86	0.06	*	1.92				
Suburban area				-0.02	-0.91	-0.06	*	-1.92	-0.06	*	-1.86				
#Shopping within 1 km				0.02	***	0.02	*	1.7	0.01	*	1.67				
#Café/Restaurant within 1 km				-0.00	***	-0.002	***	-6.63	-0.002	***	-6.53				
#Attractions within 10 km				-0.02	***	-0.02	**	-2.46	-0.02	**	-2.41				
Distance to highway (log)				0.03	*	0.04	*	1.84	0.03	*	1.79				
Distance to train station (log)				-0.03	**	-0.03	*	-1.83	-0.03	*	-1.76				
Distance to public green (log)				-0.02	*	-0.02		-0.54	0.00		-0.62				
I5: History of social interaction and distance															
F2F before: daily				3.33	***			90.28	3.34	***	89.85				
F2F before: weekly				2.20	***			61.45	2.20	***	60.84				
F2F before: monthly				0.81	***			17.47	0.81	***	17.39				
NOWFAR				-0.09				-1.33	-0.43	**	-2.13				
NOWCLOSE				-0.03				-0.67	-0.06		-1.01				
I6: Interaction variables															
Neighbour*change in residence										-0.35	***	-5.07			

Urban densities have varying effect on face-to-face social interaction frequency. For instance, the effects are positive for rural and non-urbanized, but negative for suburban areas. This implies that face-to-face social interaction frequency is higher in rural areas, compared to highly urbanized areas. On the other hand, *ceteris paribus*, face-to-face social interaction frequency is lower in suburban areas compared to densely urbanized places.

6.4.5 Path dependence effects (I5)

A significant increase in model performance is observed after including the path dependence effects. It captures the stability of social ties and regularities in contact frequencies. We observe steadily higher positive coefficients for more frequent interaction history. For example, if the ego and alter used to have face-to-face interactions on a daily basis, they are more likely to interact more frequently. On the other hand the coefficients are significantly lower for monthly interaction history category. The decrease in parameter estimates with decreasing frequency history indicates that more frequent contacts would continue to be more frequent and less would continue likewise. This indicates that face-to-face social interaction frequencies are strongly path dependent.

Changes in geographical proximity were investigated using NOWFAR and NOWCLOSE variables, as explained in section 3. If the alter lived close (within 1 km) before the event and now is located further away after the event, frequency of social interaction decreases. The findings are in line with the argument put forward by previous studies (Degenne and Lebeaux, 2005) that if an ego moves, alters who were already close are more likely to be removed from the social network than those who were already distant. Similar evidence was found in (Sharmeen et al., 2012b) on the effects of two consecutive life cycle events (starting University and residential relocation) on face-to-face interaction frequency of students. The effects are not significant for alters with whom proximity has increased after the event (NOWCLOSE).

6.4.6 Effects of Interactions between life cycle events and proximity dynamics (I6)

In the final group of indicators, we tested the effects of interactions between life cycle events, with geographical proximity and with neighbours. We observe that

change of residence has a negative effect on face-to-face interaction frequency with neighbours. It should be noted that this relates to old neighbours. Therefore, it is plausible that change in residence reduces contact frequency with old neighbours. Effects of both NOWFAR and NOWCLOSE after residential relocation are positive. It should be noted that individual effects of NOWCLOSE were not significant. Yet, if the interaction effects with residential relocation are investigated, significant effects can be noted. This implies that if ties are NOWCLOSE, due to a residential relocation, the level of face-to-face interaction frequency increases. On the other hand, events related to change in work/study hours have a negative effect on NOWCLOSE ties. However, the positive effects of NOWFAR ties with residential relocation are counter-intuitive, when the individual effects (of both residential relocation and NOWFAR) were negative with face-to-face interaction frequency.

6.5 Conclusion

The chapter demonstrates a model of face-to-face social interaction frequency as a function of accessibility, degree of urbanization, and path dependence. It shows that inclusion of local geographical and accessibility indicators and long term dynamics improves model performance.

Social interactions are argued to be a decoupling process to some extent (Carrasco et al., 2008a), since one does not need to be in the same place and time to communicate with each other owing to the growth of virtual ways of communication (e.g. via e-mail, mobile telephone, online social media). However empirical evidence suggest that distance still matters in the maintenance of social networks (Dijst, 2009; Mok et al., 2010). The study contributes to this body of literature by investigating face-to-face social interaction frequency where the geographical features are duly accounted for in a long term dynamic context. The findings imply that urban densities influence social interaction/activity frequency differently. Lower densities have a positive effect, whereas suburban densities have a negative effect relative to highly urbanized areas. Effects of distance to transport infrastructures also vary. Proximity to highways has a negative effect whereas proximity to train stations has a positive effect on social interaction/activity frequency. On the other hand, distance to city centre has a negative effect on social interaction/activity frequency, implying the closer one is to the village/town/city centre the higher their social interaction/activity frequency probabilities are.

Moreover, number of shopping (non-grocery) facilities within one km of ego's residence would influence social interaction/activity frequency positively. However, the quantities of café/restaurants and attraction facilities have a negative effect on social interaction/activity frequency. These factors could contribute in creating sociable cities and cohesive communities, as argued in recent studies (Farber and Li, 2013; Farber et al., 2013).

In terms of the long term dynamics in face-to-face social interactions, one of the chapter's major findings is that social interaction/activity frequency is path dependent. Individuals tend to maintain their social ties with similar frequencies as they did before. However, when life cycle events take place, social preferences, need and aspirations might change or get constrained. The fact that less frequent pre-event meetings have a lower coefficient than more frequent ones implies that they are more likely to change than more frequent ones. Previous studies support the finding that individuals keep the frequency of social interaction with family and stronger ties on a similar level (Sharmeen et al., 2012a). This implies that it is unlikely that ties with whom one meets daily would disappear from the social activity agenda.

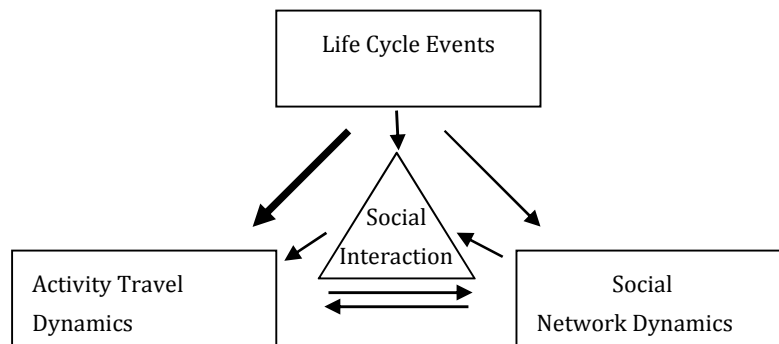
However, changes in geographical distance triggered by life cycle events have significant influence on social interaction frequency. Frequency of contact decreases with ties that become distant after an event. Analysis of the interaction effects of distance changes and life cycle events reveal some interesting results. For instance, ties those are geographically close after an event also explains that social interaction/activity frequency are subject to the type of event. If it is residential relocation, the meeting frequency increases whereas the opposite is the case for events related to a change in work/study hours. The findings add to the long debated body of literature in sociology about distance decay in social relationships (Dennis, 1977; Stewart, 1941). The novel contribution is the inclusion of the effects of changes in geographical distance induced by life cycle events. The findings are consistent with the notion of distance decay.

The thesis adopts the theory of path dependence in the context of individual's activity and travel behaviour. In this chapter, it shows that physical social

interactions (and hence social travel) are path dependent and also influenced by the accessibility to transport infrastructure and facilities that may create opportunities for social interaction. The effects of accessibility and density are quite low and therefore can be argued to be negligible. However, the degree of model improvement shows the importance of including them in predicting social activity and travel. The effects may intensify for particular activities such as shopping and dining out. Therefore, more research on these issues would provide valuable insights on social and recreational demand assessment and spatial planning and budget allocation particular to social and recreational activities.

Some limitations specific to this analysis are worth mentioning. First, the data lack information about the alters, such as for instance their life cycle events, accessibility and density indicators at the alter's home location. These attributes may have an impact on social interaction/activity frequency. Second, there is a discrepancy in the time frame of the three datasets used in the chapter. We assumed negligible changes in accessibility and density indicators in the time interval.

7. Dynamics of Activity and Travel⁵



⁵ Reproduction from Sharmeen, F., Arentze, T. and Timmermans, H. (2013) Incorporating Time Dynamics in Activity-travel Behaviour Analysis: A Path Analysis of Changes in Activity and Travel Time Allocation in Response to Life Cycle Events. *Transportation Research Record: Journal of Transportation Research Board* 2382 (1): 54-62.

7.1 Introduction

In the activity-based research community, it is generally accepted that travel is derived from the organization of daily life in time and space. Individuals and households participate in activities, often at locations other than home. In turn, activity participation reflects underlying needs for productive and reproductive time use. People need to work, wish to relax, need to replenish their food supply, desire to interact with other people, etc. With time these needs change and so does the activity allocation. In an attempt to forecast activity and travel demand, transportation research has focused on modelling these dynamics in the short term, mid-term and long term. The short-term dynamics are more concerned with within day and day-to-day activity-travel behaviour. Contemporary research has covered almost all aspects of activity and travel (mode choice, timing, sequence, duration and activity-travel party) and has shown that they are mostly dependent on household characteristics and available mobility choices (Alexander et al., 2010; Ettema et al., 1995; Habib and Miller, 2008; Schwanen et al., 2007b). There are a number of advanced and operational models to predict short-term dynamics of activity-travel behaviour (Arentze et al., 2006; Horni et al., 2009)

In the long term, lifecycle events have been considered an important trigger of change in activity-travel patterns. Particular life trajectory events such as marriage, birth of a child, job change or residential move may bring the system out of balance, increase stress, and prompt travellers to reconsider their travel options. Life trajectory events may therefore lead to changes in activity-travel schedules and patterns (Verhoeven, 2006; Zimmerman, 1982). These dynamics may apply to all activities and all aspects of travel behaviour. However, only a few aspects have been explored so far, such as mode choice (van der Waerden, 2003), car ownership (Oakil et al., 2011b; Prillwitz et al., 2006), commute distance (Prillwitz et al., 2007) and travel time (Golob, 1990). There are also studies focusing on one particular event and its effects on travel behaviour, such as residential relocation (Scheiner and Holz-Rau) and childbirth (Lanzendorf, 2010). However, to the best of our knowledge, the long-term dynamics of time allocation for different activities and associated travel has been overlooked. There is also limited research incorporating a range of lifecycle events to see the combined dynamics. We stress that it is important to incorporate a number of key events so as to get a comprehensive image of the type

and level of impacts caused by different types of life-trajectory events. The chapter contributes to this end.

7.2 Literature review

A number of studies have investigated different aspects of activity and travel behaviour dynamics and lifecycle events. Most of the studies have focused on one of the travel behaviour indicators with one of the lifecycle events. Some have incorporated several lifecycle events with one of the travel behaviour components. Since the objective of the paper is associated with two key concepts, namely, lifecycle event and activity-travel dynamics, here we will focus on literatures on the association of those only.

Literature on long-term dynamics of activity-travel behaviour can be broadly divided into two parts: studies investigating mode choice or car ownership changes with one or several lifecycle events and studies analysing travel (commute) time changes with one or several lifecycle events.

7.2.1 Lifecycle events and mode choice dynamics

One of the earliest work on lifecycle events was conducted by Lanzendorf (Lanzendorf, 2003). He extended the theory of Salomon and Ben-Akiva (Salomon and Ben-Akiva, 1983) and proposed a mobility biography approach, which says that travel behaviour is habitual and defines three hierarchical domains: a lifestyle domain, an accessibility domain and a mobility domain, within which the interactions occur and travel behaviour is evaluated. Based on the concept Prillwitz, et al. (2006) explain changes in car ownership by changes in life course stages. They show that key lifecycle events have a strong impact on car ownership growth.

Van der Waerden et al. (2003) argued that critical incidents (such as accidents) and lifecycle events may bring disequilibrium in activity-travel repertoires. Such incidents change individual's mode choice and available options. Following that, Verhoeven, et al. (2006) reported effects of life trajectory events on mode choice behaviour using Bayesian Belief Networks. They confirmed that events have an influence in leading to structural decision about mode choice. The study was based on a retrospective survey among 710 respondents, administered in 2004.

A more recent study is conducted by Oakil, et al. (2011b). Using retrospective survey data collected in 2010 in the Netherlands, they estimated a mixed logit model assuming that lifecycle events have a lag and lead effect. Their findings suggest that an increase in car ownership is associated with residential relocation and (anticipated) child-birth event, and a decrease in car ownership is associated with divorce and change in job.

7.2.2 Lifecycle events and commute time changes

There are only a few studies investigating the association of lifecycle events with travel time dynamics. In most cases, commute time changes were investigated with life cycle events. Similar to the car ownership study, Prillwitz, et al. (2007) used mobility biographies to study the influence of key lifecycle events, with a focus on residential relocation and commute distance. Using the German socio-economic panel data they ran descriptive analyses and linear regression models. They used commute distance as an indicator of travel behaviour and concluded that events like marriage and birth of child do not play a significant role in terms of commute distance changes. However, residential relocation has an influence. Commute distance increases when people move from a regional core to a non-core area.

Clark, et al. (2003) investigated the effect of residential relocation and job location on commute distance using the Puget Sound Transportation Panel. The results support rational behaviour of people as they choose to move at places closer to the work location, hence decreasing commuting distance. They also noted that women commute less than men. Using the same panel data, Chen and Chen (2006) show that the built environment affects the response lag of a significant increase. Moreover, their results show that an increase in income will result in a longer response lag, while an increase in the number of vehicles and household size will result in a shorter response lag in time allocation for discretionary activities.

However, the understanding of the long-term dynamics of joined activity and travel time allocation and their interdependencies has largely been overlooked in the empirical studies. To that end, in this chapter, we develop a structural model to explain how activity and travel time allocation change with lifecycle events.

7.3 Conceptual framework

The conceptual framework proceeds with the basic assumption that lifecycle events may bring the daily activity-travel schedule out of balance and may introduce the need for rescheduling and reallocating time for activities and travel. Since the total time budget is fixed, we hypothesize that distribution of daily time is allocated on a priority basis. Time is first allocated to subsistence activities, then to maintenance activities and the remaining to leisure activities. Activities are divided into three broad categories and we define them as follows:

1. Subsistence activities: Work; study
2. Maintenance activities: Daily grocery shopping; picking up/dropping off people/goods; visit to pharmacy/barber shop/post office/dry cleaning, etc.
3. Leisure activities: Non-daily shopping; dining out in restaurant/café/bar; going to movies/theatre/concert; visiting family and friends; organizing/attending parties; going to park/nature; sport activities; social club or community activities.

The concept is displayed in Figure 7.1. The elements in the box represent activity travel behaviour at a specific point of time or life stage. However, when an important lifecycle event occurs, this whole scheduling process may need to be re-shuffled. In this regard, we categorize the events as well which may have an impact on particular sets of activities. Not all lifecycle events should influence all types of activity and travel, we assume. The level and intensity of the effect on the time allocation should differ as well. Henceforth, we hypothesize that:

H1: Events with direct components related to subsistence activities (such as, starting new job or education) directly affect time allocation on subsistence activities.

H2: Events with components related to the entire household (such as, moving house, children starting school) directly affect the time allocation between subsistence and maintenance activities.

H3: Events with high potential influence on personal social networks (such as getting married/cohabitation) directly affect the time allocation in maintenance and leisure activities.

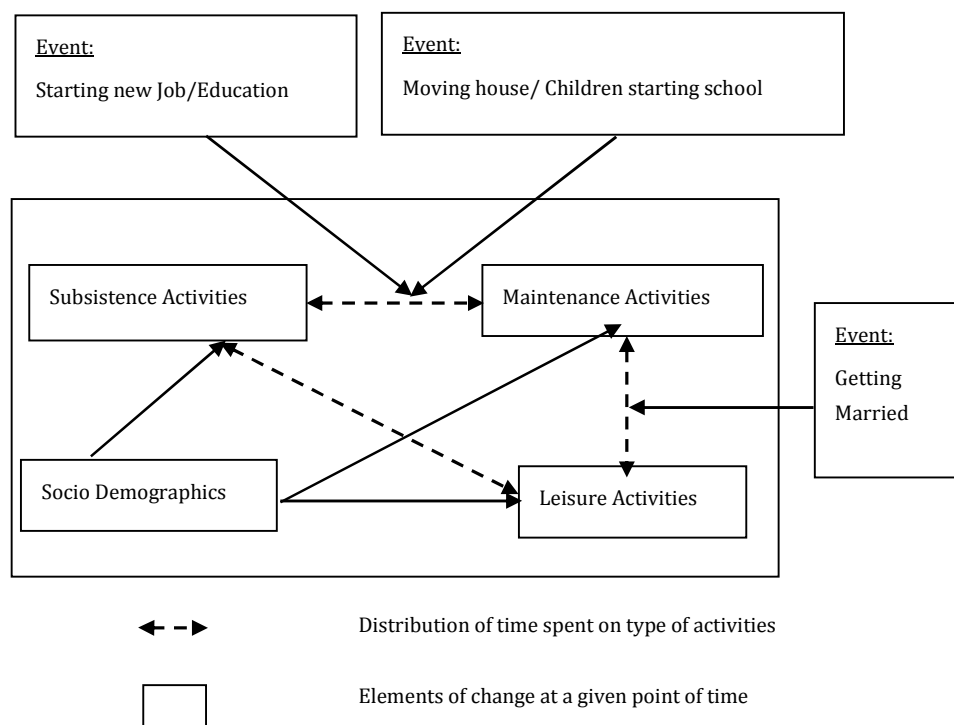


Figure 7.1 Conceptual framework of dynamic distribution of time spent on activities

7.4 Data and methodology

In this chapter, we analyse part of the data collected in part three of the questionnaire. The (translated) phrasing of the question was as follows:

‘In the next question we want to know about your activities and travel before and after the (specified) event. Please mention which activities you perform and how you travel in a typical week. Think of your last regular (non-holiday) week when you answer the following questions. Some activities you might do on weekends (e.g. visiting friends / relatives, outdoor recreation). Please mention them as well. If an activity or trip is not applicable to you then please select "not applicable." for that specific activity/trip.’

Table 7.1 Sample Characteristics (mean of 632 cases)

Variable	Definition	Type	Unit	Value
Exogenous Variables				
Socio-Demographics				
Age	Age (years)	Continuous	n	34.74
Male	Gender (male)	Categorical 1 if true, 0 if not	%	53.10
#HHmember	Number of household member	Continuous	n	3.21
#child	Number of child in the household	Continuous	n	1.04
Working	Working (yes)	Categorical 1 if true, 0 if not	%	67.20
Studying	Studying (yes)	Categorical 1 if true, 0 if not	%	18.80
Driving License	Driving License (yes)	Categorical 1 if true, 0 if not	%	78.50
#car	Number of cars	Continuous	n	1.04
Have car always	Car available always (yes)	Categorical 1 if true, 0 if not	%	57.20
Lifecycle Events				
Event: New Job	Event: Starting new job	Categorical 1 if true, 0 if not	%	23.40
Event: Start University	Event: Starting University	Categorical 1 if true, 0 if not	%	11.00
Event: Child Starts School	Event: Children starting school	Categorical 1 if true, 0 if not	%	23.80
Event: Relocation	Event: Residential relocation	Categorical 1 if true, 0 if not	%	20.80
Event: Wedding	Event: Getting married/separated/divorced/cohabitation	Categorical 1 if true, 0 if not	%	21.00
Endogenous variables				
Social Network Size	Size of social network	Continuous	n	28.53
Activity-Travel time allocation variables (dynamics)				
AT: Subsistence	Change in subsistence activity time (AT)	Continuous	n	0.40

Variable	Definition	Type	Unit	Value
AT: Maintenance	Change in maintenance activity time (AT)	Continuous	n	0.36
AT: Leisure	Change in leisure activity time (AT)	Continuous	n	0.48
TT: Subsistence	Change in subsistence travel time (TT)	Continuous	n	1.46
TT: Maintenance	Change in maintenance travel time (TT)	Continuous	n	1.42
TT: Leisure	Change in leisure travel time (TT)	Continuous	n	1.48

The respondents then had to complete a table. The rows showed the activities, while the columns provided details of the activities (number of activity per week, average activity duration, company of activity, travel mode and average travel time per mode). For each activity, two rows were assigned: one for before the event and one for after the event (present day). If nothing has changed for an activity, then respondents were asked to keep the latter row for each activity blank.

In this chapter, we focus on the changes in activity and travel time allocation for the activity categories mentioned in section 7.3. We calculated the changes in activity time before and after the event. To calculate travel time, we multiplied trip duration per mode with the number of times that the mode was used per week for that specific activity. If multiple modes were used, we added all the travel times together to obtain the total travel time for one specific activity per week. Then, we calculated changes in travel time before and after the event for each specific activity.

Finally, we consolidated the activity types according to the categories mentioned in section 7.3. Here, we consider only out-of-home activities and the unit is hours per week. Table 7.1 represents the characteristics of the sample (632 cases, excluding missing values) used in the study. Respondents also gave an estimate of the size of their present social network, which was included in the study as an endogenous variable.

As mentioned above, the objective of this chapter is to explore the relationships between socio-demographics and lifecycle events with the dynamics in time allocation of activity and travel and the size of the social network. The second set of variables is endogenous (changes in activity-travel time allocation and social

network size) and assumed to have some sort of interdependencies among each other. Please note that while the activity-travel variables were calculated as changes, social-network size was presented as a static variable and represents the present social network (i.e. after the event). Although size of social network is a static variable, we believe that the variable is important to consider and was taken as a context variable to give an overview of the social commitments of the respondent.

It should also be noted that since the activity and travel times are adopted as (positive or negative) changes relative to the before-event situation, the effects of independent variables, which we estimate in this framework, should be interpreted as effects on a response to the event. Structural Equation Modelling is a powerful technique to effectively handle these relationships as it can effectively capture the causal influences of the exogenous variables on the endogenous variables and the endogenous variables on each other (Golob, 2003). Since all of them are observed variables, we developed a structural model (path analysis).

7.5 Analysis and results

The results of path analysis using LISREL are discussed in this section. The objective was to examine the relationships between changes in activity and travel time allocation (for subsistence, maintenance and leisure activities before and after event) with type of event and socio-demographic characteristics. We followed the network structure as mentioned in the conceptual framework. Based on the modification indices, we modified the final model and removed those relationships that were not significant at the 0.1 significance level.

Figure 7.2 shows the structure of the final model. Since the activity categories are endogenous, we also look into their interdependencies. Table 7.2 presents the results. The interpretation of the results is organized in four sub-sections below. At first the influence of exogenous variables on endogenous variables (Figure 7.2) is described followed by a discussion on the effect of endogenous variables on each other (Figure 7.3).

A number of measures are employed to assess the goodness-of-fit in SEM. One is

the Akaike Information Criteria (AIC) which compares the Maximum Likelihood estimation goodness-of-fit and the parsimony of the model (Akaike, 1981). A good fit is when the model AIC and saturated AIC are close to each other. Another is that the Normed Fit Index (NFI) should be close to 1. Another indicator is the value of Chi-square divided by the degree of freedom, which should be less than 2. Also the Root Mean Square Error of Approximation (RMSEA) should be less than 0.05 (Golob, 2003; Washington et al., 2009). The goodness-of-fit measures are presented at the bottom of Table 7.2 and suggest the model is acceptable. The reduced R-squares show that the explanatory power of the exogenous variables is only modest, especially for the social network size and maintenance activity time. Since the study is focused on time allocation dynamics, the exogenous variables explain little about the size of the social network. The values are larger for leisure activity and travel time dynamics, which indicates their flexibility. The low values for the other activity categories indicate that there are other important variables that need to be considered for explaining those. For instance, similar data of partner's agenda can be an important contribution to understand inter-household arrangement of maintenance activities.

7.5.1 Socio-demographics and activity-travel dynamics

First, let us discuss about the effect of socio-demographic characteristics with changes in activity and travel time allocation. We observe that age has a positive association with changes in leisure activities (both activity time and leisure time). With growing age the time spent on leisure activities in response to an event increases. Professions like working and studying have a positive effect on changes in activity time for subsistence activities. Number of household members has a positive effect on changes in leisure activity time whereas the effect on changes in leisure travel time is negative. In contrast, number of children has a negative effect on change in leisure activity time and a positive effect on change in leisure travel time.

Change in time spent on leisure activities decreases for households with more children whereas change in the time spent on leisure travel increases. Perhaps households with children after the event go on longer leisure trips and reduce the activity time spent on leisure to compensate for this. Interesting effects can be seen

in the activity and travel (commute) time changes for subsistence activities with number of children in the household. People with more children tend to work and commute less in response to the event.

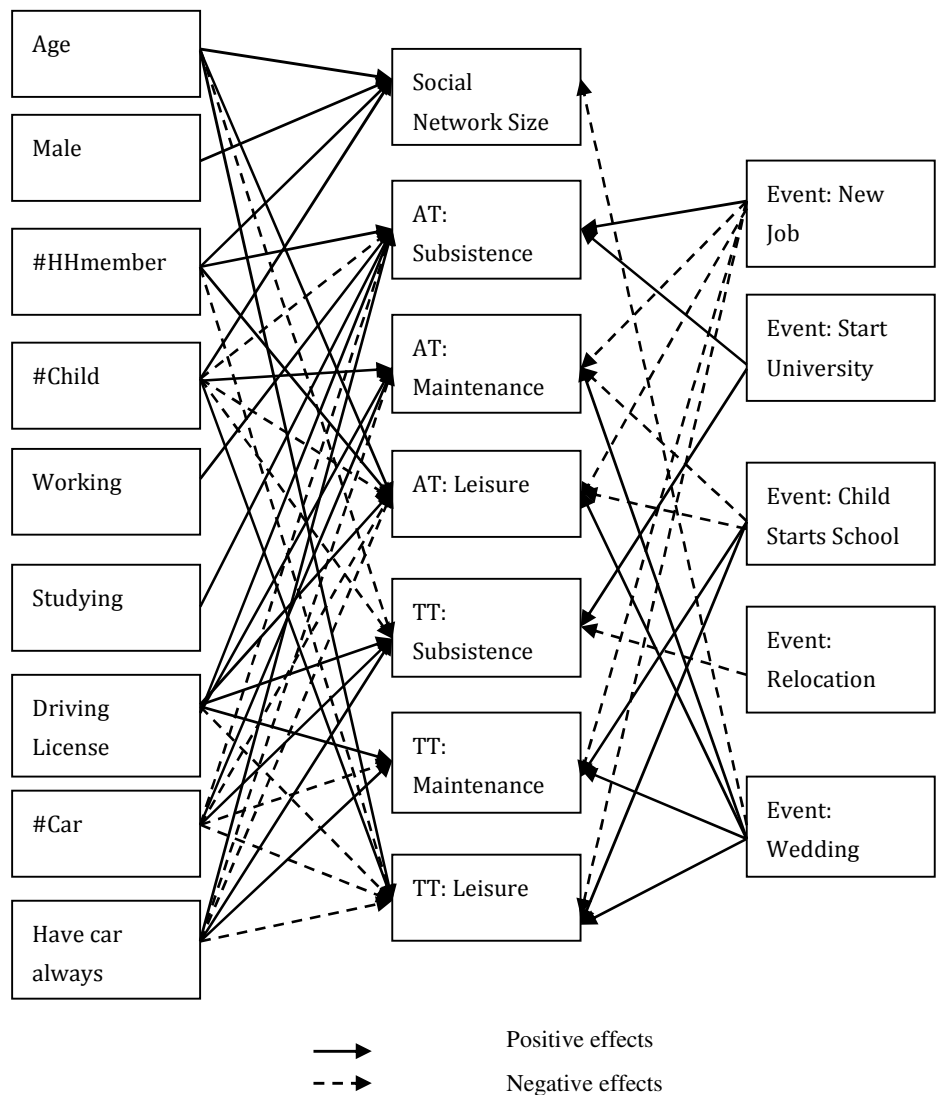


Figure 7.2 Effects of exogenous variables on endogenous variables

Change in leisure travel time also decreases with all transport mode availability (driving license, car always available and the number of cars in the household) variables. Variables like, households with more car, people with driving license and car always available have a negative influence on changes in leisure travel and activity time. Only a positive effect is seen with possession of driving license and leisure activity time. Moreover, car availability (always) has a positive association with time spent on subsistence activities after the event. On the other hand, change in subsistence activity time is influenced negatively by number of cars available in the household. Moreover, availability of car (always) has a negative effect on change in maintenance activity time but a positive effect on change in maintenance travel time. An opposite effect can be observed for the number of cars in the household.

7.5.2 Social network size

The size of personal social network was included in the study as an endogenous variable also depending on socio-demographics and lifecycle events. We observe that age has a positive association with the size of social network. Number of household members and number of children in the household have a positive effect on the size of social network. Interestingly, the event of getting married, divorced, separated or starting cohabitation has a negative effect on the size of social network after the event. Other types of event do not have an impact on social network size.

The size of social network has a positive influence on the change in leisure activity time, which is somewhat expected. Empirical evidences show that size of social network and social/recreational activity duration are positively related (Tilahun and Levinson, 2010a; van den Berg et al., 2012b). Thus it can be expected that the rescheduling needs would be higher as well. It also has a positive impact on change in travel time for maintenance activities. However, it has a negative impact on change of activity time for maintenance activities.

7.5.3 Type of lifecycle events and activity travel dynamics

Type of event has varied and significant impacts on time allocation dynamics of activity and associated travel. The impacts are consistent and logical. Getting a new job increases subsistence activity time and reduces maintenance and leisure activity time. However, travel time for leisure and maintenance activities increases. Starting at the University for higher education increases both activity and travel

time for subsistence activities. The travel time increase can be explained by the fact that Netherlands is a small country with practically free public transport for students. Therefore, they can still live with parents and commuting to attend the university is a common practice among the young population (Sa et al., 2004; Shirom, 1986). Hence, hypothesis one (H1) is consistent with the results that events associated with subsistence activities would affect time allocation on subsistence activity and travel. In addition, we observe some effects on leisure and maintenance activities. The event of children of the household starting school reduces time spent on leisure and maintenance activities. Similar to the effect of number of children variable, it is observed that travel time to leisure activities increases. This might also incorporate the seasonal effect of leisure travel.

In general, in Netherlands (and most of the European countries) households with children enjoy long holidays and leisure activities during summer vacation of schools. They plan their holidays of the year around the summer months. The data here represents activities in a typical week before and after the event and was collected in September. The results show that residential relocation decreases travel time for subsistence activity. This can be explained by the fact that most of time people relocate to places closer to their work places to reduce commute time (Clark et al., 2003). The event does not have significant effect on other activity travel dynamics. Thus, the second hypothesis (H2) is consistent, which was that events related to big changes for the entire household will affect the time allocation between subsistence and maintenance activities. There are some effects on leisure activity and travel time allocation as well.

The event starting cohabitation or getting married/separated/divorced increases both activity and travel time for leisure and maintenance activities. This is in support of the hypothesis three (H3) that events with potential significant impact on social network, affect maintenance and leisure activity (and travel) time allocation. Perhaps because people go on leisure trips and social events more after they got married or started cohabitation. Similarly, new households may have new maintenance activities. Empirical evidence shows that newly married couples without responsibility of children spend more than 5 hours per week on out-of-home recreation, which is higher than for other family lifecycles, except bachelors

Table 7.2 Results from Path Analysis of Time Allocation Dynamics of Activities and Associated Travel

	Change in Activity Time (AT)			Change in Travel Time (TT)			Social Network Size
	Subsistence	Maintenance	Leisure	Subsistence	Maintenance	Leisure	
Age			0.01	-2.17		0.03	0.03
Male							4.42
Working	0.14						
Studying	1.12						
#HHmember	0.94		2.10			-1.19	0.45
#child	-0.83	0.13	-1.42	-1.81		4.06	2.02
Driving License	0.50	0.66	0.36	0.57	0.06	-1.16	
Have car always	0.02	-1.09	-0.27	0.61	0.16	-3.37	
#car	-0.20	0.07	-2.77	0.57	-0.18	-3.43	
Event: New Job	0.44	-0.66	-1.03		0.24	1.72	
Event: Start University	1.74			2.53			
Event: Child Starts School		-0.77	-1.21		0.12	1.51	
Event: Relocation				-0.55			
Event: Wedding		0.77	1.15		0.34	2.18	-8.96
AT:Subsistence		0.24	0.19				
AT:Maintenance	-0.17			0.17			
AT:Leisure		1.96				0.06	
TT:Subsistence	0.11						
TT:Maintenance	0.02			0.05			
TT:Leisure	-0.92		0.04	-0.08	3.69		
Social Network Size		-0.09	0.10		0.41		
R²	0.05	0.01	0.35	0.05	0.03	0.30	0.01
R² reduced form	0.05	0.01	0.30	0.03	0.03	0.30	0.01

Goodness of Fit Statistics
Degrees of Freedom = 47
Minimum Fit Function Chi-Square = 49.16 (P = 0.39)
Chi Square/Degree of Freedom = 1.04595
Root Mean Square Error of Approximation (RMSEA) = 0.0084
90 Percent Confidence Interval for RMSEA = (0.0 ; 0.028)
Model AIC = 459.04
Saturated AIC = 462.00
Normed Fit Index (NFI) = 0.99

(Landon and Locander, 1979). Maintenance activities may increase after separation or divorce since the partner is no longer around to help out. Moreover, singles might also have more time at hand. The event has no significant effect on subsistence activity dynamics, which is as expected.

7.5.4 Interdependencies between activity and travel dynamics

In this section, we will discuss activity and travel interdependencies among the activity categories (Figure 7.3). We started with the assumption that people prioritize subsistence activities first, maintenance activities second (if any) and leisure activities next and schedule them accordingly. So if there is any change in time budget, first they would allocate the time to subsistence activities and then to maintenance and leisure activities respectively. This assumption is based on the flexibilities associated with each type of activity. This would imply a one-way link from subsistence activity to other activity categories. However, the results do not necessarily confirm the activity-priority assumption. Hence, we gradually tested all possible links and finalized the model by removing those relationships that were not significant at the 0.1 significance level.

First, we will report the interdependencies between activity time dynamics, next we will focus on travel time dynamics, followed by inter-relations between activity and travel time dynamics. Finally, we will discuss the indirect effects between activity and travel time dynamics.

When an event takes place, the allocations of activity and travel time may need to be adjusted to fit the new routines. We assume that activity time allocation for the

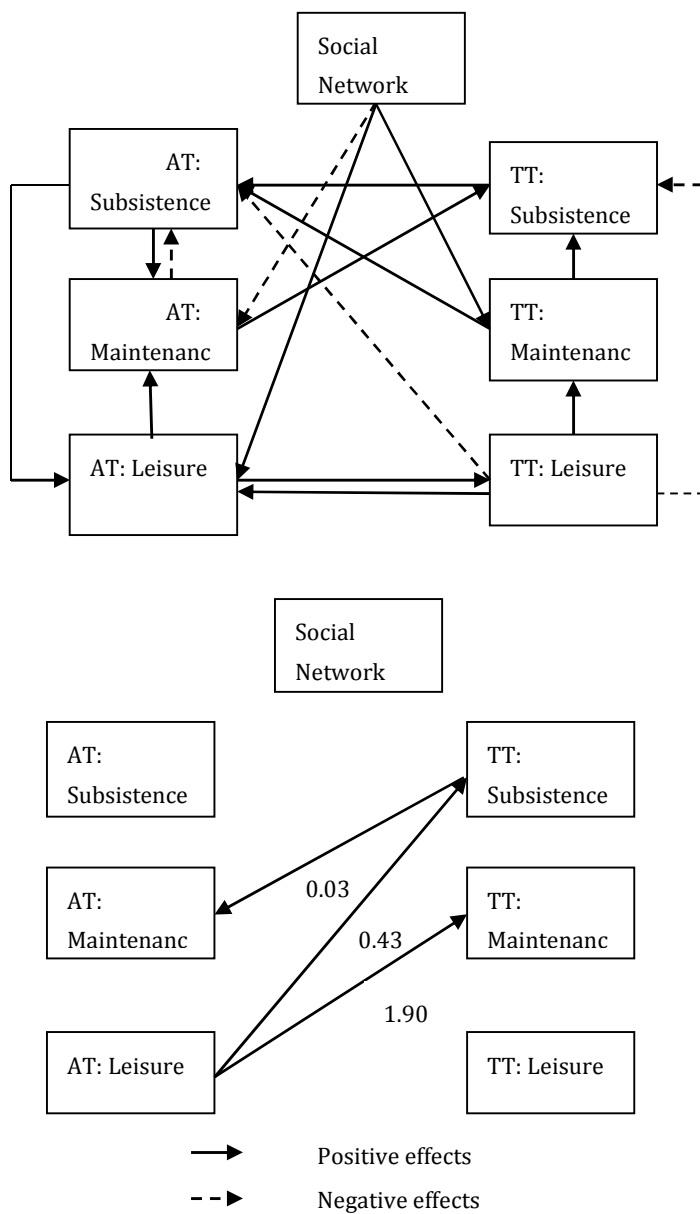


Figure 7.3 Interdependencies among endogenous variables, direct effects - top, indirect effects - bottom

for indirect analysis only significant ($p > .05$) effects are reported

concerned three types of activities will change and any change in one would affect the others. The findings suggest that changes in subsistence activity time positively relate to changes in time allocation of maintenance and leisure activities. On the other hand, changes in maintenance activities have a negative relation with changes in subsistence activities. Leisure activity time dynamics has a positive relation with the dynamics of maintenance activity. A change in leisure travel time is negatively associated with changes in travel time of subsistence activities and positively with changes in travel time of maintenance activities. Moreover, changes in maintenance travel time have a positive effect on changes in travel time of subsistence activities.

In terms of interdependencies between activity time and travel time, we observe a mutual effect for leisure activities. A change in leisure travel time is positively associated with changes in leisure activity time and vice versa. For subsistence activities, travel time dynamics have a positive effect on activity time dynamics. Levinson (Levinson, 2009) found relations in the other direction: activity duration has a strong positive effect on travel duration, in general. However, the study did not account for dynamics.

There are some cross-over relationships as well between activity time of one and travel of another and vice versa. Notably, the changes in maintenance activity time have a positive relation with changes in travel time for subsistence activities and changes in maintenance travel time have a positive relation with changes in activity time for subsistence activities. Hence, maintenance activity and travel time dynamics have a positive influence on dynamics of subsistence activities. In the other direction (i.e. from subsistence to maintenance), some indirect effects are found reported in the next section. Changes in activity time of subsistence activities are also negatively influenced by leisure travel time changes.

An analysis of indirect effects of the endogenous variables shows additional cross-over relationships (Figure 7.3). Results suggest that changes in leisure travel time indirectly and positively affect changes in both subsistence and maintenance travel times. Also, we observe an indirect positive effect from changes in travel time of subsistence activities to changes in maintenance activity time.

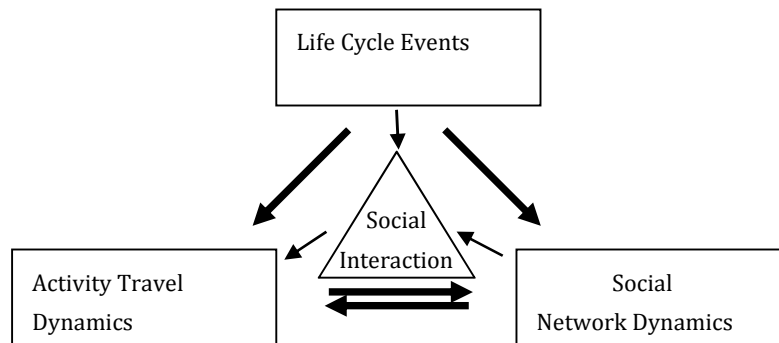
7.6 Conclusion

The aim of the chapter was to determine the relationships between lifecycle events and dynamics of time allocation to activity and travel. By developing a structural model, we analysed the effect of several lifecycle events on changes in activity and travel time allocation. The results support the arguments presented in the paper. We observe significant impacts of lifecycle events on time allocations. Moreover, the effects are varied and differ according to the type of event in existence, intensity and direction.

The findings by and large support the three formulated hypotheses regarding lifecycle events and activity travel dynamics. Events related to subsistence activities, such as new job and starting university, affect time allocation to subsistence activities. Events related to big household changes, such as residential relocation and children starting school, influence time allocation to maintenance and leisure activity-travel. Events related to changes in civil status, which potentially changes the social network size and composition, such as, getting married/separated/divorced/co-habitation, influence the time allocation to maintenance and leisure activities. We also have found evidence that all events affect time allocation to leisure activities in varying intensity and direction. This is most likely because leisure activities are the most flexible and discretionary of all. However, this finding also acts as an indicator that lifecycle events are associated with social networks since they are key in most leisure activity planning. Any change in leisure activity time allocation potentially means change in the type and pattern of maintenance of social networks, which in turn affects their size and composition. Consequently, dynamics of social networks are associated with dynamics of activity travel behaviour.

There were some missing issues (key events such as child birth and details of residential moves) in the analysis. This was primarily due to lack of data. We acknowledge that situational changes may have occurred during the after-event period that are not recorded and hence could not be included in the analysis. Moreover, details on dynamics of other aspects of activity and travel (mode choice, activity-travel party) should be included in a comprehensive model. This remains for the future agenda.

8. Linking the Dynamics of Social Networks and Activity Travel⁶



⁶ Reproduction from Sharmeen, F., Arentze, T. and Timmermans, H. (2014) An Analysis of the Dynamics of Activity and Travel Needs in Response to Social Network and Life-Cycle Dynamics: A Structural Equation Model. *Transportation Research Part A: Policy and Practice* 59 (1): 159-171.

8.1 Introduction

The activity-based approach to travel modelling 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 behaviour 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 modelling. 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 behaviour 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 (Nijland et al., 2009; Srinivasan and Athuru, 2005). The intra-household joint decision dynamics are also reported to be dependent on socio-demographic characteristics and car availability (Habib et al., 2008; Schwanen et al., 2007a). Another stream of studies focuses on the life cycle events and how they are interdependent triggering travel choices, such as car ownership (Oakil et al., 2011b; Verhoeven et al., 2006) and activity and travel duration dynamics (Sharmeen et al., 2013). Further studies focused on the relationship between social network and activity and travel behaviour (Axhausen, 2005; Carrasco and Habib, 2009; Dugundji and Gulyás, 2008; 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 (Ettema and Kwan, 2010; 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 behaviour). 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 chapter 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 chapters, we argued that social networks are dynamic and developed the conceptual framework.

Later the dynamics of social interaction and the dynamics of activity-travel behaviour 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.

8.2 Concept and methodology

The concept is defined in Chapter 2 (section 2.6) with three parallel phenomena: namely, life cycle events, social networks and activity-travel behaviour. All three of them are interdependent. Any change in one could result in change in the other two or any one of them. For instance, the event of 'getting married' could mean that the spouse's (partial) social network is now included, resulting in a change in social network and could eventually lead to a changed activity-travel behaviour. On the other hand, new activity-travel behaviour, such as joining a new gym or club may possibly result in a change in social networks and so on.

Moreover, we assume 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.

A Structural Equation Model (SEM) was developed in this study, based on the concept presented in Chapter 2 (Figure 2.2). A complete SEM (details in Chapter 5) 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.

8.3 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 8.1 and 8.2 show the exogenous and endogenous components of the final model respectively. Table 8.1 presents the measurement model (composition of latent constructs) and Table 8.2 presents the structural model. The interpretation of the results is organized in four sub-sections below. First, the influence of exogenous variables on endogenous variables is described, followed by a discussion of the effects 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 8.1, 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.

Table 8.1 Measurement model of activity and travel needs before and after life cycle events

	Indicator variable	Latent Variable	Parameter estimate
Variables measuring <u>present</u> 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 <u>present</u> 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
Variables measuring <u>previous</u> 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 <u>previous</u> 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

Trips associated with social purposes have a considerably stronger relationship with the concept than recreational and maintenance activity related travel. The measurement relationships of the indicators do not differ significantly between the previous and present case of activity needs and travel needs, which is as expected given that the concepts are the same.

8.2.1 Effects of socio-demographics

The structural-equation model estimation results are presented in Table 8.2. 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 losing ties and more likely to make new ties when a life cycle event occurs. Young adults (age 21-40) have larger change in activity needs in response to an event. They are more likely to lose 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.

8.2.2 Effects of life cycle events

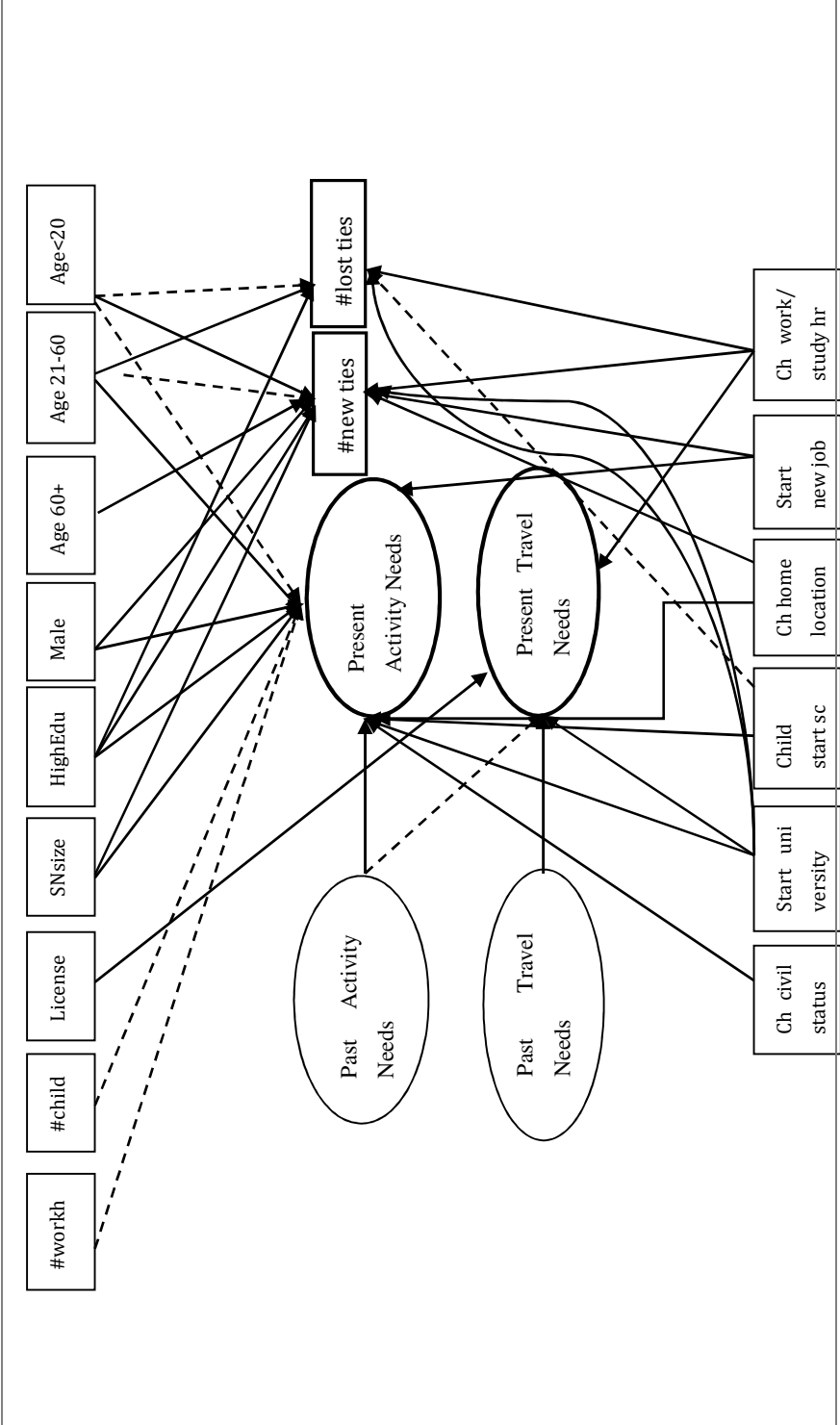
The effects of life cycle events on activity and travel needs were investigated by means of six observed variables. Those are change in home location, change in

work/study hour, change in civil status (living together, getting married, separated or divorced), children of the household starting school, respondent starting new job and respondent starting university education. Results show that all these variables 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 these events, starting university has the strongest effect. The size of effects of other events is fairly similar. In terms of travel needs, significant positive effects are found for two life cycle events, namely, change in work/study hours and respondent starting university education. Among these, the latter has the strongest positive effect.

Life cycle events also have a substantial effect on social network dynamics. The number of lost ties increases when a change in work/study hours occurs 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. An explanation may be 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 and seems to be the most significant event in terms of social network dynamics. It suggests that people make new friends but also lose 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 bonds as well as separation under the same variable. Thus, the individual effects may have been compromised.



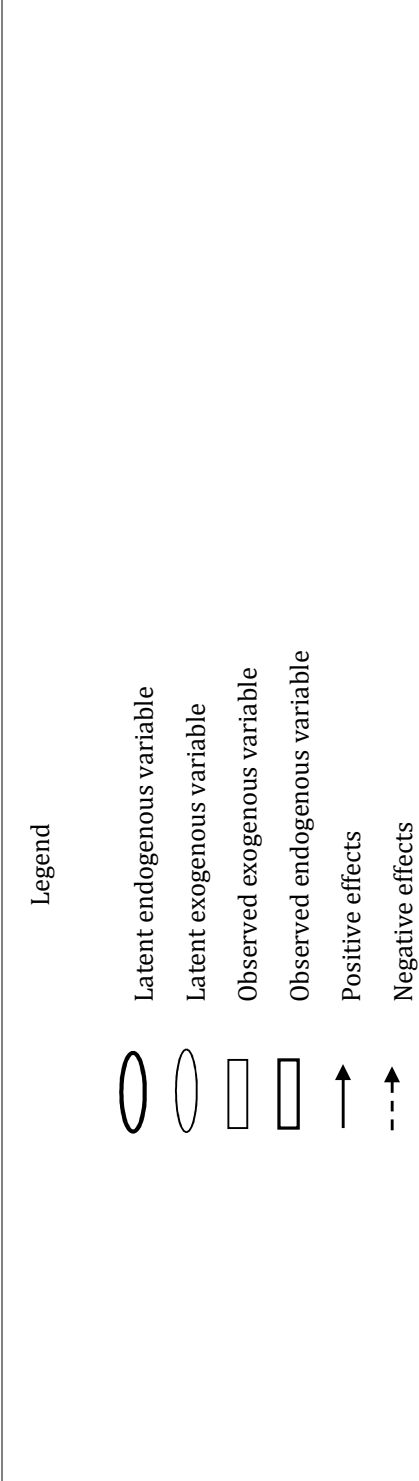


Figure 8.1 Structural model of dynamics of social network, life cycle events and activity-travel needs (Exogenous effects)

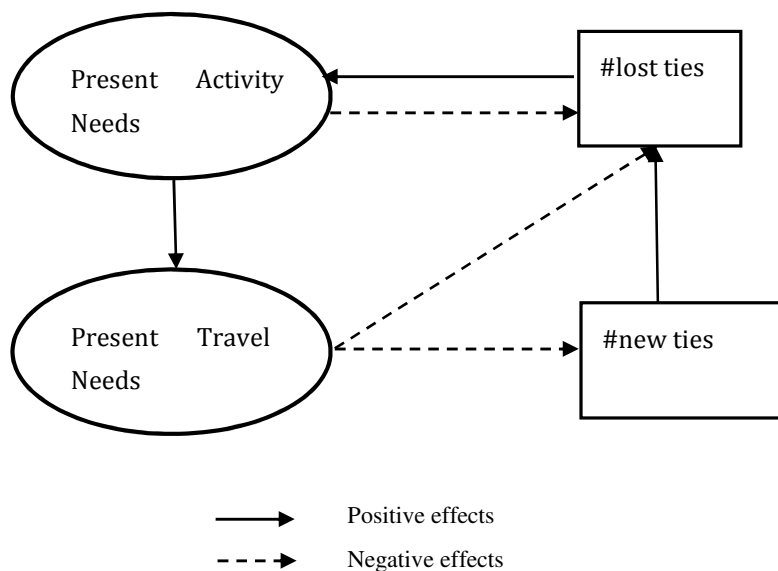


Figure 8.2 Structural model of dynamics of social network, life cycle events and activity-travel needs (Endogenous effects)

8.2.3 Path dependence effects

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 present activity and travel behaviour. However, in most studies, 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.

Results show that, as expected, previous activity and travel needs have a positive effect on present activity and travel needs. 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 path dependent 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.

Table 8.2 Structural Model of dynamic relationship between social network and activity travel needs with life cycle events

	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 sch	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***
<i>R</i> ²	<i>0.70</i>	<i>0.86</i>	<i>0.39</i>	<i>0.55</i>

***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

However, previous activity needs have a negative effect on present travel needs. It is to note that the effects hold after controlling for the path 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.

8.2.4 Endogenous effects

Personal social networks tend to be dynamically changing with every major life cycle event. New ties are added and some old ties fade away. As the social network changes, so might the activity and travel needs do 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 were 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 the number of lost ties. This implies that, as new ties are added to 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 needs on activity needs 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 the number of lost ties and a positive relation with the number of new ties. On the other hand, the number of lost ties has a positive effect on activity needs. Travel needs have a negative relationship with both 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 losing old ones increases, implying a threshold concept of social network size. Similar findings were reported in chapter 5.

8.4 Concluding remarks

The chapter examined the relationships between social network dynamics and activity travel needs in response to life cycle events. The concept discussed in this chapter is to the best of our knowledge the first study in travel behaviour research linking the dynamics of social networks and activity-travel dynamics. 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 socio-demographic and life cycle event variables have a direct impact on activity needs, which in turn generate travel needs.

These 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 size for social networks. The threshold may vary among individuals and perhaps also throughout life stages. A detailed study of this concept is needed and remains on the future research agenda.

9. Predicting Tie Formation and Dynamics for Population- Wide Social Networks⁷

⁷ To be published as Sharmeen, F., Arentze, T. and Timmermans, H. (forthcoming) Predicting Tie Formation and Dynamics for Populationwide Social Networks. *Transportation*.

9.1 Introduction

The purpose of this chapter is to develop a model to predict the dynamics of a population-wide social network. In large-scale travel demand micro-simulation frameworks, social network and prediction of social travel have received only limited attention. Scholars have been investigating ways of simulating social networks for population-wide predictions using theoretical concepts of social networks and tie formation (Arentze and Timmermans, 2008; Arentze et al., 2012; Arentze et al., 2013; Kowald et al., 2012) and rational behavioural assumptions and network statistics (Hackney and Marchal, 2011; Hackney, 2009; Hackney and Axhausen, 2006; Illenberger et al., 2009; Illenberger et al., 2012; Páez and Scott, 2005; Páez and Scott, 2007). These studies have developed methods to predict tie formation. However, a tie may also disappear over time. The notion of tie disappearance was taken into account by Hackney (2006) but not validated with empirical data. We argue that to develop our understanding of network influence on individual/household's long term travel behaviour it is imperative to predict social networks in a dynamic setting. Given the emerging call for the inclusion of social network attributes in travel behaviour studies, it is understandably the forthcoming arena of exploration (Axhausen, 2008; Larsen, 2006).

Therefore, in an attempt to contribute to the analysis of travel behaviour from a long term perspective, we focus on the dynamics of personal social networks in this study. We extend and apply a utility-based friendship formation model to predict the dynamics of a population-wide social network for the Netherlands, in which life cycle events are considered as triggers of social network dynamics. The study is based on the utility-based tie formation model developed in Arentze, et al. (2012, 2013). The model is extended to incorporate the influence of life cycle events on social ties. The model draws from social network theories (e.g. homophily and reciprocity), the life course approach and takes geographical distance into account. In the following sections, we will discuss the relevant theory and literature, methodology and approach, data and descriptives, and the results of model estimation. We conclude the chapter by summarizing the major conclusions and delineating avenues for future research.

9.2 Literature Review

There exists a long tradition of social network simulation in the fields of sociology, physics and health studies. In travel behaviour simulation models, however, this is an emerging field. In travel behaviour research, primary attention was given to the prediction of activities and trips associated with mandatory and maintenance purposes. Discretionary activities and trips have received much less attention and have been modelled in rather minimalistic ways. Due to the increasing share of social and recreational activities and travel in societies all around the world, consideration of social travel in a more behavioural way is now generally seen to be essential. Therefore, a very relevant stream of research focuses on the ways social networks can be modelled for nationwide predictions.

The basic theories of social tie formation consider homophily, reciprocity and transitivity as core concepts. Homophily describes the notion that individuals' preferences for social ties are based on the degree of similarity with others (McPherson et al., 2001). Reciprocity is a property often present in social networks that social ties are two-sided, i.e. that if A is a friend of B then B is also a friend of A (Byrne, 1971). Transitivity accounts for the existence of common friends; it describes that a tie between A and C is more probable if they have a common friend B (Bidart and Degenne, 2005). Apart from that, accounting for geographical distance is also crucial since social networks of populations are extended in geographical space. Studies provide evidence that social relationships are significantly influenced by geographical distances (Mok et al., 2010).

One of the first studies in social network simulation in the field of transportation was conducted by Hackney and colleagues (Hackney and Marchal, 2011; Hackney, 2009; Hackney and Axhausen, 2006). They developed a multi-agent system using behavioural assumptions and network statistics. They incorporated the notion that new links may appear and existing links may disappear from an individual's social network. The link removal algorithm uses a face-to-face social interaction parameter. If a link is not renewed by social interaction, it can be removed after a threshold time has passed. Although this study does formulate a theory and model of social network dynamics, the results were not validated with empirical data. Illenberger, et al. (2009, 2012) simulated social networks using a different

approach, which is more focused on the spatial properties of social networks. They tested the model based on network indicators such as edge-length distribution and network degree distribution. On the downside the model they proposed does not take into account social network theories related to homophily and transitivity.

A more comprehensive theoretical and modelling framework was developed by Arentze and Timmermans (2008) to capture the essence of social networks, social interactions and activity travel behaviour. A core assumption of this model is that the utility a person derives from social interaction is a function of dynamic social and information needs. The study is theoretical in nature and was not empirically tested. Arentze, et al. (2012b) proposed a link formation model and a method to simulate population-wide social networks. The model is consistent with the traditional social network theories (homophily, reciprocity) in the social science literature as well as with random-utility theory and takes geographical distance into account. The process model has been tested in a case study using a dataset on ego-centric networks collected in the Netherlands (van den Berg, 2012). It led to the conclusion that known properties of social networks can be reproduced by the model. The transitivity component was however not incorporated in this model. In a follow-up, Arentze, et al. (2013) developed an extension of the model to incorporate transitivity. They estimated and tested the model using a Swiss dataset. The model considers relationships between persons that are relevant for leisure activities and provides insights on the connectedness between actors and the factors affecting the leisure relationships between them. Furthermore, the model is scalable to the populations generally involved in large-scale micro-simulation systems. Kowald, et al. (2012) described an extension of the tie-formation model within this framework to take into account a wider set of person and location attributes.

The studies mentioned so far have considered social networks at a given point in time and therefore do not take the dynamics into account. However, the social network of a person generally changes as an individual grows older, changes home or changes job, etc. The contemporary research focus in transportation is moving towards methods of incorporating time dynamics. In line with this shift in research focus, the present study focuses on the dynamics of social networks. The tie formation model proposed by Arentze, et al. (2012b, 2013) is taken as the basis.

To model the dynamics in social networks the life course theory is used. The theory has been employed widely in different disciplines (O'Rand and Krecker, 1990). In transportation research, the theory is used to investigate changes in car ownership (Oakil et al., 2011b; Prillwitz et al., 2006), mode choice (Oakil et al., 2011; Verhoeven et al., 2007) and activity and travel time allocation in general (Sharmeen et al., 2013). It is argued that key events disturb the general equilibrium, induce stress and trigger individuals or households to make changes in their activity and travel schedule to restore the equilibrium. Similarly, in this research, we assume that life cycle events bring about changes in individuals' and households' experiences and also influence their relationships or ties (Elder, 1998; Elder Jr, 1994). Life cycle events are therefore used to differentiate between two phases: an initial and an adaptation phase, referring to before and after event situations respectively. The model predicts new tie formations in both phases and modifications of existing ties in the adaptation phase. The next section explains the methodology in detail.

9.3 Methodology and Approach

The model is based on a utility-based tie formation function introduced by Arentze et al. (2012b, 2013). The model predicts the probability of formation of a social tie between two random persons in the population based on a random utility maximization approach. The utility is defined by three structural utility components related to homophily, geographical distance and transitivity. As said, homophily refers to the phenomenon that individuals have a preference to form a social tie with other individuals who are similar to them. The influence of geographical distance is that, keeping everything else equal, the farther two persons are apart in geographical space the smaller the probability that there is a tie between them. Transitivity refers to the existence of common friends, which may facilitate the formation of a tie. As a general assumption of the model, friendship ties are reciprocal. In other words, if person i is a friend of person j then person j must also be a friend of person i . Of course preferences may vary, but for the sake of simplicity at this stage, the model assumes that U_{ij} equals to U_{ji} .

Formally, the utility of a tie is formulated as:

$$U_{ij} = V_{ij}^Q + V_{ij}^D + V_{ij}^C + \varepsilon_{ij} \quad (1)$$

where U_{ij} is the utility of forming a tie between individual i and individual j and V_{ij}^Q , V_{ij}^D and V_{ij}^C are structural utility components related to homophily, geographical distance and transitivity (common friends), respectively, and ε_{ij} is an error term. The model therefore states that a tie between two individuals is more probable if the persons are similar in attributes, live nearby each other and have common friends. In this study we leave the transitivity component out of consideration since we do not have relevant data and only look at the homophily and geographical distance effects on tie formation.

To account for the opportunity of meeting a person and/or the costs (time, money) associated with maintaining a tie, the model includes a threshold utility. The threshold values may differ between persons depending on the time they are willing or able to invest in maintaining social ties and possibly other constraints. A tie is worthwhile to make or maintain when the largest value of the threshold utility is met:

$$P(i \leftrightarrow j) = \Pr(U_{ij} > \max[u_{ij}, u_{ji}]) \quad (2)$$

where u_{ij} , u_{ji} are the threshold utility values for individual i and individual j . To incorporate the dynamics induced by life cycle events in personal social networks, we model decisions of tie formation in two phases (before and after an event). In the initial phase individuals make tie-formation decisions as described by the basic model above. In the adaptation phase, an individual has two sets of decision to make (Figure 9.1):

1. Whether to make a new tie or not
2. Whether to keep a tie or not (break/lose it)

The proposed extension of the utility function to cover both phases can be defined in operational terms as follows:

$$U_{ijg} = \mu_g[V_{ijg}^Q + V_{ijg}^D + Z_{ig}] + \alpha_g + \eta_i + \varepsilon_{ij} \quad (3)$$

where g is an added index of existing condition, α_g is a condition specific constant, η_i is a random error component related to agent i , Z_{ig} is an additional term that

captures the influence of the existing network and type of the event on the utility of a tie ($Z_{ijg} = 0$ in the initial phase), μ_g is a condition-specific scaling factor and ε_{ij} is a random error term as before. In the initial phase, $g = 0$ by definition and in the adaptation phase $g = 1$ if no tie exists and $g = 2$ otherwise. Thus, in the $g = 2$ case the function defines the utility of maintaining the tie and in the $g = 0$ and $g = 1$ case the utility of forming a new tie in the initial and adaptation phase respectively. In this equation, the constant, α_g , captures the threshold utility of forming a new tie ($g = 0, 1$) or maintaining an existing tie ($g = 2$). The structural utility terms, V , on the right-hand side of the equations are operationalized for the different conditions as follows. First, in the initial phase where no tie exists ($g = 0$), the attribute-similarity utility is specified in a straight-forward way as:

$$V_{ij0}^Q = \sum_k \beta_{ik} X_{ijk} \quad (4a)$$

where X_{ijk} is a homophily characteristic between person i and j regarding attribute k and β are parameters to be estimated. For the adaptation phase the term is extended to account for a possible re-evaluation of the same attributes in the adaptation phase, when the tie is new ($g = 1$) or already exists ($g = 2$):

$$V_{ij1}^Q = V_{ij2}^Q = \sum_k (\beta_{ik} X_{ijk} + \beta_k^\Delta X_{ijk}) \quad (4b)$$

where β^Δ parameters represent adaptations of the evaluations. The distance related utility term is specified differently for the cases where the tie is new ($g = 0$ or $g = 1$) and already exists ($g = 2$), as follows:

$$V_{ij0}^D = \theta_i \ln(D_{ij}) \quad (5a)$$

$$V_{ij1}^D = \theta_i \ln(D_{ij}) + \theta^\Delta \ln(D_{ij}) \quad (5b)$$

$$V_{ij2}^D = \theta_i \ln(D_{ij}) + \theta^\Delta \ln(D_{ij}) + \theta^+(D_{ij}^+) + \theta^-(D_{ij}^-) \quad (5c)$$

where, D_{ij} is geographical distance between persons i and j , D_{ij}^+ is a dummy variable to indicate an increase in distance for the tie caused by the event, D_{ij}^- is the other dummy variable indicating a decrease in distance and θ , θ^Δ , θ^+ and θ^- are related parameters.

The log transformation of distance is implemented to take decreasing marginal utility of distance into account, which generally is assumed to be the case in tie formation models. Note that in this case of distance a possible re-evaluation of distance is left out of consideration. Finally, the influence of the existing network and type of event is zero by definition in the initial phase ($g = 0$):

$$Z_{i0} = 0 \quad (6a)$$

and is defined for the adaptation phase as (if the tie is new or exists):

$$Z_{i1} = Z_{i2} = \sum_m \tau_m E_m + \lambda N_i \quad (6b)$$

where E_m is the m^{th} dummy variable indicating the type of event, N_i is the size of the existing social network of person i and τ and λ are parameters to be estimated. To account for taste heterogeneity the core parameters are included as random parameters in this model:

$$\beta_{ik} = \beta_k + \gamma_{ik} \quad (6)$$

$$\theta_i = \theta + \chi_i \quad (7)$$

where γ_{ik} and χ_i are agent-specific error terms regarding attribute similarity and distance parameters, respectively.

The parameters have the following interpretation: β^Δ parameters represent the effects of being in the adaptation phase on the way similarity is valued on the various attributes (k); τ parameters represent effects of particular events on a base utility (or threshold) of a relationship; λ represents the effect of the current size of the network in the adaptation phase on the utility of a relationship and μ takes into account a possible scale effect on how attributes and distance are valued under the different conditions. In the application a scale will be estimated for the condition where a relationship already exists (μ_2) relative to the condition where the tie is new ($\mu_0 = \mu_1 = 1$).

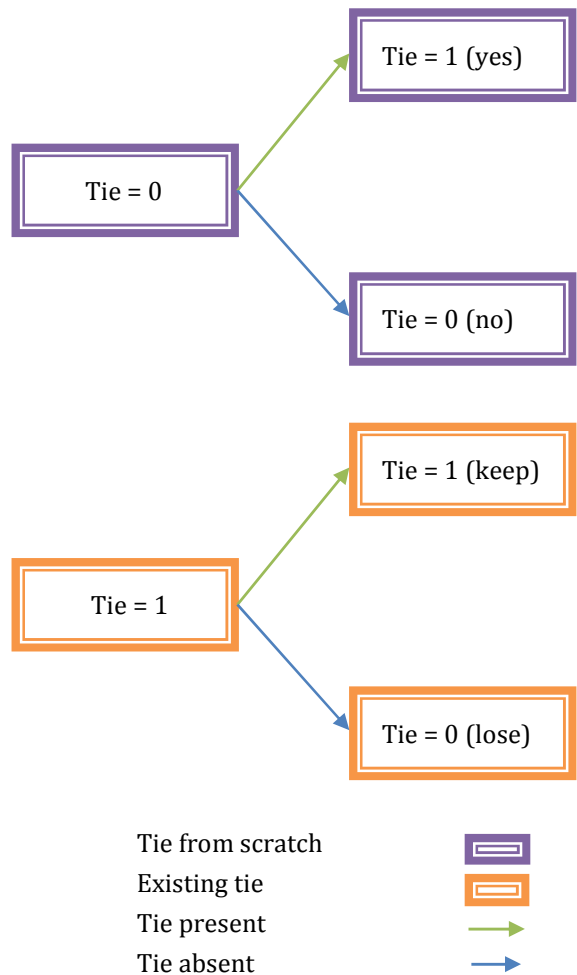


Figure 9.1 Problem definition
(top diagram – no tie; choice is to make a tie or not,
bottom diagram- tie exists; choice is to keep it or lose it)

In sum, the above equations (3) – (7) define the model of tie formation decisions in the initial phase and adaptation phase taking into account the event that have taken place in the adaptation phase. The model takes into account the nature of the event as well as a possible change in geographical distance and allows for scale differences in the structural utility of a relationship depending on whether a

relationship already exists or not, as well as for a difference in base utility (threshold) between these two conditions. Furthermore, the model takes into account taste-heterogeneity across agents (ego's) in terms of homophily, geographical distance and base utility (threshold) for formation or keeping ties.

The model can be estimated using maximum likelihood estimation. For this estimation we need a dataset that contains a sample of social ties as well as a sample of non-existent social ties {Arentze, 2013 #366}. Further we need to have observations of tie dynamics (i.e. a tie that appears or disappears) and tie maintenance (ties that are retained) after a life cycle event. Finally, we need geographical distance changes (if any) for each pair of individuals after the event. In the next Sections 9.4 and 9.5 we discuss the data collection and estimation method in more detail in the context of an application.

9.4 Data Preparation and Descriptive Analysis

Two datasets are used to estimate the model. The first data set is from a national travel survey (MON) of The Netherlands collected by the Ministry of Transport (Ministry of Transport, 2009) . It is a travel-diary survey. For this study we have taken the latest version of 2009. It is a large sample (in 2009, approximately 30,000 individuals) representative of the Dutch population. The second dataset is the event-based questionnaire survey we conducted to obtain information about the dynamics of personal social networks.

The first dataset is used to obtain a complementary sample of the population. The sample is used to provide for each person negative observations, i.e. the persons with whom no tie exists. Although in principle all persons of the entire population with whom the person does not have a friendship relationship constitute a negative observation, it has been shown that a sample suffices to obtain reliable estimates (Arentze, et al., 2013) except for the constants⁸. However, the second dataset is the principle dataset that provides the key information to estimate a friendship model that allows us to predict probabilities of ego-alter tie dynamics.

⁸ The use of sampling for estimation is a well-known method in discrete choice modelling, Sampling leads to biases in the estimation of constants; methods exist to correct for such biases King, G., Zeng, L. (2001) Logistic regression in rare events data. *Political analysis* 9, 137-163. which is relevant when the model is to be used for prediction.

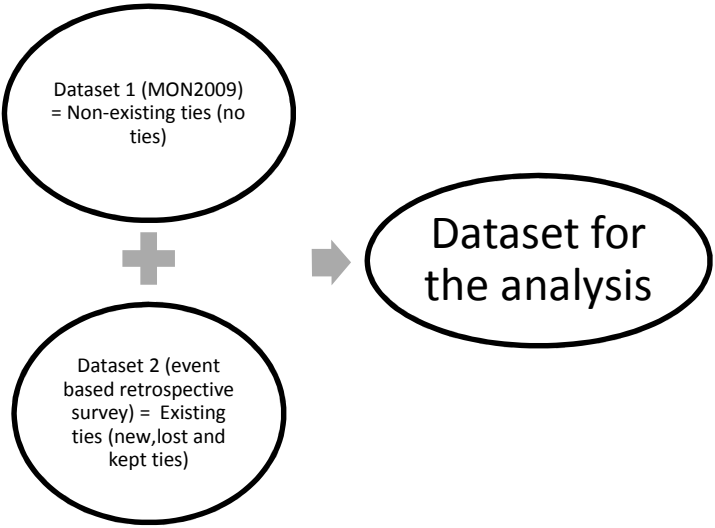


Figure 9.2 Schema representing which information was obtained from which dataset

To better organize the study in terms of activity travel behaviour, we reorganized the second dataset, similarly as in Chapter 6. Two events were consolidated and named ‘change in job/study’ to indicate changes in mandatory activity and travel. The event of children starting school poses demands in maintenance activity and travel, whereas residential relocation can bring in changes in all types of activity and travel budget allocation. The event of change in civil status is a basic demographic event and was taken as a base event in the study. The sample characteristics were same as presented in Chapter 3.

As stated above, a sample was drawn from the national travel survey data to account for negative ties existing in the population⁹. The sample accounted for 0.56% of the Dutch population in the Netherlands. From our collected data ties reported for the before-event case (collected in section two of the questionnaire)

⁹In two years’ time attributes of the cohorts may change due to lifecycle changes. To take such changes into account one would need to have longitudinal panel data which was not available in the present study.

are relevant for the initial (before event) phase. In total 8,021 ties were reported (positive observations) and 82,100 persons represented the persons in the population with which no tie existed for this phase (Table 9.1).

The new ties that were made and the ties that were lost after the event are relevant data for the adaptation phase. Since the numbers of new ties are very small compared to the big population-wide sample and the number of lost ties is very small compared to the number of maintained ties, we applied sampling to prepare the data for the adaptation phase.

First, for the decision form new ties a random sample of 887 was drawn from the population-wide sample. Second, for the decision to maintain ties a random sample of 827 ties were drawn from the 8021 existing ties. By using the sampling method the parameters can be estimated except for the constants (α) in the utility functions which will be biased.

Table 9.2 presents the distributions of ties in the initial phase based on the similarity between the socio demographic characteristics of ego and alter. The columns present the percentage distribution of ties present and absent in terms of the homophily attributes and geographical distance between the ego and alter.

We can observe strong homophily effects for gender and age, and almost no homophily effects for education level. Approximately 87% of the ties were formed with individuals having different education levels. This is somewhat different than what was reported by Kowald et al (2012) using a Swiss dataset. They reported homophily effects for both age and education level (in their study presence of a tie

Table 9.1 Overview of sample of ties in initial and adaptation phases

Phases	Type of ties	# of ties
Initial (before event)	before 0 after 0 (no)	82100
	before 0 after 1 (yes)	8021
Adaptation (after event)	before 0 after 0 (no)	887
	before 0 after 1 (new)	326
	before 1 after 0 (lost)	68
	before 1 after 1 (kept)	827

was 14% higher if ego and alter had same education level than different education levels).

However, it is to note that the categories used in the Swiss dataset are broad (mandatory school, apprenticeship and university) and not directly comparable to the Dutch system. The age categories are rather comparable. Further to note is that the name generators used in our data collection picked up a significant number of family ties and siblings which are more likely to be dissimilar in education levels but some may fall in the same age category (such as, siblings and cousins). Nonetheless the difference in the statistics with respect to education level is remarkable.

9.5 Estimation Results

Using a mixed-logit framework, the model was estimated based on the total set of 92229 observations (Table 9.1) with 200 Halton draws. Biogeme 2.0 was used to estimate the model. A mixed logit formulation was used to account for the panel-

Table 9.2 Data descriptive for initial (before event) phase (90121 cases)		
Ego-alter socio demographics	Tie present (%)	Tie absent (%)
Same age	46.70	13.70
Age difference by 1 category	28.70	27.50
Age difference by 2 categories	11.10	23.40
Age difference by 3 or more categories	13.50	35.40
Different age (total)	53.30	86.30
Same gender	62.80	49.80
Different gender	37.20	50.20
Same education level	12.60	9.20
Education level difference of 1 category	33.60	16.40
Education level difference of 2	16.80	14.30
Education level difference of 3 or more	37.00	60.10
Different education level (total)	87.40	90.80
Distance (mean) in km	38.40	133.21

Note: for each category, column totals are equal to 100%, for instance same gender and different gender for 'tie present' column the total equals 100%. The same holds for 'tie absent' column.

structure of the data, i.e. multiple observations for the egos of the sample. The estimation was conducted in two steps. At first the scale parameter, μ (in Eq. 3), was estimated in a multinomial specification of the model. Then the data were rescaled accordingly and the model was estimated using the final mixed logit estimation with the scale parameter omitted (given that the data have been rescaled and hence the scale difference is solved). This two-step procedure was used since existing software packages for estimation do not allow scale parameter estimation in a mixed-logit framework. The best fitting model was obtained after evaluating random effect variations in constants, same age group and distance parameters. The log likelihood estimates and Rho square statistics display that the model has a good fit compared to a null model.

The model constants are negative for both initial and adaptation phase, which is expected, indicating all else being equal the probability is that a tie is not made. Strong homophily effects are indicated by the parameter estimated for the initial phase. The probability of making a tie with an individual of same age group is higher. The utility of a tie decreases monotonically for the age differences. This is a plausible finding; it reflects that friendships among the same age group are more probable (Kowald et al., 2013). Similar findings are shown for actors with same gender.

Same education level has no significant effect on the utility of a tie in the initial phase estimate. However, difference in education level of two categories does have a negative effect on the utility and this negative utility further increases when the difference further increases (to three or more categories). This implies that making friends with someone with a relatively large difference in education level is relatively improbable which coheres to the homophily effect. These findings related to homophily are comparable to the similar Swiss study conducted by Kowald et al. (2012). However, in the latter study a positive effect of same education was found in addition to the negative effects of education differences of two or more categories.

Distance has a negative effect on the utility of a tie, which is expected and in line with the general notion of the effects of proximity. As the geographical distance

between two individuals increases, the probability of a tie between them decreases. Thus geographical distance still matters in formation of ties despite the advancement of information and communication technologies, as was also reported in earlier studies (Mok et al., 2010)

Utility effects for the adaptation phase (after a lifecycle event) are estimated as effects to the base (initial/before life cycle event phase) parameters (Eq. 4b). The effects of age variables are opposite in sign to those at the initial phase; this suggests that in the adaptation phase the size of homophily effects is reduced (note that the parameters should be interpreted as effects on the parameters of part A). Specifically the correction parameter is high for the largest age difference category (age difference by three categories). The effects are also reducing the effects for same education level and education level difference by three or more categories, indicating a decrease in homophily tendency and even a marginal inclination towards heterophily (for three or more category difference in age and education level) in the adaptation phase.

The adaptation phase has no significant effect on the utility of same gender. The effect of distance however is strongly reduced in the adaptation phase. To summarize the estimates of the effects of the adaptation phase suggest that when the social network is existent an individual is less sensitive to similarity in age, education and geographical proximity compared to the initial phase where a network is being formed.

In terms of individual specific variables, such as type of events and size of social network, findings suggest that the utility of forming a new tie or maintaining an existing tie increases for all three types of events when compared to the base event type (i.e. change in civil status). The utility effects is largest for the event of children of household starting school and the lowest for starting new job or study. All these events potentially create opportunities of meeting new people as new activity and/or travel spaces are introduced, either in the form of a new neighbourhood, school for children, job or education place. The size of the existing social network, however, does not have a significant effect on the utility of a tie.

**Table 9.4 Binary mixed logit model of social ties formation and maintenance
(population wide prediction)**

Dependent variable: tie present (kept for existing ties) or absent (lost for existing ties)

Parameter Estimates	β	t-stat
A. Initial (before event) phase		
Constant	-2.63	-21.16
Same age group	1.46	23.73
Age difference by 2 category	-0.54	-8.43
Age difference by 3 categories	-1.00	-10.17
Same gender	0.54	14.41
Same education level	-0.04	-1.4
Education level difference by 2 categories	-0.26	-4.24
Education level difference by 3 or more categories	-0.96	-8.48
Log of distance in km	-3.38	-43.52
B. Adaptation (after event) phase		
	Effects on β	t-stat
Constant	-2.77	-3.58
Same age group	-0.72	-2.99
Age difference by 2 category	0.37	0.67
Age difference by 3 categories	1.23	2.32
Same gender	-0.19	-0.63
Same education level	1.23	3.36
Education level difference by 2 categories	0.28	0.69
Education level difference by 3 or more categories	1.04	2.74
Log of distance in km	3.24	13.77
Event: Relocation with other events	1.26	2.65
Event: Change in work/study hr	0.73	2.86
Event: Children of the household starts school	1.34	2.93
Size of social network (close ties)	-0.03	-0.12
C. Existing ties (with a history)		
		t-stat
Constant	3.49	6.08
Scale	1.55	3.95

C. Existing ties (with a history)		t-stat
Decrease in geographical distance	6.64	7.41
Increase in geographical distance	-1.03	-1.46
Std Dev Random Effects	η_i, γ_{ik} and χ	t-stat
Constant	1.86	23.13
Same age group	1.18	14.48
Std Dev Random Effects	η_i, γ_{ik} and χ	t-stat
Distance	0.62	7.10
<u>Model fitting information:</u>		
# Observations	92229	
# Halton draws	200.00	
Init log-likelihood	-63935.90	
Final log-likelihood	-15373.50	
Rho-square	0.76	

Evidently the social network size does not matter in making new friends or maintaining existing ones. Note that by definition the existing social network here is limited to the close friends.

For existing ties, we calculated a scale parameter to correct for a possible difference in scale of utility when the tie exists and the choice is about the question of yes or no keeping the tie. The scale parameter is positive (1.55) indicating an increase of the effects of structural homophily and distance variables when a tie exists. Therefore, for existing ties, the effects are strengthened. In other words, both the decrease in homophily and an inclination towards heterophily is intensified. The heterophily effects can be explained as that a major part of the ties that are kept after the event are family ties which tend to include an age difference and may include gender difference. Investigation related to social interaction dynamics confer that individuals keep in touch with family ties in one way or another. If face-to-face interaction frequency has been reduced after an event it was compensated by increased amount of contacts using ICT (Sharmeen et al., 2012a; Sharmeen and Timmermans, 2011).

Finally, in terms of geographical distance findings suggest that a decrease in

geographical distance increases the utility of keeping the tie. An increase in geographical distance has a negative sign but the effect is not significant. In our previous empirical study (Sharmeen et al., 2014), we found evidence that changes in geographical distance and local accessibility indicators affect maintenance of existing ties. Nonetheless we can emphasize that changes in geographical distance are important and should be taken into consideration in determining maintenance of existing ties.

9.6 Conclusion

The study offers a method to estimate a dynamic model of tie formation that is relevant for micro simulating social tie dynamics. Incorporation of social networks into activity and travel demand models requires a methodology to predict the probabilities of friendship formation. Existing research in this regard is limited to begin with, being a relatively new frontier in transportation. Recent promising progresses (e.g. Arentze et al., 2012; Kowald et al., 2013 and Arentze et al., 2013) have been made to predict and simulate static social networks. The contribution of this chapter is extending the method towards dynamic analysis (therefore not only considering friendship formation but also friendship maintenance). The motivation stems from the fact that social networks and travel decisions are not static. They change throughout life.

The proposed model predicts the formation of and changes in social ties among two actors in the population. The empirical analysis demonstrates how the model can be estimated.

The relevance of this model is appealing not only to researchers but also to practical analysts and policy evaluators. With respect to travel demand forecasting the need to simulate and predict transitions within the state variables of individuals is well recognized (Ben-Akiva and Bowman, 1998; Bhat and Koppelman, 1999). On the other hand, social networks generate and influence activity and travel patterns (Carrasco and Habib, 2009). Therefore, we need similar approach to simulate the dynamics of social networks. Otherwise, by definition, the input to dynamic and quasi static models of travel demand forecasting will be biased. Hence to improve application of activity and travel model and to optimize policy assessments, we need to develop methods to include social networks in the forecasting and policy

analysis framework. This paper has put forward a way to incorporate social network dynamics in line with the recent developments and emphasizes the need to include individual's social context in every stage of forecasting models (from data collection, analysis, simulation and prediction).

The model derived from previous work is based on fundamental theories of social networks, such as homophily, reciprocity and degree distribution. To determine the social ties between two actors in the population it uses the random utility maximization concept. The utility of a tie is measured by the degree of similarity between the actors and the geographical distance between them. A tie between two individuals is worthwhile only if the utility exceeds a threshold value for both persons involved. Thus the model predicts if a new tie emerges or not between two individuals. However, social ties and social networks are dynamic and may change especially in relation to life cycle events (Chapter 2). Therefore, the model is extended to also predict behaviour in an adaptation stage in case a life cycle event occurred.

Findings suggest that the formation of new ties is influenced by homophily between the actors in the initial phase. The effects however are minimized in the adaptation phase, in the sense that sensitivity to homophily declines or in some cases a marginal inclination towards heterophily can be observed. However for existing ties the effects become stronger; in the sense that both decrease in homophily and an inclination towards heterophily is intensified. A major part of the ties that are retained after the event are family ties, which may explain the heterophily effects. This finding also seem plausible since family ties are not maintained by choice, like other types of ties. Separate investigation for type of ties (relation) could provide detailed insight, which remains to be explored in future.

In addition to that, geographical proximity influences the formation of a tie. Further investigation on the effects of changes in geographical distance for existing ties show that decrease in distance has a positive effect on tie maintenance. Coherent with an earlier empirical analysis (Sharmeen et al., 2014), these findings suggest that not only prevailing but also variations in geographical distance affect friendship formation and maintenance.

The model predictions can be used to simulate social networks for a population wide distribution. One can create a social network at the initial phase and then update friendship relationships in response to particular life cycle events. However, further steps are needed before the model could be transferred. The generalization of this model is not straightforward. The model is based on a selected sample who experienced a lifecycle event in the past two years. The sampling was done purposefully to report the effects of long term lifecycle events on social networks, a trait that is completely absent in literature. However, this sampling poses hindrance in using the model for predicting changes not triggered by lifecycle events. Further comprehensive data collection and extensive research is needed to fulfil the purpose. As a first empirical finding of predicting social tie dynamics the research shows promising results.

In addition, there are a number of limitations and possibilities of extension of the model. First, data limitations have prevented us from incorporating effects of reciprocity and transitivity (having a common friend). Tie formation and deletion decisions are reciprocal. Those decisions depend on both ego and alter and can be affected by lifecycle events experienced by both parties. In the present model only one sided decisions were considered. The influence of having common friends (or circle of friends) on tie formation/deletion was also not captured in the present study. Second, due to budget limitations important lifecycle events, such as childbirth, could not be included in the survey and remains as future work. Moreover, other geographic attributes such as density, accessibility and urban form can be incorporated to extend the model to cater for the variety of geographical places. Moreover work status and mobility patterns of the actors can determine the possibilities to make new ties, to some extent. For instance, a full time worker and a long distance commuter may have different possibilities of meeting new people than a part time student or a full time homemaker. For larger and mixed communities, cultural differences should also be taken into due consideration when applying this model across population.

10. Conclusion and Discussion¹⁰

¹⁰ The segments on limitations and future research have also been discussed in the Editorial: Sharmeen, F., van den Berg, P. and Timmermans, H. (2014) Networked individual in networked city: Reviewing social network in transportation literature. *Social Networking* 3 (3): 147-149.

10.1 Summary

The aim of this thesis is to enhance our understanding of the social dimensions of travel behaviour. Its novelty concerns the focus on long term dynamics of social networks in the transportation literature. The concept stems from the simple connotation that social networks are not invariant over time or over the life course of an individual. The key feature of the research is, therefore, long term dynamics. Life cycle events are assumed to be triggers of these dynamics.

Aiming at broadening our view from static to dynamic attributes of social networks, this research project has systematically investigated changes in social networks, social interaction and activity-travel patterns with life cycle events. We identified three interrelated domains of life cycle events, social network and activity-travel behaviour and argue that understanding dynamic repertoires of these three interconnected domains are crucial to predict long-term travel demand. The general approach was to test and validate the conceptual framework, i.e. the existence and nature of the interdependencies by means of empirical data. First, we investigated the effects of life cycle events on social networks, social interactions (including effects of ICT) and activity-travel behaviour. Then, in an integrated framework, we explored the dynamic interrelationships between the domains of social networks and activity travel profiles, triggered by life cycle events.

The empirical analyses provided evidence that these domains are interconnected. Social network dynamics affects activity-travel needs and vice versa. The numbers of lost and new ties and time allocations to activity and travel vary according to the types of life cycle events. Moreover, the numbers of new and lost ties are interdependent indicating a threshold personal social network size. In terms of social interaction, we observe that face-to-face social interactions are influenced by change in geographical distance with alters and accessibility and urban density of ego's home location. Further, we observe that ICT and face-to-face social interactions influence each other in the long term.

Summarizing the findings, we proclaim that social networks are dynamic and so are the activity-travel choices, needs and aspiration levels. Evidently, they influence each other. These long term dynamics and their interdependencies are essential for

a comprehensive understanding of travel behaviour. Modelling with the assumption of static or independent nature of what are actually varying dimensions could deviate from actual prediction and lead to erroneous design and output of decision support systems. Social policies and travel demand forecasting models are designed for the long run, making these incorporations just and relevant. Of course, we are far from completely grasping the interferences and time dynamics; nonetheless the thesis indicates the necessity, relevance and justification of dynamic interdependencies in transportation research and travel demand forecasting models.

10.2 Contribution

The research contributes to a shift in focus by moving from short term behavioural analysis to mid and long term dynamics. To the best of our knowledge, this is the first attempt to explore the dynamics of social networks, and the dynamics of activity and travel needs triggered by life cycle events. Therefore, first of all, the research makes a contribution to the transportation literature as it presented a conceptual framework to incorporate social network dynamics into travel behaviour models and provided new empirical evidence to validate the concept. The study argues that the dynamics of life cycle events, social network and activity-travel needs are interrelated and should be modelled in an integrated manner. Several studies in travel behaviour dynamics have investigated one or two of these domains. Most of those studies were cross-sectional, yet a shift towards dynamic modelling can also be observed, particularly the dynamics of activity and travel were investigated. Evidently, the domains under discussion are not only dynamic but also interrelated. To analyse them in fragments and in considering them static would thus be incomplete and erroneous. With that motivation, this research offers an integrated representation of the domains that not only caters for their dynamic nature, but also captures the interrelation among them. The study, therefore, is crucial, timely, and contributes to the dynamic and comprehensive travel behaviour models.

Moreover, we investigated the nature and extent of influential causalities of life cycle events on changes in social networks and activity travel needs. The thesis contributes to the literature by providing insights into the dynamics of activity and

travel demand. Furthermore, the results will feed into an integrated agent-based model to predict the dynamics of scheduling activity and travel. We have outlined a model that could be used to predict of population-wide social network dynamics to be used in travel behaviour simulation frameworks.

Secondly, in this study, we extend the theory of relationships between ICT and face-to-face communication pattern by adding time dynamics. Moreover, the relationships among the modes of social communication are interdependent. Face-to-face social interactions may also affect ICT communication frequencies when we consider evolution of networks across different time frames (such as, changes in time budget of the ego or changes in geographical distance between ego and alter). This concept is worth testing for other types of communication as well. Now, more than ever, the emerging socio-cultural communication and travel insurgencies necessitate broadening the views of theorists and policy makers towards interdependent and dynamic relationships throughout domains, modes and time frames.

Thirdly, we adopted and explained the theory of path dependence in the context of activity travel behaviour. The theory has been widely used in social, political and evolutionary economic geography. We explained and applied it in transport geography in this thesis.

In the context of policy formulation and practical application, the thesis contributes to the formation and application of dynamic activity and travel behaviour models. It illustrates the relevance of defining and assessing future policies within the context of life cycle events. In particular, the thesis induces the importance of social networks in terms of how they are triggered and contextualized to changes in life cycle events. It implies that policy formation can be targeted or at least should be aware of the social context, in which behavioural changes takes place and could be positioned using social media, social communication, etc.

10.3 Limitations

Most of the study limitations relate to the data and assumptions related to the data collection. Some typical errors and biases are associated with retrospective surveys, which were inevitable in this case. However, 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 is employed. In order to reduce errors, the survey was carefully designed and administrated with the aim of reducing 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. Three rounds of pilot testing were organized and detailed feedback reports from respondents and academics were taken into account to improve the design at each step. Applying possible and pragmatic measures, it was attempted 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.

There were some missing issues (key events such as child birth and details of residential moves) in the analysis. This was primarily due to lack of data. We acknowledge that situational changes may have occurred during the after-event period that are not recorded and hence cannot be included in the analysis. The objective of the thesis (and data collection) is to capture the effects of major life cycle event to the activity-travel scheduling. People need some time to absorb and incorporate the effect of the event in their activity-travel budget. To capture such effects in the data, we carefully chose the period of two years so that respondents would have a new settled activity-travel plan comparable to their pre-event agenda. The survey was based on the above assumptions.

We also assumed that life cycle events trigger long term dynamics in social networks and activity travel needs. Although this assumption is based on literature review, there are other reasons that may bring in changes in social networks, which could not be incorporated in the study.

Social networks and interactions are a two-way street. In this research project, we only hear and include one side of the story. Similar life cycle events and changes may occur to the alters. Their home locations, urban density and accessibility features may also have an influence on social interactions and travel, which we could not account for. Neither do we have detailed information about social media use and their effects.

10.4 Future Research

In recent times, researchers have addressed several aspects of the influence of social network on activity and travel planning, such as duration, frequency, start time, distance, mode choice, etc. The reported results are intuitive and demands due attention by researchers as well as policy makers and practitioners to incorporate the social context in activity and travel demand forecasting. However, it is a long way to completely understand the social dimensions of activity and travel. Therefore challenges remain. Specific future works have already been mentioned in the chapters. Here, we summarize the broader topics.

A first challenge is to incorporate social networks in application oriented travel demand forecasting models, so as to predict social and leisure travel demand with greater certainty. To see the big picture, we need to broaden our view from egocentric social networks to a population wide projection. An agent based simulation environment is a potential platform to serve the purpose and has been utilized accordingly. Further, to simulate the potential of tie formation, the negotiation of a social meeting (mode choice, place, time etc.) has been simulated in transportation research using multi-agent simulation. However our knowledge is still limited. In this study, we have extended ways to predict population-wide social network dynamics, which needs further modification, for instance, incorporating geographical attributes, and sensitivity tests and error and biases associated with replication.

A big challenge of investigating social networks is obtaining the necessary data. To get a good impression of the heterogeneity of activities, it is desirable to collect longitudinal diary data. Traditional travel diary surveys collect one or two days of travel data from participants. While cross-sectional travel diary surveys are useful in determining the overall average travel behaviour of the regional population, they do not capture repetitive patterns in social activities, for instance weekly routines of people. New GPS technologies and use of smartphones may provide a promising way of collecting longitudinal travel data without asking too much effort from respondents.

This study focuses on social network dynamics in response to life cycle events.

Possibly there are many other ways through which social networks change. A relevant future extension therefore could be looking into social network dynamics without any presumptions.

In addition, the study of the effect of ICT's on social activity-travel remains a topic for future research. Although this topic has been studied recently, the possibilities of ICT's are increasing rapidly. These changes will affect social travel, for instance in arranging a social trip (e.g. making reservations, buying tickets, checking routes, weather and travel conditions), making additional research necessary. With the growing influence of social media in individual's social life, dynamics of social network has become important more than before. Possibly virtual social networks are more flexible, at least in terms of new ties, where social media plays an important role in information dissemination, publicity of social events, etc., having further impact in activity and travel needs. We could not incorporate the effects of social media in particular. This can be done by collecting information about virtual social networks, interaction and travel patterns. Further peer influence on travel choices could also be investigated by tracking information dissemination in social media. The possibilities of extension are therefore diverse and promising.

A further challenge is to link the a-spatial aspect of social network to the spatial one. There is a spatial facet attached to an individual's social network as far as travel and transportation is concerned. The distance and accessibility of the peers should matter in planning and maintaining social networks. In this thesis, we only had data from the ego, not from the alter, which is a very relevant and possible future extension. Snowball sampling method can be used to collect the relevant information. Alternatively targeted stated adaptation questionnaire can be designed to understand the role of geography and infrastructure on social interaction to a greater depth.

Furthermore, the findings support the assumption that personal social network tends to change with major life cycle events. New ties are added and some old ties fade away. They also suggest that there is a threshold of the size of personal 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.

Finally, due consideration should be attached to social network dynamics in choice set developments. In travel behaviour modelling identifying choice sets is a challenge as individuals are not aware of a universal choice set when selecting an activity-travel profile. They cannot even always consider all of those they are aware of, constrained by their habitual preferences (path dependence) or resource availability. Information about attitude and personality may assist to understand these characteristics. Moreover, the choice sets are dynamic and a major source is induced by the evolving social networks.

The analysis of social networks has a far reaching potential in understanding almost all aspects of human behaviour. These potentials have been realized for long. A recent growing field of exploration is activity and travel behaviour. The history of social networks and transportation literatures is nonetheless in an exploration stage. There have been some commendable works already. Further comprehension and integration of the local social context, social externalities and social dynamics to the travel behaviour models remain on the contemporary agenda.

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Curriculum Vitae

Fariya Sharmeen was born on the 30th of May, 1981 in Dhaka, Bangladesh. She completed her bachelor and master degree in urban and regional planning at the Bangladesh University of Engineering and Technology (BUET), Bangladesh. She graduated with honours and joined the same institution as a lecturer. She served at the position for three years before joining the postgraduate programme on City Regeneration at the London Metropolitan University, UK. During her studies, she also worked as a GIS specialist in Cities Institute, London and as a Researcher in Utrecht University, the Netherlands. From 2009, she started her PhD at the Eindhoven University of Technology, the Netherlands, for which the results are presented in this dissertation. She published several articles in leading journals and wrote book chapters. She received the BUET Dean's List award and the BUET'70 Alumni Scholarship in 2002 and 2003, the LondonMet Postgraduate Scholarship and the Commonwealth Scholarship in 2008. She received the Royal Geographic Society (RGS) postgraduate award in 2013.

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Thesis and Dissertation

MSc: Modelling Urban House-Rent Variation in Bangladesh: A Study of Four Metropolitan Cities.

Supervisor: Prof Dr Sarwar Jahan

Bangladesh University of Engineering and Technology, Dhaka, Bangladesh

BSc: Income generating training program for poverty alleviation: a study of the poor women members of 'Nari Maitree' (a NGO, the meaning of the name is Women Alliance)

Supervisor: Dr Gulsan Ara Parvin

Bangladesh University of Engineering and Technology, Dhaka, Bangladesh

Reports

Overview of community mapping in Somerstown, London
Co-authors: Antje Witting, Bas van de Geyn, Steve Shaw, Stephanie Gledhill
Cities Institute, London, UK

Appendix 1

SURVEY QUESTIONNAIREⁱ

Enquête om informatie te verzamelen over sociale netwerken en reisgedrag (m.b.t. activiteiten) na huwelijk / samenwonen / geregistreerd partnerschap / uit elkaar gaan / scheiding

Beste deelnemer,

Via dit onderzoek willen we de effecten van grote veranderingen op sociale netwerken en reisgedrag omtrent activiteiten onderzoeken. Soms, wanneer mensen verhuizen naar een andere locatie of wanneer hun studie-/werklocatie verandert, kan dat effect hebben of hun sociale netwerk. Zij kunnen nieuwe mensen ontmoeten en nieuwe contacten leggen. Anderzijds, sommige oude vriendschappen kunnen verwateren. Tegelijkertijd kunnen de activiteiten die iemand onderneemt en het bijbehorend reisgedrag veranderen, omdat de reis, de reisbestemming, de afstand en reismanier anders zijn dan voorheen. Wij kijken naar deze veranderingen behorende bij één verandering, bijvoorbeeld trouwen / geregistreerd partnerschap aangaan / uit elkaar gaan / scheiden of het gaan samenwonen. Door deze enquête proberen wij informatie te verzamelen voor een analyse. Wij waarderen uw hulp hierbij.

Alle informatie die u geeft in deze enquête zal strikt voor **academische doelen** worden gebruikt. Geen enkel gegeven zal worden gebruikt om wie dan ook te identificeren. **Het onderzoek is volledig anoniem.**

Enkele definities en toelichting:

Wat verstaan we onder sociaal netwerk? Alle niet zakelijke relaties met wie u sociaal contact heeft. Collega's van het werk kunnen daartoe behoren, namelijk wanneer zij goede vrienden zijn of personen waar u een beroep op kunt doen voor emotionele of sociale steun. Familie, vrienden, buren en collega's kunnen ook tot uw sociale netwerk behoren.

Familie: Uw uitgebreide familie, dus ook evt. grootouders, uw broers/zusters familie, neven/nichten, ooms/tantes, enzovoort.

Vrienden: Sterke of enigszins sterke vrienden met wie u altijd contact houdt, die dus meer dan slechts kennissen zijn.

Buren: Mensen uit uw buurt met wie u sociaal contact onderhoudt, bijvoorbeeld met wie u informatie uitwisselt, met wie u weleens gaat winkelen, die u kunt vragen voor kinderoppas e.d.

Collega's: Mensen die u kent van uw werkplek en die u beschouwt als vriend met wie u emotionele ervaringen deelt, kortom, met wie u een relatie heeft die verder reikt dan werk. In de enquête kunt u hen bij 'vrienden' noemen. Degenen waar u alleen zakelijk contact mee heeft, hoeft u niet te noemen voor dit onderzoek.

Eventuele personen die niet in één van de bovenstaande categorieën vallen, kunt u noemen bij 'Anderen'.

DEEL I: ALGEMENE PERSOON'S EN HUISHOUDEN'S GEGEVENS

1. Wat is uw leeftijd?..... jaar
2. Wat is uw geslacht? ☐ Man ☐ Vrouw
3. Vult u s.v.p. de volgende gegevens in over uw en uw partner's opleiding en werk status. Als u geen partner heeft of hij of zij woont niet samen met u, dan kunt u de tweede kolom overslaan. Bij opleiding s.v.p. **hoogst genoten opleiding** invullen.

	U	Uw Partner
Hoogst voltooide opleiding	<div><input type="checkbox"/> Geen</div> <div><input type="checkbox"/> Basisschool</div> <div><input type="checkbox"/> IBO/VBO/ITS/VMBO</div> <div><input type="checkbox"/> MAVO/ULO/MULO</div> <div><input type="checkbox"/> HAVO/MMS</div> <div><input type="checkbox"/> VWO/Atheneum/Gymnasium</div> <div><input type="checkbox"/> MBO</div> <div><input type="checkbox"/> HBO/Bachelor</div> <div><input type="checkbox"/> Universitaire opleiding</div> <div><input type="checkbox"/> Anders, namelijk.....</div>	<div><input type="checkbox"/> Geen</div> <div><input type="checkbox"/> Basisschool</div> <div><input type="checkbox"/> IBO/VBO/ITS/VMBO</div> <div><input type="checkbox"/> MAVO/ULO/MULO</div> <div><input type="checkbox"/> HAVO/MMS</div> <div><input type="checkbox"/> VWO/Atheneum/Gymnasium</div> <div><input type="checkbox"/> MBO</div> <div><input type="checkbox"/> HBO/Bachelor</div> <div><input type="checkbox"/> Universitaire opleiding</div> <div><input type="checkbox"/> Anders, namelijk</div>
Werk status	<div><input type="checkbox"/> Werkend</div> <div><input type="checkbox"/> Werkzoekend</div> <div><input type="checkbox"/> Studerend</div> <div><input type="checkbox"/> Gepensioneerd</div> <div><input type="checkbox"/> Geen werk</div>	<div><input type="checkbox"/> Werkend</div> <div><input type="checkbox"/> Werkzoekend</div> <div><input type="checkbox"/> Studerend</div> <div><input type="checkbox"/> Gepensioneerd</div> <div><input type="checkbox"/> Geen werk</div>
Iniden werkend, vult u s.v.p. in:		
Aantal uren werk per week		
Beroep		

4. Wat is de postcode van uw woonadres?
5. Hoe lang woont u al op dat adres?.....jaar (jaren).....maand(en)

6. Wat voor type woning is het?
☐ Appartement ☐ Rijtjeshuis ☐ Twee-onder-één-kap
☐ Hoekhuis ☐ Vrijstaand huis ☐ Groepswooning/studentenhuis
☐ Anders, namelijk
7. U bent :
☐ Ik woon alleen ☐ Samenwonend met partner, zonder kinderen
☐ Samenwonend met partner en kinderen ☐ Alleenstaande ouder met thuis wonende kinderen
☐ Samenwonend met ouders ☐ Samenwonend met kamergenoten
☐ Anders, namelijk
8. Vult u s.v.p. aantal leden van uw huishouden inclusief kinderen (inclusief uzelf).
.....aantal volwassenaantal kinderen (beneden 18 jaar)
9. Waanneer heeft u uw ouderlijk huis verlaten ?
.....maand.....jaar
10. Heeft u een rijbewijs?
☐ Ja ☐ Nee
11. Is er tenminste één auto aanwezig in uw huishouden?
☐ Ja, hoeveel?..... ☐ Nee
12. In hoeverre heeft u de beschikking over een auto?
☐ Altijd ☐ In overleg met mijn partner of andere leden van het huishouden
☐ Alleen voor speciale behoeften, zoals.....
☐ Nooit ☐ Niet van toepassing (geen rijbewijs)

13. Wanneer bent u gehuwd / partnerschap aangegaan / samen gaan wonen / uit elkaar gegaan / gescheiden? maand jaar

14. Noteer een schatting van uw sociale netwerk inclusief uw eigen familieleden en kinderen.

Aantal mensen nu	
Familie	
Vriend	
Buurtgenoot	
Anders	

DEEL II: UW VERANDERDE SOCIALE NETWERK

De volgende vragen hebben te maken met de veranderingen die u heeft meegemaakt na uw huwelijk / partnerschap / samenwonen / uit elkaar gaan / scheiding. Houdt dit alstublieft in gedachten bij het antwoorden van de volgende vragen. Deze vragen (15-17) zijn het belangrijkste deel van het enquête. Vul het met oprechtheid in a.u.b.

15. Noteer de volgende gegevens alleen voor de relaties die u nieuw heeft opgedaan of die juist veranderd zijn als gevolg van de gebeurtenis (samenwonen/huwelijk/scheiden, enz). Begin met nieuwe contacten (gebruik de codes zoals vermeld).

Nieuwe contacten: U kunt nieuwe mensen ontmoet hebben wanneer u getrouwd bent / partnerschap bent aangegaan / bent gaan samen wonen / uit elkaar bent gegaan / bent gescheiden. Hier noemen wij die uw toegenomen sociale netwerk. Vult u alstublieft '0' in bij 'VOOR' om aan te geven dat het een nieuw contact betreft.

Veranderde contacten: Wellicht heeft u veranderingen in de frequentie waarop u contact hebt met uw sociale netwerk nadat u getrouwd bent / partnerschap bent aangegaan / bent gaan samenwonen / uit elkaar bent gegaan / bent gescheiden. Met sommige mensen heeft u wellicht minder of helemaal geen contact meer. Daarover willen wij graag meer weten door deze vragen. Vult u ook deze velden in voor uw veranderde sociale netwerk. U kunt een '0' invullen in de kolom 'NU' om aan te geven dat het om een verloren contact gaat.

Als heeft u geen veranderde contacten vult u dan 'geen' hier ☐

1	2	3	4	5	6	7	8	9	10	11	12
Persoon (vul de initialen in voor uw eigen overzicht)	Leeftijd (in jaar) 1=0-9 2=10-19 3=20-29 4=30-39 5=40-49 6=50-59 7=60-69 8=70-79 9=80 of ouder	Geslacht 1=man 2=vrouw	Relatie 1=ouders 2=partner 3=kind 4=familie 2=vriend 3=buurtgenoot 4=collega 5=kennis 6=andere	Hoogst genoten opleiding 1=Geen 2=Basisschool 3=IBO/VBO/ITS/VMBO 4=MAVO/ULO/MULO 5=HAVO/MMS 6=VWO/Atheneum/ Gymnasium 7=MBO 8=HBO/Bachelor 9=Universiteit 10=Anders 11=onbekend	Datum laatste contact (jaar)	Hoe ver ze wonen van u (in km)?	Hoe lang (in jaar)	Hoe sterk is uw band met hem/haar? Geef u dit s.v.p. aan op een schaal van 1 tot 5. 1=heel zwak.....5=heel sterk	Hoe vaak hebben jullie contact? FACE TO FACE NU 1=dagelijks 2= 2-3 keer of vaker/week 3=eens/ week 4=2-3 keer of vaker/ maand 5=eens/maan d 6=minder 7= geen	Hoe vaak hebben jullie contact? TELEFOON/INTERNET NU 1=dagelijks 2= 2-3 keer of vaker/week 3=eens/ week 4=2-3 keer of vaker/ maand 5=eens/maan d 6=minder 7= geen	
1											
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Persoon 1 (vul de initialen in voor uw eigen overzicht)	Leeftijd (in jaar) 1=0-9 2=10-19 3=20-29 4=30-39 5=40-49 6=50-59 7=60-69 8=70-79 9=80 of ouder	Geslacht 1=man 2=vrouw	Relatie 1=ouders 2=partner 3=kind 4=familie 2=vriend 3=buurtgenoot 4=collega 5=kennis 6=andere	Hoogst genoten opleiding 1=Geen 2=Basischool 3=IBO/VBO/ITS/VMBO 4=MAVO/ULO/MULO 5=HAVO/MMS 6=VWO/Atheneum/ Gymnasium 7=MBO 8=HBO/Bachelor 9=Universiteit 10=Anders 11=onbekend	Datum laatste contact (jaar)	Hoe ver ze wonen van u (in km)?	Hoe lang (in jaar)	Hoe sterk is uw band met hem/haar? Geef u dit s.v.p. aan op een schaal van 1 tot 5. 1=heel haar? zwak.....5=heel (jaar) sterk	Hoe vaak hebben jullie contact? FACE TO FACE NU VOOR 1=dagelijks 2= 2-3 keer of vaker/week 3=eens/ week 4=2-3 keer of vaker/ maand 5=eens/maan d 6=minder 7= geen	Hoe vaak hebben jullie contact? TELEFOON/INTERNET NU VOOR 1=dagelijks 2= 2-3 keer of vaker/week 3=eens/ week 4=2-3 keer of vaker/ maand 5=eens/maan d 6=minder 7= geen
13										
14										
15										
16										
17										
18										
19										
20										

DEEL III: UW SOCIALE NETWERK

16. Noteer de volgende gegevens over uw 20 nauwe contacten, buiten uw eigen gezin om. Begin met uw **nauwe contacten** en daarna uw **redelijk nauwe contacten**. Zij kunnen uw uitgebreide familie zijn, buren, vrienden, enz. Met **nauwe contacten** bedoelen we de mensen waarmee u de belangrijkste informatie deelt, persoonlijke problemen / zaken mee bespreekt, bij wie u advies zoekt of om hulp vraagt bij noodgevallen / dagelijkse nodigheden en mensen waar u regelmatig contact mee heeft. Sla alstublieft de contacten over die u al in de vorige vraag (vraag 15) heeft vermeld.

Leeftijd (in jaar)	Geslacht	Relatie	hoogst opleiding	genoten	Hoe ver ze wonen van u (in km)?	Hoe lang (in jaar) kent u hem/haar?	Datum laatst contact (jaar)	Hoe sterk is uw band met hem/haar? Geeft u dit s.v.p. aan op een schaal van 1 tot 5. 1=heel zwak.....5=heel sterk	Hoe vaak hebben jullie contact?	
1=0-9	1=man	1=familie	1=Geen						Face to face	Per telefoon/web
2=10-19	2=vrouw	2=vriend	2=Basisschool						1=dagelijks	1=dagelijks
3=20-29		3=buurtgenoot	3=IBO/VBO/ITS/VMBO						2= 2-3 keer of vaker/week	2= 2-3 keer of vaker/week
4=30-39		4=collega	4=MAVO/ULO/MULO						3=eens/ week	3=eens/ week
5=40-49		5=kennis	5=HAVO/MMS						4=2-3 keer of vaker/ month	4=2-3 keer of vaker/ month
6=50-59		6=anders	6=VWO/Atheneum/Gym						5=eens/month	5=eens/month
7=60-69			7=VBO		1=<1				6=minder	6=minder
8=70-79			8=HBO/Bachelor		2=1-2				7= geen	7= geen
9=80 of ouder			9=Universiteit		3=2-5					
			10=Anders		4=5-15					
			11=onbekend		5=15- 30					
					6=30- 60					
					7=60- 100					
					8=100- 200					
					9=>200					
1										
2										
3										
4										
5										

Leeftijd (in jaar)	Geslacht 1=man 2=vrouw	Relatie 1=familie 2=vriend 3=buurtgenoot 4=collega 5=kennis 6=andere	hoogst opleiding 1=Geen 2=Basisschool 3=IBO/VBO/ITS/VMBO 4=MAVO/ULO/MULO 5=HAVO/MMS 6=VWO/Atheneum/Gym 7=MBO 8=HBO/Bachelor 9=Universiteit 10=Anders 11=onbekend	Hoe ver ze wonen van u (in km)? 1=<1 2=1-2 3=2-5 4=5-15 5=15- 30 6=30- 60 7=60- 100 8=100- 200 9=>200	Hoe lang (in jaar) kent u hem/haar?	Datum laatst contact (jaar)	Hoe sterk is uw band met hem/haar? Geeft u dit s.v.p. aan op een schaal van 1 tot 5. 1=heel zwak.....5=heel sterk	Hoe vaak hebben jullie contact?	
								Face to face	Per telefoon/web
6								1=dagelijks 2= 2-3 keer of vaker/week 3=eens/ week 4=2-3 keer of vaker/ month 5=eens/month 6=minder 7= geen	
7									
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15									

Leeftijd (in jaar)	Geslacht 1=man 2=vrouw	Relatie 1=familie 2=vriend 3=buurtgenoot 4=collega 5=kennis 6=anders	hoogst opleiding 1=Geen 2=Basisschool 3=BO/VBO/ITS/VMBO 4=MAVO/ULO/MULO 5=HAVO/MMS 6=VWO/Atheneum/Gym 7=MBO 8=HBO/Bachelor 9=Universiteit 10=Anders 11=onbekend	genoten ze wonen van u (in km)?	Hoe ver (in jaar) kent u hem/haar?	Datum laatst contact (jaar)	Hoe sterk is uw band met hem/haar? Geef u dit s.v.p. aan op een schaal van 1 tot 5. 1=heel zwak.....5=heel sterk	Hoe vaak hebben jullie contact?	
1=0-9								Face to face	Per telefoon/web
2=10-19								1=dagelijks	1=dagelijks
3=20-29								2= 2-3 keer of vaker/week	2= 2-3 keer of vaker/week
4=30-39								3=eens/ week	3=eens/ week
5=40-49								4=2-3 keer of vaker/ month	4=2-3 keer of vaker/ month
6=50=59								5=eens/month	5=eens/month
7=60-69								6=minder	6=minder
8=70-79								7= geen	7= geen
9=80 of ouder									
16									
17									
18									
19									
20									

DEEL IV: VERPLAATSINGEN EN ACTIVITEITEN

17. In de volgende vraag willen we graag weten wat uw activiteiten en reisbewegingen vóór en na de gebeurtenis (gebeurtenis = huwelijk, samenwonen, etc) waren. Gaat u s.v.p. na welke activiteiten u zoal heeft en hoe u reist in een gemiddelde of normale week. Wanneer een activiteit of reis niet van toepassing is selecteert u dan 'geen' in de kolom Geen. Als er niets is veranderd voor een activiteit laat u dan de 'situatie na de gebeurtenis' rij leeg.

Als u 40 uur per week werkt, noteert u dan 40 in de activiteitsduur kolom. Denk aan uw laatste normale (niet vakantie)week en beantwoord alstublieft het volgende. Sommige activiteiten doet u wellicht in het weekend (b.v. vrienden/familie bezoeken, buitenshuis recreatie). Betrek deze hier ook bij. De eerste rij is een voorbeeld.

Activiteit	Hoe vaak en reistijd	Vervoermiddel L: Lopen F: Fiets B: Bus/tram/metro T: Trein AB: Auto als bestuurder AP: Auto als passagier A: Anders T: Thuis	Gemiddelde duur van de activiteit per week (uur)	Reistijd niet meegereke nd	Met wie A: Alleen S: Samen met anderen B: soms alleen soms met anderen	Als samen met anderen, dan hoeveel deelnem ers (u zelf niet meegere kend)?	Geen
Werk voor de gebeurtenis	Aantal keer per week per vervoermiddel	L 4 F 4	32		X		
	Gemiddelde reistijd (enkele reis in minuten)	5 10					
Werk na de gebeurtenis	Aantal keer per week per vervoermiddel	8 8	32		X		
	Gemiddelde reistijd (enkele reis in minuten)	10 20					
Werksituatie vóór de gebeurtenis	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
Werksituatie na de gebeurtenis	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
Onderwijs vóór de gebeurtenis	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						

Activiteit	Hoe vaak en reistijd	Vervoermiddel L: Lopen F: Fiets B: Bus/tram/metro T: Trein AB: Auto als bestuurder AP: Auto als passagier A: Anders T: Thuis	Gemiddelde duur van de activiteit per week (uur) Reistijd niet meegerekend	Met wie A: Alleen S: Samen met anderen B: soms alleen soms met anderen	Als samen met anderen, dan hoeveel deelnemers (uzelf niet meegerekend)?	Geen						
Onderwijs na de gebeurtenis	Aantal keer per week per vervoermiddel	L	F	B	T	AB	AP	O	T			
	Gemiddelde reistijd (enkele reis in minuten)											
	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											
Dagelijkse boodschappen, film huren, eten halen bij snackbar, chinees e.d. vóór de gebeurtenis	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											
	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											
Dagelijkse boodschappen, film huren, eten halen bij snackbar, chinees e.d. na de gebeurtenis	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											
	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											
Winkelen voor niet dagelijkse boodschappen vóór de gebeurtenis	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											
	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											
Winkelen voor niet dagelijkse boodschappen na de gebeurtenis	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											
	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											
Bezoeken van familie of vrienden vóór de gebeurtenis	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											
	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											
Bezoeken van familie of vrienden na de gebeurtenis	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											
	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											
Organiseren feest/evenement vóór de gebeurtenis	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											
	Aantal keer per week per vervoermiddel											
	Gemiddelde reistijd (enkele reis in minuten)											

Activiteit	Hoe vaak en reistijd	Vervoermiddel L: Lopen F: Fiets B: Bus/tram/metro T: Trein AB: Auto als bestuurder AP: Auto als passagier A: Anders T: Thuis	Gemiddelde duur van de activiteit per week (uur) Reistijd niet meegereke nd	Met wie A: Alleen S: Samen met anderen B: soms alleen soms met anderen	Als samen met anderen, dan hoeveel deelnem ers (u zelf niet meegere kend)?	Geen	
		L F B T AB AP O T		A S B			
Organiseren feest/evenement na de gebeurtenis	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
Bezoek bioscoop, theater, museum, concert, schouwburg vóór de gebeurtenis	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
Bezoek bioscoop, theater, museum, concert, schouwburg na de gebeurtenis	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
Recreëren in het groen (in park, natuur) vóór de gebeurtenis	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
Recreëren in het groen (in park, natuur) na de gebeurtenis	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
Sporten, fitness, zwem, sauna, schoonheidssalon bezoeken vóór de gebeurtenis	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						
	Aantal keer per week per vervoermiddel						
	Gemiddelde reistijd (enkele reis in minuten)						

Activiteit	Hoe vaak en reistijd	Vervoermiddel L: Lopen F: Fiets B: Bus/tram/metro T: Trein AB: Auto als bestuurder AP: Auto als passagier A: Anders T: Thuis	Gemiddelde duur van de activiteit per week (uur)	Met wie A: Alleen S: Samen met anderen B: soms alleen soms met anderen	Als samen met anderen, dan hoeveel deelnem ers (uzelf niet meegere kend)?	Geen					
Sporten, fitness, zwem, sauna, schoonheidssalon bezoeken na de gebeurtenis	Aantal keer per week per vervoermiddel	L	F	B	T	AB	AP	O	T		
	Gemiddelde reistijd (enkele reis in minuten)										
Bezoek aan postkantoor, bank, salon, bibliotheek, apotheek, etc. vóór de gebeurtenis	Aantal keer per week per vervoermiddel										
	Gemiddelde reistijd (enkele reis in minuten)										
Bezoek aan postkantoor, bank, salon, bibliotheek, apotheek, etc. na de gebeurtenis	Aantal keer per week per vervoermiddel										
	Gemiddelde reistijd (enkele reis in minuten)										
Internetten om te socialiseren, voor informatie, e.d. vóór de gebeurtenis	Aantal keer per week per vervoermiddel										
	Gemiddelde reistijd (enkele reis in minuten)										
Internetten om te socialiseren, voor informatie, e.d. na de gebeurtenis	Aantal keer per week per vervoermiddel										
	Gemiddelde reistijd (enkele reis in minuten)										
Overige georganiseerde activiteiten, club of verenigingsactiviteit (geen sport) vóór de gebeurtenis	Aantal keer per week per vervoermiddel										
	Gemiddelde reistijd (enkele reis in minuten)										
Overige georganiseerde activiteiten, club of verenigingsactiviteit (geen sport) na de gebeurtenis	Aantal keer per week per vervoermiddel										
	Gemiddelde reistijd (enkele reis in minuten)										

Activiteit	Hoe vaak en reistijd	Vervoermiddel L: Lopen F: Fiets B: Bus/tram/metro T: Trein AB: Auto als bestuurder AP: Auto als passagier A: Anders T: Thuis	Gemiddelde duur van de activiteit per week (uur) Reistijd niet meegerekend	Met wie A: Alleen S: Samen met anderen B: soms alleen soms met anderen	Als samen met anderen, dan hoeveel deelnem ers (zelf niet meegerekend)?	Geen
Anders, namelijk, vóór de gebeurtenis	Aantal keer per week per vervoermiddel	L F B T AB AP O T		A S B		
	Gemiddelde reistijd (enkele reis in minuten)					
Anders, namelijk, na de gebeurtenis	Aantal keer per week per vervoermiddel					
	Gemiddelde reistijd (enkele reis in minuten)					

18. Bent u lid van één of meer clubs of verenigingen? Hieronder verstaan we ook activiteiten als avondopleiding, avondcursus, muziekschool, e.d.

☐ Ja ☐ Nee

Zo ja, vult u s.v.p. onderstaande gegevens in. De eerste rij is een voorbeeld.

Naam van de club/vereniging	Type club/vereniging	Hoe vaak gaat u daar naartoe?
TU/e roeiclub	Sport	Aantal keer per maand

Naam van de club/vereniging	Type club/vereniging	Hoe vaak gaat u daar naartoe?

ZEER BEDANKT VOOR UW TIJD EN MOEITE!

¹ Please note that this is an example of the survey questionnaire for one life cycle event, i.e. change in civil status. Other life cycle events have the same questions except a few additions (such as, for the event of starting university we asked information about leaving parental home). The questionnaire was transferred into a web based version that differ in appearance (use of drop down menu for choice options, for instance).

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Dynamics of Social Networks and Activity Travel Behaviour

This research is based on two concepts, one is that social networks are dynamic and the second is that life trajectory events, social networks, and activity travel presumably have some level of interrelation. Relating to the evolution of egocentric social networks and activity travel behaviour, this study argues that present choices and behaviour are not independent of past actions. 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 employment means new colleagues and this may have direct or indirect (via the social network) effects on activity and travel scheduling. Conversely, a change in activity and travel schedule may also introduce modifications in one's time budget. This may promote or hinder the maintenance of social ties causing the social network and activity travel agenda to change. To that end, the study focuses on the interdependency of dynamics in social network and activity travel behaviour triggered by life cycle events. It relates to three domains, viz. activity and travel, social network and life cycle events, and the interdependencies among them aiming towards an integrated analytical framework. Empirical evidence were documented using data collected through an event-based retrospective survey.

The study contributes to a shift in focus by moving from short term behavioural analysis to mid and long term dynamics. In the context of policy formulation and practical application, the study contributes to the formation and application of dynamic activity and travel behaviour models. In particular it induces the importance of social networks in terms of how they are triggered and contextualised to the changes in life cycle events and how they can influence individual's travel behaviour.

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