Summary

Synchronizing Networks:
the Modeling of Supernetworks for Activity-Travel Behavior

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Activity-based modeling is currently an active research field in transportation research and urban studies. It aims at predicting activity-travel patterns, including which activities are conducted where, when, with whom, for how long, using which transport modes and taking which routes. Due to the high number of choice dimensions in this process, contemporary activity-travel scheduling methods tend to overlook certain choice facets or/and adopt a sequential/hierarchical structure. To the former, multi-modal trip chaining, parking choice, and recently promoted new modalities are seldom explicitly represented in the full activity-travel patterns; to the latter, the considered choice facets cannot be modeled simultaneously, resulting in ignorance of synchronization among different service provisions.

Supernetworks have the potential to represent higher level choice facets and model them in a network-synchronized fashion. However, existing supernetwork models are restrictive either owing to the costly representation or low choice dimensions. The present thesis developed and extended the state-of-the-art of supernetwork approach for modeling activity-travel behavior and patterns. As high dimensionality is one of the main challenges for activity-based modeling, considerable effort has been dedicated to efficiently represent the choice space. In particular, a more efficient multi-state representation was proposed with the network scale considerably reduced and without compromising representation power. The network unit -- an integrated land-use multi-modal transport network -- is split into a PTN (public transport network) and several PVNs (private vehicle network). This procedure does not only remove redundant nodes and links, but also more clearly represents the transition among activity-vehicle states. Moreover, a heuristic approach was developed to generate the PTN and PVNs, which lead to heavily reduced personalized multi-state supernetworks.

As time-dependency is a common phenomenon in activity-travel patterns, the multi-state supernetwork was extended from static to time-dependent contexts through incorporating space-time prisms in the location selection process and five time-dependent components in the links. Thereafter, a path through the supernetwork represents an activity-travel pattern with higher space-time resolution. PVN and PTN connections refer to a time-dependent road network and a time-expanded PT timetable graph respectively. Activity participation and parking search also refer to time-dependent profiles. In addition, time window constraints at the activity locations were taken into account. To accommodate these aspects, a bi-criteria label correcting algorithm was proposed to find the optimal path, based on a new dominance relationship.
Furthermore, an individual’s multi-state supernetwork is extended for two-person’s joint activity programs. To that end, a new state definition of activity-vehicle-joint combination is suggested to capture interpersonal activity-travel trip chaining. For the joint travel problem, three variants were discussed, and the solutions and the time complexity were presented accordingly. If all links are attached with individual or interpersonal activity-travel preferences, the optimal activity-travel patterns denote the most desirable and possible way to conduct the joint activities. The optimal pattern contains the individuals’ choices concerning mode, route, facility location, and where and when to meet the other person.

Likewise, based on the concept of state differentiation in the process of conducting activities, several new modalities, such as ICT, E-bike, and PT-bike, were integrated respectively in the supernetwork representation in a consistent fashion. All of them expand the action space and thus potentially result in new activity-travel patterns. ICT mainly expands the activity states and relax space-time constraints, while E-bike mainly expands vehicle states. PT-bike brings forth a new definition of vehicle states, i.e. with the combination of private vehicles and PT-bike.

The time-dependent multi-state supernetwork model was applied to analyze the likely effects of a set of integrated land-use transport scenarios on individuals’ travel patterns. Due to the lack of data concerning the new modalities, the application was carried out without considering the new modalities and joint travel. The model was applied to the City of Rotterdam (The Netherlands), where several policy scenarios are considered by the municipality concerning transit improvement (including P+R), parking prices, and land-use redevelopment. Key mobility indicators such as accessibility, VMT, mode distribution, shift in facility usage etc. are compared under different scenarios.

To summarize, the modeling of supernetworks in this thesis made an important step in the development of supernetwork models. It extends the state-of-the-art and fills several major gaps in the literature. First, an efficient activity-based multi-state supernetwork representation was proposed. This representation provides a basis for any kind of future extensions to include other choice facets. Second, space-time constraints and time dependent components were both considered in the supernetwork for location selection and path-finding process. It fundamentally improves the representation of the temporal dimension, which contributes to outputting activity-travel patterns at a high level of detail and with higher space-time resolution. Third, higher dimensionalities of choice facets such as ICT, E-bike and PT-bike etc. have been integrated in the multi-state supernetwork in a consistent fashion. The inclusion of new modalities allows operators or planners to systematically assess traveler’s response. Moreover, the explicit representation of joint travel with other choice facets can avoid inconsistencies in route choice otherwise appearing in other travel demand models; it also provides a solid foundation for the next-generation of joint routing systems. Fourth, the supernetwork model was applied for analyzing accessibility and activity-travel patterns, considering synchronization of different network provisions.