MODELLING THE DYNAMICS BETWEEN SOCIAL NETWORKS AND ACTIVITY-TRAVEL BEHAVIOR: LITERATURE REVIEW AND RESEARCH AGENDA

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ABSTRACT

Social networks are evidently dynamic; they evolve continuously. Our circle of friends, neighbours and contacts keeps changing with our age and lifecycle events (e.g. marriage). So do our beliefs about our (cognitive) environment, later translated into our activity-travel behaviour. To understand long-term behaviour and decision changes, it is imperative to understand these patterns in a dynamic setting. In this paper, we review the state of the art in travel behaviour research related to social networks and put forward our research concept for a project that is part of a larger research program which aims at developing dynamic activity-based models.

Keywords: Dynamic, Social Network, Activity Travel Behaviour, Literature Review

INTRODUCTION

In travel behaviour 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. Then, the concern shifted from a trip-based to activity-based approach incorporating activity duration, frequency, location, etc. The concept was further widened towards joint activity scheduling and rescheduling. Hence time and task allocation at the household level was incorporated in the models (e.g. Borgers,

Hofman and Timmermans, 2002, Ettema, Schwanen and Timmermans, 2004, Zhang, Timmermans and Borgers, 2005). However, joint activities do not only involve household members, but may also include members of 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) notes:

> *Instead of relying exclusively on the generalised costs of travel and the hedonic utility of a location as modulated by the sociodemographics 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.*

Tthe relationship between social networks and travel has been subject of an increasing number of studies in recent years (e.g., Carrasco and Miller, 2005; Hackney and Axhausen, 2006; Silvis, Niemeier and D'souza, 2006, Páez, Scott and Volz 2008; Van den Berg, Arentze and Timmermans, 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 more dynamic activity model analysis, focusing on behavioural adaptability with response to demographic, social and policy changes. This is also a research frontier for transportation as the evolving nature of social networks and corresponding activity travel agendas have not been addressed in any detail in transportation research. This paper proceeds with the aim to draw attention to this issue with a comprehensive review of previous research in this field and a discussion of promising avenues of future research.

Social networks induce, alter and even constrain travel. And 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 keep changing as we age and lifecycle events (e.g. marriage) happen. And so do our beliefs about our environment, later translated into our activity-travel behaviour. 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. (2007) 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 behavior. Páez and Scott (2004), Hackney and Axhausen (2006) also used less complicated simulation approaches to demonstrate the possible 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 (Watts, 1999 and Hummon, 2000), but it is not readily evident how such research can be elaborated to fit the agenda in transportation research.

To this end, in this paper we review the contemporary researches on social networks and travel and reason the way forward, i.e. the need to explain evolving social networks and corresponding changes in activity behaviour. We also argue the constraints and benefits of incorporating these dynamics and suggest our future endeavours in this regard.

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. Formal relations are social relations due to ones position and roles in society. It includes professionals and acquaintances. Social network is individuals and linkages between individuals with whom one has a close family 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 project, 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 (e.g., Ohnmacht, 2009). For short and mid-term mobilities we depend on our social networks as they form our social support system (spatial aspect) and a reliable information source (a-spatial aspect). As far as long-term mobility is concerned (such as, residential mobility) social networks can influence through local social capital neighbourhood attachment (spatial aspect). Thus, social networks might be considered to have two broad dimensions (or aspects): spatial and a-spatial, by means of which they influence mobility decisions (Figure 01). 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.

Spatial dimension of social networks

The spatial dimension is related to the arrangement of support systems (physical and emotional), place attachment and physical social interactions. Social support systems work through social networks, particularly crucial for families with children and for elderly residents. Social networks could have a significant influence on short-term mobility decisions, for example, by taking care of children, pets, by watching the house, car, plants. Wellman and Frank (2000) report that the probability of giving and receiving support (and

consequently travel behaviour) depend on the characteristics of social networks. 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 kinship is not in decline in complex societies; for daily life problems and crises management people turn to family and kin. In Chinese cities, 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). Ethnic affiliation has also been considered in social support studies. A study of Hispanic Americans, for instance, showed that kin and local ties are more important than neighbours and friends are for socializing only (Schweizer, Schnegg and Berzborn, 1998). To this end, social support systems 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, 2000). One could 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). It could also be that cultural differences are of significance here (Molin and Timmermans, 2003), who found that, on average, these factors were less important in the Netherlands.

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, 2000). 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. For some households, the friendly contacts in the neighbourhood apparently function as a form of self-selected kinship. Many families talked with enthusiasm about their pleasant neighbours: "If it weren't for my neighbours, I might have moved away a long time ago" (Karsten, 2007). Local social ties may also influence one's decision to move out of one's existing neighbourhood. Many have referred to this hypothesized linkage between local social ties and residential immobility as the 'affinity hypothesis' (e.g., Ritchey, 1976; Connerly, 1986). 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, 2000).

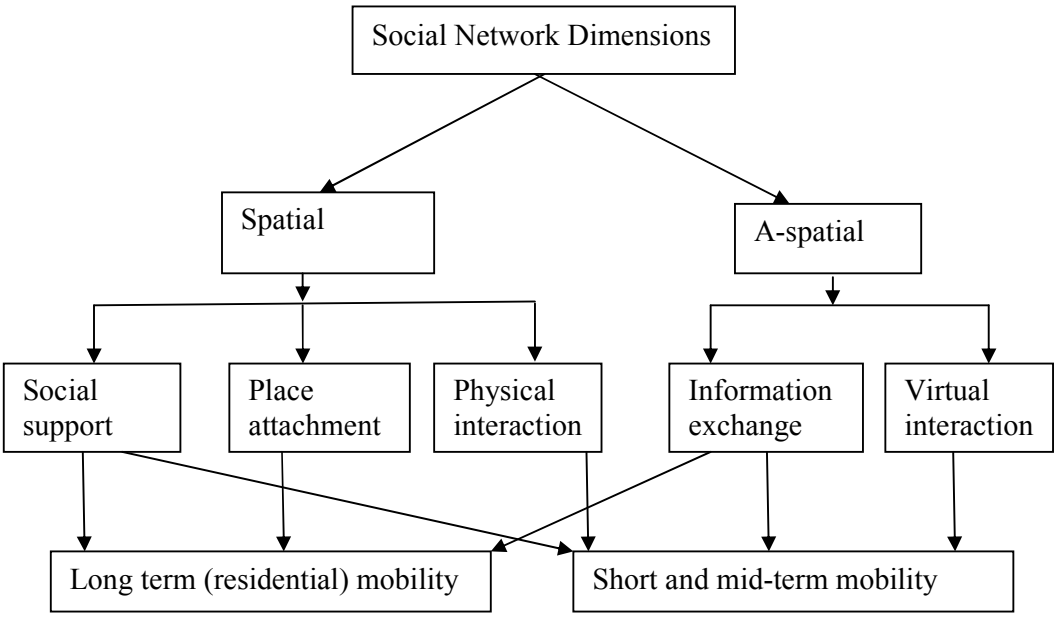

Figure 01: Dimensions of Social Network

The third component of the spatial dimension of social networks is local physical social interaction. In most cases, social activities are conducted with someone else. 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.

A-spatial dimension of social networks

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 (e.g., Ettema, Arentze and Timmermans, 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 (Roper, Volker and Flap, 2008) and greater social diversity could assist in finding a job (Stoloff, Glanville and Bienenstock, 1999). Information dissemination could also change people's attitudes and perceptions leading to changes in travel behaviour decisions (Han et al, 2007; Molin, Arentze and Timmermans, 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 (Shklovski and Mainwaring, 2005; Shklovski, Kraut and Cummings, 2006; Axhausen and Frei, 2008;). 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 and Dijst, 2007). 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.

SOCIAL NETWORKS IN TRAVEL BEHAVIOUR RESEARCH

As far as the incorporation of social networks in the travel behaviour literature is concerned, two broad categories can be distinguished. First, the influence of social networks on travel behaviour has been empirically analyzed. Second, numerical simulations with partial or complete hypothetical data have been used to demonstrate the potential and relevance of social networks in travel behavior. These fields are discussed here separately.

Empirical studies

Seminal empirical work in transportation on social networks has been conducted by Carrasco and his co-workers (Carrasco and Miller ,2005; Carrasco et al., 2008 and Carrasco, Miller and Wellman, 2008). Their 'connected lives study' 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. Moreover, network ties are important issues as is network structure, which defines the relationship with ego and attributes of alters as well. Finally, how ICT could play a role in social activity is put forward. They pointed out that locational attributes were out of scope, only distance is considered in terms of spatial context. And as Axhausen and Frei (2008) noted, they have primarily focused on trip generation effects of the structure of social networks.

In a recent study 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.

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 frequent 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 is remained for further investigation.

Axhausen (2008) argues 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.

A few studies are ongoing. For example, van den Berg, Arentze and Timmermans (2009, 2010) have reported the first analyses of their social interaction diary and social network data collected in Eindhoven in 2008. Instead of name generators, they used a social interaction diary for social network data. They examined the impact of ICT on social travel behaviour and report that the results differ significantly from a previous study conducted by Molin, Arentze and Timmermans (2007), 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.

In previous studies, social interaction diaries were commonly used. Silvis (et al., 2006) used a similar social interaction diary in Davis. Rather than 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 to visit 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 test 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 also 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.

Simulation frameworks

The interplay between social networks and travel behaviour has been explored in travel behaviour research, but 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. Although given the recency of inclusion of 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 require which is difficult within limited resources. However, using synthetic data some simulation studies have been conducted to account for network dynamics. In this section, we present a brief overview of that literature.

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. Here they consider the interdependencies between individual's choice and the aggregate decision of socio-economic networks in close proximity. Using pseudo-panel microdata collected by the Amsterdam Agency for Traffic, Transport and Infrastructure they extended standard 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 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 action on individual decision. 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) a similar methodology was applied for decisions about telecommuting to consider social influence on travel behaviour.

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., (2007) 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. This research opens the scope for empirical analysis which is not done at this level. Here the structure of the social network and its characteristics are not incorporated. In consideration of long-term dynamics, dynamics of social networks must be a significant advancement to the model.

Hackney (2007) and Hackney and Axhausen (2006) developed a multi-agent representation, incorporating dynamics of social network, by addition and deletion of links, based on feedback through activity choice sets. They accounted for homophily, and associations and assume some maximum number of contacts per agent.

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 (2009), which can best be seen of an extension of this line of work, focusing on numerical simulation.

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.

CONCEPTUAL FRAMEWORK

Social networks are dynamic. People do not have the same circle of friends and neighbours all their life. With age, education, job, marriage and other lifecycle 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 come the nature of the social network changes again and so on.

In the field of sociology, demography and anthropology the need for constructing a dynamic social network has been realized a number of times (e.g., Hummon, 2000; Stoloff et al., 2008). The attempts made so far are fragmented and focused on specific groups or parts of the life cycle. It is plausible that with age and life cycle events the size and diversity of social networks change. 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 lifecycle can be explained by an inverted-U shaped curve (Kan, 2007).

Nevertheless, networks do evolve with socio-demographic status and life-cycle events. These changes in social networks are most likely to affect long-term mobility and short-term activity-travel decisions. These arguments can be conceptualized as in the following diagram. We hypothesize that with changing socio-demographics and with life-cycle events, social network (and corresponding social support system) changes, having an impact on our activity-travel behaviour, both direct (frequency and duration of contact, use of ICT) and indirect (exchange of information).

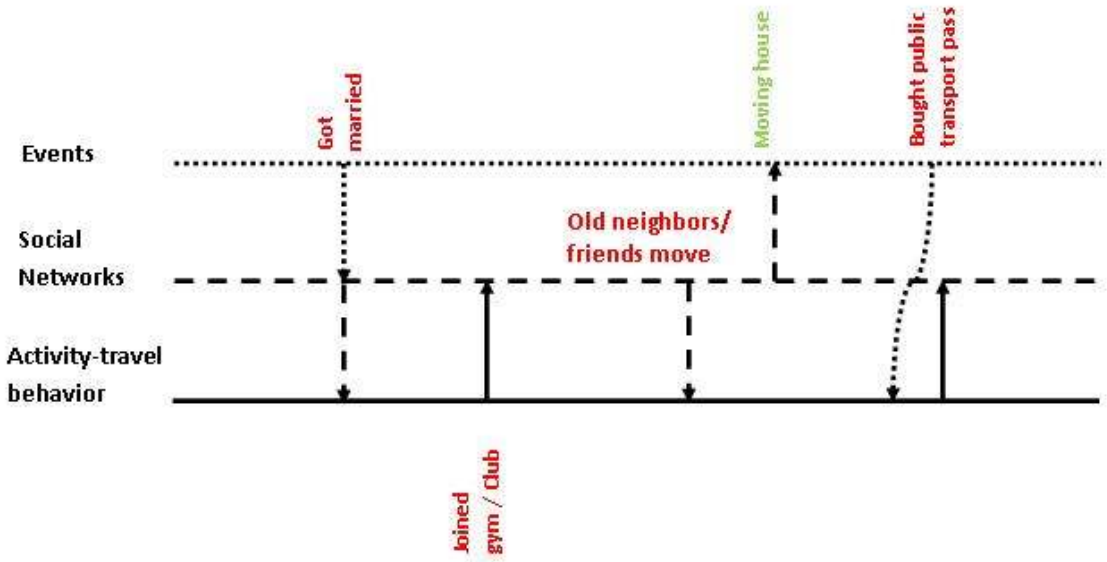

Figure 02: conceptual framework to capture the dynamics of social network and travel behaviour

Hence, we conceptualize 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, we hypothesize that 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.

CONCLUDING REMARKS

As part of a larger research program on developing dynamic activity based models, this paper has argued for the need to expand the recent studies on social networks in the transportation research community to include the *dynamics* of social networks. The results 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 influence travel demand.

However, social networks, especially the network of friends, are not static but change with particular lifecycle 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 seriously 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 frequency and nature of changes in social networks, triggered by lifecycles 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. We have set out collecting such data. We plan to report on empirical findings in future publications.

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