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Title:

Linking activity-based travel demand models and traffic assignment: A Flemish case study

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Abstract:

A custom agent-based simulation framework is developed that combines the fields of traffic demand modeling and traffic assignment, applied to the region of Flanders (Belgium). The framework uses an activity-based approach to model traffic demand and an assignment module that is linked to the traffic demand module. Activity data for the framework is provided by a large scale survey, conducted on 2500 households in the study area. The agent-based simulation model consists of over six million agents, one for each inhabitant, to represent the Flemish population. The simulation of the linked traffic demand and assignment models results in traffic intensities for the links in the Flemish transportation network..

1.INTRODUCTION

Much research is going on in both the fields of traffic demand modeling and traffic assignment. In the past, both research fields have been developing independently. It is clear that by coupling traffic demand modeling and traffic assignment a powerful tool can be obtained. The traditional approach towards the integration of traffic demand models and traffic assignment consists of aggregating travel demand in origin-destination (OD) matrices and subsequently assigning these OD matrices to the transportation network.

In this paper, a practical application is discussed where an activity-based travel demand model is linked to traffic assignment for the region of Flanders. Feathers (Forecasting Evolutionary Activity-Travel of Households and their Environmental RepercussionS) is the acronym given to the custom simulation framework that is used. Using this framework, traffic demand is modeled using an activity-based approach and assigned to the Flemish transport network. The model outputs link intensities for the Flemish network. These link intensities can then be evaluated using traffic intensities, based on the Flemish multimodal model. This multimodal model is maintained by the Flemish government and calibrated using real-life traffic counts.

Other international initiatives that integrate activity-based traffic demand modeling and dynamic traffic assignment are Transims (Transims, 2008), Matsim (Balmer et al., 2006; Matsim, 2008) and TASHA (Miller and Roorda, 2003).

2. THE FEATHERS FRAMEWORK

The link between traffic demand modeling and traffic assignment for the region of Flanders is investigated in the Feathers framework. The Feathers framework is a custom agent-based travel demand simulation framework. In agent-based simulation, the behavior of individual agents and their interactions with other agents are simulated explicitly. The overall behavior of the system is formed by the cumulative effects of these individual behaviors. Feathers uses an activity-based approach to model traffic demand. Activity-based models predict traffic demand by predicting activity-travel diaries for individuals. Traffic demand can be derived from the requirement to travel from one activity location to the next. Travel is merely seen as a means to pursue goals in life but not as a goal itself. Therefore, modeling should merely concentrate on modeling activities or on a collection of activities that form an entire agenda which triggers travel participation. Other efforts reported in the literature that are using agent-based technology to simulate activity-based traffic demand include Albatross (Arentze and Timmermans, 2000), FAMOS (Pendyala et al., 2005), PCATS (Kitamura en Fujii, 1998) and CEMDAP (Bhat et al., 2004). The Feathers framework links an assignment module to this activity-based travel demand model. Other models that combine traffic demand modeling and traffic assignment are Matsim (Balmer et al., 2006; Matsim, 2008), Transims (Transims, 2008) and TASHA (Miller and Roorda, 2003).

Data

Traditionally, travel surveys have been collected by paper and pencil or over the phone. The coming of activity-based analysis, which prompted the need for considerably more detailed data on travel behavior, identified the advantages of collecting activity or time use diary data (e.g., (Clarke et al, 1981), see (Ettema et al, 1997) for an overview). At the same time, however, the use of diary data virtually precluded the use of telephone interviews and in addition substantially increased respondent burden and error proneness, e.g., (Dowling an Colman, 1995; Sun et al., 1995). To avoid such error or at least reduce it, computer assisted diary instruments were developed.

An activity-travel diary survey tool, called PARROTS (PDA (Personal Digital Assistant) system for Activity Registration and Recording of Travel Scheduling) was developed (Kochan et al., 2006). PARROTS runs on a PDA and uses the Global Positioning System (GPS) to automatically record location data. The PDA was programmed such that besides automatically registering its location, respondents can provide information about their activity-travel behavior as well. Whenever an activity or trip is registered in PARROTS, a number of attributes for this activity or trip are collected using a customized GUI. The most important activity and trip attributes PARROTS collects are: activity type, date, start and end time, location, mode of transportation, travel time and travel party.

In order to collect the required data for building an activity-based model for Flanders, a large scale survey is being conducted on 2500 households. A paper-and-pencil survey and PARROTS are both being used on half of the surveyed households. The survey is conducted on households since the household context in which individuals operate has a very strong influence on individuals' decisions, particularly when household resources are shared, there are shared household responsibilities and there are decisions that are made jointly by multiple household members.

Besides the survey data, the Feathers framework also contains demographic and socio-economic geographical information about Flanders, such as age, gender, number of inhabitants, employment level, and the number of shops in geographic zones as well as data on the transportation networks. This data is available in the framework and constitutes the context in which the agent-based simulation is run.

Activity-based travel demand

To have a real-life representation of Flanders, the agent-based simulation model consists of over six million agents, each agent representing one member of the Flemish population. For each agent, a schedule of activities and journeys is drawn up. The scheduling model that is implemented in the Feathers framework for the simulations in the scope of this paper is based on the scheduling model that is present in the

Albatross model (Arentze and Timmermans, 2000). The scheduling is static and is based on decision trees. The data of the survey is used to train these decision trees. A sequence of 26 decision trees is used in the scheduling process. Decisions are made based on a number of attributes of the individual (e.g., age, gender), of the household (e.g., number of cars) and of the geographical zone (e.g., population density, number of shops). For each agent with its specific attributes, it is for example decided if an activity is performed. Subsequently, amongst others, the location, transport mode and duration are determined, taking into account the attributes of the individual.

An important attribute related to e.g. the choice of the location to perform an activity is the accessibility of a location. Accessibility can be expressed in terms of the travel time from the origin of the journey to the destination, which is an indication of the quality of service of the transportation system. The travel times are dependent on the traffic demand, e.g. congestion due to the demand exceeding the capacity on certain links in a network. Real-life individuals take accessibility, and hence the level of service of the transport network, into account in their decisions for the location of an activity, modal choice (e.g. choose public transportation if it provides a better quality of service compared to traveling by car), departure time, … Travel demand on the transportation network is incurred by the activities that individuals wish to perform, but there is a clear feedback from the state of the transportation network towards the scheduling of activities.

In the simulations that are performed in the context of this paper, the link between the activity-based model towards the state of the transportation system is modeled by assigning the traffic that is generated by the agents in the activity-based model to the traffic network. More details on assignment will be discussed in the next section.

In practice, there is also a dynamic feedback loop from the state of the transportation system back to the activity-based model. However, this paper makes some simplifying assumptions about this feedback link. The extension towards dynamic feedback, including e.g. issues such as replanning due to congestion on a link and the dissemination of information on the quality of service of the transportation network towards the individuals is the subject of further research.

In order to simplify the implementation of the activity-based model for this paper, it is assumed that all agents in the simulation have similar knowledge about the travel times between origins and destinations and that this knowledge is constant throughout the simulation. Translated towards a real-life situation, this amounts to the assumption that agents do not possess of traffic information. They only use historical data (general 'knowledge' about the transportation system) in their scheduling decisions. Agents possessing of identical information for the whole network implies that there is no concept of familiarity with nearby routes nor unfamiliarity with routes distant from the home location (an agent making a short trip near home has identical knowledge about the network as another agent making the same trip but living far away).

Despite the limitations that are introduced by the assumptions discussed above, the suggested model allows for a joint simulation of traffic demand and traffic assignment. Care needs to be taken to avoid drawing conclusions based on simulations where there is a significant offset between the travel times that are used by the agents during scheduling, i.e. 'knowledge', and the resulting travel times in the network after assignment of the generated traffic demand. If the difference between the travel times is too large, the simulation needs to be re-run with an update of the travel times of the agents as it makes sense that agents 'learn' from the offset between their knowledge and the experienced reality on the network.

The matrix with travel times between the origin and destination zones as they are known by the agents is obtained by using simulation results of the Flemish multimodal model. Different travel times are used for peak and off-peak periods. The classification between a trip in a peak and a trip in an off-peak period is categorical but since the simulation model works with over six million agents an averaging near the cut-off points occurs.

Based on the individual schedules of all the agents, Feathers computes an origin-destination matrix. This origin-destination matrix aggregates all journeys in traffic demands between geographic zones. The origin-destination matrix serves as the input for the traffic assignment algorithm.

Traffic assignment

The activity-based travel demand model of Feathers includes several modes of transport. Origin-destination matrices are computed for each mode and for different times of day (on- and off-peak conditions). However, in the traffic assignment model, incorporated in the Feathers framework, the focus is on the car mode. The model assigns the traffic generated using the activity-based simulation model, to the road network of Flanders. A wide variety of traffic assignment methods exist. A well-known assignment method is the All-or-Nothing assignment, which uses a shortest path method to assign traffic to the network. This method, however, ignores the fact that link travel times are flow dependent. More advanced assignment methods take into account this volume dependence of travel times. Despite the additional computational burden, these more advanced models lead to more accurate results and are therefore preferable. The Feathers framework uses one of the more advanced methods: the equilibrium method. This method uses a speed-intensity curve to model the impact of the link intensity on the speed. The information on the speed-intensity curves to use for the links is extracted from the Flemish multimodal model.

Once the origin-destination matrix is assigned to the network, the traffic intensity on each link is known. To validate the output of the Feathers model, the link intensities simulated by Feathers are compared to the link intensities based on the Flemish multimodal model.

3. CONCLUSIONS AND DISCUSSION

In this paper, the Feathers framework, a framework that integrates activity-based traffic demand modeling and dynamic traffic assignment, is introduced and applied to Flanders (Belgium). The main contributions of this framework are the application of an activity-based model on a large scale in combination with the link between traffic demand modeling and traffic assignment that is made.

The paper makes some simplifying assumptions about the feedback loop from the state of the transportation system back to the activity-based model. Despite the limitations imposed by these assumptions, the suggested model allows for a joint simulation of traffic demand and traffic assignment. However, care needs to be taken that no conclusions are drawn based on simulation results with strongly differing values of the travel times assumed by the agents ('knowledge') and the resulting travel times after assignment of the simulated traffic demand to the network.

In future work, the focus is on a tighter integration between the activity-based traffic demand model and the traffic assignment by alleviating some assumptions that were made in this text. This is the subject of ongoing research for which detailed routing information is being used that is being collected using the PARROTS tool.

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