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Guest editorial

New impetus to theoretical and empirical perspectives on space–time behavior: stochastic representation, dynamic choice sets and activity spaces

Since the mid-1990s, activity-based analysis of travel demand has rapidly gained popularity in transportation research and has evolved into the dominant framework of travel behavior analysis in academic research. The approach is based on the contention that travel represents induced demand (travel is a function of people’s needs, which in turn require them to become engaged in activities) and cannot be fully understood without understanding how individuals and households organize their daily activities in time and space.

The theoretical foundations of this approach go back to the urban planning and time-geography literature in the writings of authors such as Chapin (1968; 1971; Chapin and Hightower, 1965), Hägerstrand (1970), Cullen and Godson (1975), and Jones et al (1983). In reaction to the highly abstract and normative location and consumer behavior theories of their era, these authors have in common the focus on more realistic assumptions and formalizations of spatial choice behavior. Chapin (1971) argued that most land uses and transportation routes exist not for their own sake but because they are opportunities to let people get involved in activities. Predicting activity schedules of the population is important in the sense that it gives urbanists a better overview of how to distribute urban facilities to improve accessibility. In contrast, Hägerstrand (1970) emphasized the constraints people face in conducting activities, which limit their opportunities. Constraints such as capability, coupling, and authority constraints imply that individuals and households are bounded in time and space when organizing and implementing their daily activities. Cullen and Godson (1975), exploring the middle ground, argued that it indeed is true that people’s behaviors are not consistently rational to be captured in a classical economic framework, but they do contain highly organized episodes that might be formulated to some extent in such a framework. They contended that the combination of priority and constraints results in differential flexibility to schedule activities. Activities with least flexibility act as pegs, while other more flexible activities are arranged around these pegs. Jones et al (1983) also attempted to combine theoretical components of Chapin and Hägerstrand, arguing that needs and constraints are fundamental factors affecting individual activity–travel patterns.

These different theoretical perspectives can still be observed in current activity-based analyses and models. While civil engineers and econometricians have based their models mainly on random utility theory, largely ignoring constraints, geographers have continued their studies on various types of constraints, assumed to affect if not dictate observed activity–travel patterns (Huigen, 1986; Kwan, 1997; Lenntorp, 1976). In some senses, the latter approach has witnessed a revival of conventional time geography, in that a new generation of scholars has started to reapply and generalize old concepts using current tools of analysis, state-of-the-art technology, and new datasets.

This special issue provides evidence of this renewed interest and recent studies in the tradition of time geography. The space–time prism has been one of the central concepts of time geography. It defines the set of locations that can be reached within a particular time budget, considering the maximum speed of the selected transport mode. In addition to the set of possible locations that can be chosen to conduct a particular activity within a certain time window, the concept has been used to formulate measures of accessibility. Originally, the concept was used for individuals and their access to facilities. Recently, it has been extended
to delineate the feasible area for conducting a joint activity between activity partners (eg, Liao et al, 2013; Neutens et al, 2010; Soo et al, 2009). In this special issue, Farber et al (2014) apply their social interaction potential metric (Farber et al, 2013) to estimate an individual’s potential to participate in a face-to-face social activity at any particular location in the city. This metric uses individuals’ space–time prisms to calculate the amount of overlapping time for two individuals to participate in a joint activity at each location in the city. Case studies in Ghent, Belgium, and Concepción, Chile, demonstrate the applicability of the social interaction potential metric to predicting social interaction intensities. The case study in Ghent suggests that overall the metric is reasonably successful in identifying observed activity locations. However, it has difficulty in the case of short commute duration or when activities take place at home. The findings of the second case study in Chile, which has more detailed information about both activity partners, also indicates that the metric performs better as distance between anchors increases. These findings thus suggest that the metric captures effects of constraints on activity locations, but should be further elaborated to increase its usefulness in activity-based models of travel demand. Obvious improvements include land-use constraints, the attractiveness of the locations for the individuals, individual-level preferences for activity duration, negotiation mechanisms, early and late arrival penalties, and spatial flexibility.

The idea to use space–time prisms to delineate spatial choice sets, however, is appealing. The definition of choice sets in non-constraints-based models has been the subject of much discussion and has led to several approaches to address the problem (Pagliardia and Timmermans, 2009). It is well known that, if the IIA (independence of irrelevant attributes) property of the multinomial logit is satisfied, the parameters of the multinomial logit model can be estimated in an unbiased manner by random sampling from the choice set. However, this assumption is often violated and moreover the definition of the choice set will by definition affect predicted choice probabilities and market shares. Elaborating earlier attempts of delineating dynamic choice sets using space–time prisms (eg, Arentze and Timmermans, 2004; Kwan and Hong, 1998; Scott and He, 2012; Yoon et al, 2012), in this special issue, Wang and Miller (2014) propose a robust approach which combines the choice of gap in a provisional schedule with the concept of the space–time prism to define dynamic choice sets underlying activity scheduling processes. A nested logit formulation is chosen in their study of shopping behavior, with gap choice being the upper level and location choice conditional upon the gap being the lower level. Results for the Toronto area suggest that the goodness of fit of the model is very good at the aggregate level but shows substantial variation at the individual level. It may be important, therefore, to combine this approach with mental representations of spatial opportunities or to include learning and habit formation in models of activity–travel scheduling decisions.

In line with classic conceptualizations in time geography, both these papers are based on deterministic representations of space. Anchor or control points (activity locations) are fixed, opening hours are fixed, and most importantly travel times are taken as being time invariant. As a consequence, space–time prisms are also deterministic. In reality, however, travel times are uncertain and vary between and within days. Hence, more realistic modeling of space–time behavior incorporates this uncertainty or variability of travel times in the modeling approach. The challenge is to attach a measure of probability to the space–time prism and the corresponding potential path area. Elaborating earlier work by Winter and Yin (2010) on three-dimensional, probabilistic space–time cones, and Downs (2010) on two-dimensional probability density surfaces within a potential path area, termed time-geographic density estimation, in this special issue Downs and Horner (2014) suggest an approach coined adaptive velocity density estimation. The approach alleviates the limiting assumption in previous work that the maximum velocity of the object used to identify the
space–time prism is constant across time and space. It involves breaking up the space–time path into discrete segments and allowing the maximum speed to vary between segments of the space–time path. Examples illustrate the potential of the suggested approach, but further work is needed to explore the effects of spatial and temporal sampling and choice of distance-weighting function. The current approach assumes that the space–time trajectory data are perfect, whereas in reality such data may contain errors. Hence, uncertainty analysis, also in connection with the sampling issues, would be a highly relevant avenue for future research.

Including such stochastic representations in constraints-based models of travel demand would improve the validity of these models. However, these models would still be limited in the sense that often a fixed activity agenda is assumed. Variability in travel time, however, means that travelers have developed different regimes or scripts, and that uncertainty in travel times may lead to shifts in activity–travel patterns. Rasouli and Timmermans (2014) explore this issue by applying the Albatross model system to different samples of uncertain travel times. Using tree induction methods, different choice heuristics are derived from the variability in the input data. The impact of uncertain travel times in a corridor in the Rotterdam area in the Netherlands is then simulated, assuming that the derived decision heuristics remain stable. The results of this study suggest that variability/uncertainty in travel times covaries with the existence of different scripts and therefore varying adaptive behavior when travelers need to cope with changing conditions affecting their activity–travel decisions.

Properties of space–time prisms have often been used as measures of accessibility. Yet, there seems a strong divide between alternative approaches. In addition to the space–time measures advocated by geographers, disciples of random utility theory seem to favor log-sum measures, which have a clear theoretical interpretation in terms of consumer surplus. In an attempt to reconcile these approaches, in this special issue Jonsson et al (2014) suggest an approach to extend the conventional log-sum accessibility measure by including time constraints. Elaborating on the work by Ettema and Timmermans (2007), their approach handles space–time constraints, travel time uncertainty, and endogenous trip chaining in a single consistent framework. They use the Bellman principle to maximize the utility of a decision, considering the utility of the present and possible future states. Fixed activities are treated as constraints in the approach. Travel time uncertainty is formulated in their suggested decision rules but not considered in their implemented model because of the computational burden. The results of the dynamic choice model are context-dependent measures of consumer surplus, which respect the restrictions imposed by each individual’s space–time prisms.

Space–time prisms and their projections onto actual spaces define the constraints affecting individuals and households to organize their daily activities. In many cases, however, actual decisions may involve a subset of this space of activity spaces that people visit occasionally and that together make up their action space. It can be assumed that these locations have been learned over time and the underlying process can be modeled to simulate the formation of dynamic choice sets (Han et al, 2007; 2008; 2009). This special issue includes two interesting empirical studies on the properties of these activity spaces. Harding et al (2014) analyze whether the size of these activity spaces is related to a set of indicators of the built environment. The minimum convex polygon around the locations visited by an individual or household is used to measure the size of observed activity spaces. Next, a typology of neighborhood types is constructed using a K-means clustering algorithm, using as input population and employment densities, land-use mix, and public transport accessibility. Ordinary regression analysis and structural equation modelling were used to estimate the effects of neighborhood type on the log of the minimum convex polygon, controlling for sociodemographic variables and residential self-selection. The analysis was conducted for the cities of Montreal, Quebec, and Sherbrooke. Results indicate that neighborhood types
have a statistically significant effect on the size (dispersion) of daily activity spaces, even after accounting for household composition, vehicle ownership, and census tract properties. The authors also examine temporal changes in the dispersion of activity locations. They find evidence of a trend toward larger activity spaces over time in Montreal, whereas this trend was not significant in Quebec. Finally, it appears to be an important overall metropolitan effect, with city size correlated with dispersion. This is noteworthy as it appears to apply irrespective of how dense or ‘urban’ the environment is.

Whereas Harding et al examine the effects of the built environment on the dispersion of activity spaces, Dharmowijoyo et al (2014) are primarily concerned with differences between socioeconomic groups in the variability of daily activity spaces. Unlike Harding et al, they use the second moment (ie, squared Euclidean distance) of the location of the activity locations to the home and the centroid of the activity location, respectively, as the dependent measure. Results from the Jakarta metropolitan area show that variability in individuals’ daily activity spaces differs significantly between different groups of individuals. Nonworkers have higher variability, whilst students have least day-to-day variability in their activity spaces. The other household members’ activity space is found to be the most significant explanatory variable. Between-day variability of individual activity spaces seems lower within the same individual than between individuals.

Together, this set of selected papers provides a good overview of the state of the art and new impulses to time-geographic approaches in the study of activity–travel behavior. The papers point to some valuable trends and ideas that demand further examination. At the same time, however, it also suggests some lines of future research that warrant further attention, but seem very promising. Relevant topics for the research agenda include space–time prisms and stochastic spatial systems, space–time prisms and uncertainty in scheduling decisions, space–time constraints and coping and adaptation strategies, space–time prisms and learning, mental representations of space–time environments and activity–travel scheduling, and sequencing methods under assumptions of stochasticity. The papers included in this special issue have started to address some of these topics. We hope the issue will stimulate further research along these lines to improve existing activity-based models of travel demand.

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