



Social interactions in transportation: analyzing groups and spatial networks

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Introduction

Travel demand is derived from activities that people have to or want to engage in. Work trips have been a primary concern for transportation researchers and an early focus of transportation modeling was on commuting behavior (Ben-Akiva and Lerman 1974; Train 1980). Subsequently, non-work activities, such as shopping or doctor visits, increasingly caught the attention of transportation analysts, and interest shifted from a trip-purpose approach (i.e. work trips) towards scheduled-based travel analysis (Bhat and Koppelman 1999). However, these activity trips all have in common that they still could be modeled without considering social context. The analysis approach of choice behavior was rooted in neoclassical economics assuming methodological individualism of isolated, utility-maximizing agents (Small and Winston 1999).

While using the traditional neoclassical tool box, much has been learned about journeys to work and trip scheduling for non-work activities. Early research in intra-household interactions in travel demand modeling focused on coordination of individual daily activity patterns, joint participation in activities and travel, mechanisms for allocation of maintenance activities, and activity location and residential location choice behavior (Scott and

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Kanaroglou 2002; Gliebe and Koppelman 2002, 2005; Bradley and Vovsha 2005; Srinivasan and Bhat 2005; Bhat and Pendyala 2005; Timmermans and Zhang 2009; Arentze and Timmermans 2009). It is more recently that a social context of traveling choices, such as meeting friends, visiting events (i.e. sport games, concerts, theater, etc.), or engaging in other social activities (church, sports club, volunteering), has begun to receive attention and has been integrated into activity-based modeling (Arentze and Timmermans 2008; Ronald et al. 2012). This mirrors an important development in many regions around the world where the share of leisure trips is rising. It is one main motivation why transportation researchers have become more interested in studying personal and activity networks in general, as well as in adopting a social network perspective in transportation research specifically (Kowald and Axhausen 2015). A parallel development has been on modeling social influence where other social science approaches, including network analysis or social interaction modeling, increasingly are adopted as a complement to the traditional utility-maximizing approach in travel demand analysis (Bhat and Sener 2009; Abou-Zeid and Ben-Akiva 2011; Bhat and Sidharthan 2011; Sidharthan et al. 2011; Walker et al. 2011; Goetzke and Weinberger 2012; Whalen et al. 2012; Kamargianni et al. 2014; Kroesen 2015).

The basic idea of bringing social networks into transportation analysis is straightforward: An increasing number of trips today are undertaken that no longer can be seen as if they were individualistic and disconnected as neoclassical theory assumes, but should rather be seen in a web of social relations and context (Dugundji and Walker 2005; Páez and Scott 2007; Carrasco and Miller 2006, 2009; Axhausen 2008; Arentze and Timmermans 2008; Goetzke 2008). In this context, a distinction can be made between identifiable versus aggregate interactions (Dugundji and Gulyas 2003a, b).

- We speak of interaction between “identifiable” decision-makers when the links in the network are well-known and explicitly defined on an individual decision-maker by decision-maker basis. For example, working parents may have to negotiate who drops off their child at school or who picks their infant up from nursery (Schwanen 2008; Ho and Mulley 2015). Likewise, the fastest growing segment of travel, leisure trips, requires knowledge of social context for the analysis of travel demand (Kowald and Axhausen 2012). An understanding of friendship networks will help predicting how often, when and where friends meet, and thus the corresponding generated trips (Carrasco et al. 2008; Kowald et al. 2013).
- We speak of interaction between “aggregate” decision-makers when interdependence is assumed to take place only at an aggregate level with links being defined by implicit networks, for example, more generally based on decision-maker characteristics, by latent constructs or by studying behavior of abstract classes of social and/or spatial networks. Some explorations of the dynamic behavior of such a model include Páez et al. (2008), Dugundji and Gulyás (2008, 2013). Some examples of the empirical estimation of such a model include Fukuda and Morichi (2007), Adjemian et al. (2010), Bhat et al. (2010), Sener et al. (2010), Goetzke and Andrade (2010), Goetzke and Rave (2011), Kuwano et al. (2011), (2012). Dugundji and Gulyás (2012a, b), Scott et al. (2012), Sener and Bhat (2012), Sidharthan and Bhat (2012), Paleti et al. (2013)

In order to exchange and further develop this research, an interdisciplinary group of scholars and practitioners came together in 2005 for the first “International Workshop: Frontiers in Transportation—Social and Spatial Interactions” in Amsterdam, Netherlands (Dugundji et al. 2008), followed by another workshop 2 years later again in Amsterdam, Netherlands (Dugundji et al. 2011). The next two workshops, in 2009 (Dugundji et al. 2012) and in 2011 (Scott et al. 2013) were held in Niagara-on-the-Lake, Canada. In 2013

an important survey article on mass effects and mobility decisions summarized research progress in the field (Abou-Zeid et al. 2013). In 2014, a special issue on social context of travel behavior was also published (Carrasco and Farber 2014). Taken together this shows the steady maturity of research questions on social networks, interactions and spillovers in transportation during the last decade.

The contributions

The eight papers collected in this special issue are a selection of the work presented during the International Workshop “Frontiers in Transportation – Social Interactions” at Herrsching am Ammersee near Munich, Germany, which was held in 2013. The topics represent the breadth of the research in the field of social interactions in transportation, spanning analysis of groups and spatial networks, and identifiable and aggregate interactions. The relations between these papers can be roughly conceptualized as in Table 1.

The first four papers in this special issue deal primarily with socio-group networks. This research focuses on non-spatial relations between people, and how their interactions influence travel behavior. Two of these articles are motivated by a goal of incorporating social network dynamics, and decisions made in inter- and intra- household networks, in travel behavior simulation models. Sharmeen et al. (2015) develop a dynamic life cycle event model of friendship using a random utility maximization framework to predict the formation of a tie between two individuals. Using a Dutch dataset, the authors find that homophily as well as geographic proximity play an important role in the formation of friendship networks. This kind of research can be used, for example, to forecast recreational trips within a travel behavior simulation model.

Dubernet and Axhausen (2015) develop a game theoretic framework for the study of joint decision making and present a validation run where intra-household interactions are included into the MATSim activity-based, multi-agent travel microsimulation tool. Using data from the Zürich, Switzerland area and focusing on the possibility of joint trips, they find that the simulation performs reasonably well replicating the passenger mode shares for mandatory trips, but less so for discretionary trips.

The second two articles have an empirical focus with attention to policy implications. The study by Matous et al. (2015) centers on information diffusion in personal networks. Based on data of rural Indonesian coffee and cacao farmers, the authors investigate how agricultural information is obtained. The mode of contact could be telecommunication (mobile phone), walking or motorized transportation (mainly motor bikes). Applying a hierarchical logit model, complemented by in-depth interviews, their results reveal the following insights: the farmers strongly favor face-to-face contact; and mobile phones are predominately used to arrange and coordinate meetings with distant information sources.

Table 1 Social interactions in transportation: Contributions in this special issue

Social interactions in transportation	Identifiable individuals/agents	Aggregate effects
Socio-group networks	Sharmeen (2015); Dubernet and Axhausen (2015)	Matous et al. (2015); Goetzke and Rave (2015)
Networks which have socio-spatial characteristics	Van den Berg (2015); Joubert and Meintjes (2015)	Okushima (2015); Bhat (2015)

Also, the farmers prefer motorized transportation relative to walking to save time when contacting distant information sources. Motorbikes enable the farmers to reach outside the circle of their strong relationships which are maintained by walking and facilitate social contact between diverse communities. Furthermore, people with motorbikes have significantly more extensive extra-communal access to information and weak evidence suggests that they also have less contact within their communities.

Peer networks, defined by age group, education attainment and residential location, are the research topics of the article by Goetzke and Rave (2015). Based on German data and using a happiness regression approach, they investigate how much peers' average automobile availability has an impact on a person's quality of life. They find that, in general, subjective well-being increases with own automobile access, but decreases with peers' higher automobile access. However, when own automobile access is measured as the deviation from the peers' access, the results point to the fact that especially the difference in automobile availability with respect to peers makes a person worse off. Therefore, happiness depends on whether a person and the peers are in a similar situation or not. This finding supports the idea that automobile ownership poses a "positional" externality.

The remaining four papers deal predominately with networks which have socio-spatial characteristics, such as neighborhood or distance relations. Two of these studies focus on local and "small-world" networks, which combine the spatial with the previously discussed social group characteristics. Van den Berg et al. (2015) examine to what extent local social interactions are affected by characteristics of the residential environment as well as personal and mobility attributes. Based on a two-day social interaction diary for residents in the Eindhoven, Netherlands metro area and using a multi-level binomial logit model, the authors conduct an analysis of whether or not an interaction took place within the immediate neighborhood. They find that contact with a fellow local resident is increasing for older people, females, larger households and full-time employed, but is decreasing for households with more vehicles, and somewhat, for longer commuting time. Social interactions also correlate positively with the existence of a nearby supermarket, primary school and outdoor sport facility, as well as with suburban residential location (outside of the central city Eindhoven).

Small-world networks use spatial proximity in graphs to represent social interaction. This is the approach taken by Okushima (2015), who investigates the shift towards sustainable mobility choices among heterogeneous agents. He uses outcomes from a stated preference questionnaire to estimate a binary mode choice model for car versus sustainable transport (bus rapid transit)., the author subsequently feeds the results into a multi-agent simulation model and finds that many households show conformity in their mobility choices, however, when allowing for heterogeneity among agents, also non-conformity is observed. In addition, the simulation reveals that heterogeneity decreases share of sustainable transport. The simulation model also supports the idea that green tax policies are superior to cordon pricing and distance-based pricing in terms of achieving higher sustainable transport mode share.

The last two articles are methodological in nature. Joubert and Meintjes (2015) investigate the properties of freight networks. Using GPS-based truck origin–destination data for the Nelson Mandela Bay Municipality in South Africa, linked with facility location, the authors create a complex network, resembling the interactions between firms in a supply chain system, which they then studied using network analysis tools. Having nodes signifying firms and the edges of the network representing the connections between firms, they evaluated how density-based clustering parameters influence the completeness of the network, as well as the computational burden of the network. These results are

valuable to understand the capacity of current software and computer technology in conveniently implementing analysis methods that can introduce a social/spatial network perspective to transportation studies.

Bhat (2015) develops a spatial multinomial probit technique that extends the traditional panel discrete choice model to include social/spatial dependencies. This formulation accommodates spatial drift effects, which consists of both the spatial structure on individual-specific unobserved preference as well as the spatial structure on individual-specific response sensitivity, and is originating from endogenous group formation. This mode choice model approach allows for the possibility of residential self-selection (or spatial drift) of individuals based on mode-use propensities. In a simulation study the author finds that the estimator is efficient and the asymptotic formula performs well in estimating the finite sample standard errors. Furthermore, the results highlight the bias in estimates if spatial lag and/or spatial drift effects are ignored when both are actually present.

Moving forward

While the research subjects of all eight studies are diverse, they all use empirical data and/or quantitative methods. The themes of these papers provide an overview of how broad the topics are, reaching from studying the diffusion of agricultural information in Indonesia, to identifying peer effects in Germany, to analyzing sustainable mobility in Japan, to measuring the relation between social contact distance patterns, personal characteristics, mobility and the built environment in the Netherlands. Yet, at the same time, the approaches in the field of social interactions and transportation are unified. For example, more than half of the studies included in this special issue use survey-based micro data which are then analyzed with the help of discrete choice regression modeling.

Social interactions and transportation research has greatly benefited from bringing in concepts from other fields into their own subject area. Goetzke and Rave (2015) bring in the concept of positional externalities from public economics to their research on subjective well-being in travel behavior, which in itself draws on a stream of research in psychology. Also interesting to observe is how social spillover analysis borrows from spatial regression modeling, as demonstrated by Bhat (2015). Persons within a group or different groups are examined in analogy to more or less distant spatial neighbors. This helps addressing some of the otherwise difficult to solve issues and turns out to be a successful cross-fertilization of two sub-disciplines of econometrics. Matous et al. (2015) complement their quantitative analysis of a multilevel multivariate logistic model with qualitative data from classical semi-structured interviews from social science for a nuanced assessment of the impact of policies. Dubernet and Axhausen (2015) draw on co-evolutionary principles from natural computing to develop an algorithm to efficiently search approximate solutions for their framework for joint decision making, which in turn is inspired by game theory. Sharmeen et al. (2015) propose a model of social network evolution inspired by life course theory and concepts from social network analysis, in a novel cross-fertilization from sociology, which is then brought to a utility-maximizing framework. In a comprehensive multi-agent based social simulation model, Okushima (2015) uses results from combined revealed and stated preference estimation, a hierarchical Bayesian model and two hazard-based duration models.

It is encouraging to see new topics arise in the field of social interactions and transportation, such it is the case in this special issue in the paper which extracts and analyzes inter-firm supply chain networks in South Africa from traces of on-board GPS devices of

commercial vehicles. More of this innovative exploration of social network analysis applied to freight mobility as a complement to the stream of existing research in social interactions in passenger travel is welcome. Also, while a current focus in the field is on travel behavior and personal interactions in friendships, group and neighborhood networks, intra-household interactions, involving vehicle purchase decisions, activity choices, tour planning and the “governance” of mobility needs, as well as interactions in the society-at-large are less explored. Society-at-large interactions comprise inquiries, for example, about the link of social capital and transportation choices (Carrasco and Cid-Aguayo 2012), or social attitudes and transportation policies. At the same time, use of modern information and communication technology such as smart phones and social media applications provide a unique opportunity to collect mobility and social interaction behavior data longitudinally and at wide scale. We as the guest editors are looking forward to future studies addressing these research questions which are highly relevant for transportation planning applications and policy decision making.

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