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Social influences on household location, mobility and activity choice in integrated micro-simulation models

Dick Ettema[a,*], Theo Arentze[b], Harry Timmermans[b]

[a] Faculty of Geosciences, Utrecht University, PO Box 80115, 3508 TCUtrecht, The Netherlands
[b] Urban Planning Group, Eindhoven University of Technology, PO Box 513, 5600 MB Eindhoven, The Netherlands

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ABSTRACT

Agent-based approaches to simulating long-term location and mobility decisions and short-term activity and travel decisions of households and individuals are receiving increasing attention in land-use and transportation interaction (LUTI) models to predict land-use changes and travel behaviour in mutual interaction. Social interactions between households and between individuals potentially have an influence on a wide range of the long-term and short-term choices involved in these systems. In this paper we identify the areas in which social interactions play a role and address the question how these influences can be modelled in the context of agent-based LUTI models. We distinguish impacts on activity participation (joint activity participation, support-and-help activities) and impacts on decision making (information exchange, social adaptation of preferences and aspirations) as the two main areas of social influence. A prototype of a LUTI model is proposed that accounts for impacts of the social network on longer-term mobility decision making through information exchange and social adaptation of preferences and aspirations. The model is demonstrated in a numerical simulation.

1. Introduction

The use of land use and transportation models to support policy makers has become widespread over the past decades. During this period, a development has taken place in which traditional zone-based models (e.g. Lowry, 1963) have been replaced by more sophisticated models, such as models of urban development based on resource allocation theories (e.g. Anas and Xu, 1999). Recently, various scholars have proposed the use of micro-simulation models such as UrbanSim (Waddell, 2002), ILUTE (Miller et al., 2004), Ilumass (Strauch et al., 2005) and PUMA (Ettema et al., 2007). Whereas traditional zone-based models describe spatial development and traffic flows as the outcome of interactions between zones, micro-simulation models describe land use and transport processes at the level of the individual decision makers, such as households, individuals, firms and land owners. Although different in the details, the aforementioned models have in common that they describe how synthetic populations of households and jobs/firms are subject to demographic processes, economic development and deliberately take decisions about spatial behaviour such as locational decisions and daily travel. To this end, disaggregate models (e.g. discrete choice models or rule based models) are applied to the individual agents in the synthetic population. An important characteristic is that individual households and firms respond to changes in the aggregate conditions (e.g. prices) stemming from the aggregate decisions made by other agents. The use of micro-simulation models offers some important advantages over aggregate, zone-based models.

* Corresponding author.
E-mail addresses: D.Ettema@geo.uu.nl (D. Ettema), T.A.Arentze@tue.nl (T. Arentze), H.J.P.Timmermans@tue.nl (H. Timmermans).

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First, micro-simulation models are dynamic in nature, in contrast to traditional economic models that assume equilibrium and only describe the end state of a spatial system. In a policy environment where one is interested not only in the outcome of policies but also in the societal processes leading to this outcome, this is an important advantage.

Second, micro-simulation models describe behaviour at the level where decisions are made. The advantage of doing so is that modelling spatial behaviours (e.g. relocation decisions or trip generation) can be based on behavioural theories, such as discrete choice theory, time allocation theory, cognitive psychological theories or need based theory. To date, however, most micro-simulation LUTI models have applied rather rudimentary behavioural models, suggesting that there is considerable room for improvement in this respect. Recently, social networks have received increasing attention as a factor that influences individuals' activity and travel patterns (Carasco and Miller, 2006; Frei and Axhausen, 2007; Wellman et al., 2001). This raises the question to what extent incorporating social networks into LUTI models would strengthen their theoretical basis and provide advantages with respect to the quality of predictions or computational issues.

A first step in answering this question is to identify how social networks potentially impact on behaviours covered by LUTI models, such as activity participation, trip making, car ownership and the choice of residential and work location. In this respect, most examples of the influence of social networks on LUTI related processes reported in the literature concern activity participation. For instance, Carasco and Miller (2006) report that social links between individuals trigger social interaction, which often leads to activities and travel, such as social visits or trips to joint recreational activities. Characteristics of the link, such as similarity of the network members and kinship level, but also geographical distance, may influence the frequency of interaction. Molin et al. (2008) found significant influences of travel distance and socio-demographic variables on the frequency of social interactions. According to Tillema et al. (2007) the size and geographical configuration of social networks also impact on the interaction via telecommunication tools (phone, email), with a larger geographical distance between network members leading to fewer virtual and physical interactions. In terms of activity generation processes, this raises the question what utility is derived from social interaction. Goulias and Henson (2006) have investigated for whom individuals perform activities, suggesting that altruistic motives are important determinants of activity participation. In a similar vein, it can be argued that the utility derived from activities depends on the extent to which not only the own needs but also the needs of others are. In general, literature in this area suggests that characteristics of the social network may have a considerable impact on the decision to participate in certain activities. Applications of social networks in activity and travel models to date are scarce. An exception is a model developed by Arentze and Timmermans (2008) that describes the interaction between social interaction and the evolution of social networks. However, their model does not describe travel and activities in much detail.

Another strand of literature has discussed the influence of social interactions on choice set composition and decision-making. It is argued that, especially where spatial choices are concerned, individuals will usually not be aware of all alternatives and may be misinformed about the attributes of certain alternatives. By exchanging information through social interactions, individuals may update their knowledge about the existence and characteristics of certain alternatives (Han et al., 2007). Updated information may lead to in- or exclusion of an alternative in the choice set, since only alternatives that generate a minimum utility are part of the choice set. In this respect the concept of aspiration level is relevant (Festinger, 1954; Han et al., 2007). In particular, it is assumed that for all attributes minimum levels are defined that need to be met before an alternative is accepted as an alternative in the choice set. Hence, only alternatives that meet all aspiration levels will be considered. Through social interaction, individuals will adjust their aspiration levels. That is to say, if a social network member achieves a higher utility for a certain choice (e.g. a shopping destination), the aspiration levels of that other may be internalised, depending on the degree of similarity. A change in aspiration level may trigger a search for new choice alternatives.

A slightly different representation of the influence of others on an individual's or household's decision-making is found in Dugunji and Walker (2005), who let the valuation of attributes by one decision-maker depend on that of another decision-maker. In a related approach, Paez and Scott (2007), assume that the utility households derive from an alternative depends on choices previously made by other households. Hence, these approaches assume that copying behaviours or valuations from others are successful strategies for optimising the choice outcome. In the study by Paez and Scott, an additional element concerns the conformation to social norms, implying that decision-makers are more likely to choose a particular alternative if more peers have already chosen the same alternative.

Whereas the influence of social networks on activity participation and destination choice has received considerable attention, the influence on longer-term decisions that are relevant for LUTI processes, such as residential location, work status, car ownership etc. is hardly addressed. Yet, it is likely that social interactions play a role also in longer-term decisions. Since such decisions concern alternatives not experienced before (other residential areas, changes in work status etc.), peers' knowledge and experience may provide useful information (Paez and Scott, 2007). As for the spatial choice set formation, it can be argued that information about availability and characteristics of alternatives as well as aspiration levels are updated using social interaction. However, also mimicking behaviour of others may play a role. Including such notions into the modelling of longer-term mobility decisions in LUTI models will potentially strengthen the theoretical basis of these models.

Apart from theoretical considerations, there may be more practical reasons for considering modelling social interactions in LUTI models. If multiple dimensions of LUTI behaviour are to be modelled in mutual interaction (see Section 2), this leads to large solution spaces and high computational burden when evaluating these. Using social networks and social interactions, smaller sets of feasible solutions may be communicated and spread in a population in a realistic way, while considerably lowering the computational burden of these models. To put it another way, agents that are interconnected through social links can benefit from each others search efforts and evaluations of alternatives found.