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Geographical Extension of the Activity-based Modeling Framework FEATHERS

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Abstract

FEATHERS is an activity-based micro-simulation modeling framework used for transport demand forecasting. Currently, this framework is implemented for the Flanders region of Belgium and the most detailed travel demand data can be obtained at the Subzone level, which consists of 2,386 virtual units with an average area of 5.8 km^2. In this study, we investigated the transferability of applying the FEATHERS framework from the Subzone zoning system to a more disaggregated zoning system, i.e., Building block (BB), which is the most detailed geographical level currently applicable in Belgium consisting of 10,521 units with an average area of 1.3 km^2. In this paper, we elaborated the data processing procedure in order to implement the FEATHERS framework under the BB zoning system. The observed as well as the predicted travel demand in Flanders based on the two zoning systems were compared. The results indicated the validity and also the necessity of this extension.

Selection and Peer-review under responsibility of the Program Chairs.

Keywords: Activity-based modeling; FEATHERS; modular-based framework; zoning system; geographical level.

1. Introduction

Nowadays, using activity-based approach for transportation planning and forecasting has been given more and more attention by transportation researchers and has resulted in the development of a number of practical models[1,2,3]. Among others, FEATHERS (the Forecasting Evolutionary Activity-Travel of Households and their Environmental

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RepercussionS), developed by the Transportation Research Institute of Hasselt University, is an activity-based micro-simulation modeling framework currently implemented for the Flanders region of Belgium[4]. In this framework, an activity-based model adapted from the ALBATROSS model[5] is embedded. For each individual person with his/her specific attributes, the model simulates whether an activity (e.g., shopping, working, leisure activity, etc.) is going to be carried out or not. Subsequently, the location, transport mode and duration of the activity are determined, taking into account the 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). Based on the estimated schedules or activity travel patterns, travel demand can be extracted, which can be further used to address many policy issues and their impact, such as the introduction of Electric Vehicle[6].

To successfully apply the FEATHERS framework, a geographical structure has to be determined at the first place, because based on different levels of geographical detail, the number of required data and the way to collect and compute these data are different, such as population density. Normally, when a more disaggregated geographical level is considered, more detailed travel demand information can be derived from the model, but on the other hand, more input data are needed. Currently, the FEATHERS framework is operational at the so-called Subzone zoning system, which is defined in the form of a spatial hierarchy composed of three layers. In order of increasing detail they are Superzone (compatible with 327 municipalities of Flanders), Zone (consisting of 1,145 administrative units at one level lower than municipality), and Subzone (consisting of 2,386 virtual areas according to homogeneous characteristics with an average area of 5.8 km^2). After gathering data based on this zoning system, a full activity-travel diary schedule for each individual can be predicted by applying the model inside FEATHERS, and a series of origin and destination (OD) matrices can be generated representing the travel demand with respect to each origin and destination at the related geographical layer. Hence, the most detailed travel demand data can be obtained at the Subzone level using the current FEATHERS framework. Although a huge amount of useful information can be deduced at this layer, the size of each Subzone - an average area of around 6 km^2 - is still somewhat too large for certain research purposes that have to take precision into account, such as site selection. Therefore, a zoning system with higher resolution is required to implement the FEATHERS framework on. To this end, a Building Block (BB) layer is introduced. It is the most disaggregated geographical level currently applicable in Belgium, which consists of 10,521 units with an average area of 1.3 km^2. In this paper, we investigate the transferability of applying the FEATHERS framework from the Subzone zoning system to the BB zoning system (composed of Zone, Subzone and BB), and the results based on these two zoning systems are compared by using a 50% of the full population of Flanders.

The remaining of this paper is structured as follows. In Section 2, we briefly introduce the FEATHERS modular framework. In Section 3, we elaborate the data processing procedure in order to implement FEATHERS under the BB zoning system. The results based on the two zoning systems are presented and further compared in Section 4. The paper ends with concluding remarks and future research in Section 5.

2. The FEATHERS modular framework

FEATHERS is a micro-simulation framework particularly developed to facilitate the implementation of activity-based models for transport demand forecasting[4]. Specifically, it is a modular-based framework using an object-oriented paradigm, which allows for a flexible application by practitioners and end users. The main goal of the FEATHERS framework is to allow for easy updating and/or replacement of functionalities used in activity-based models since the state-of-the-art in the activity-based research field progresses rapidly nowadays. Therefore, the modular framework holds considerable promise to facilitate the research on and the development of dynamic activity-based models for transport demand[7]. Totally, nine different modules are classified in the FEATHERS framework. They are configuration module, data module, population module, schedule module, schedule execution module, learning module, statistics module, visualization module, and training module. In this section, we briefly introduce some of these modules that are related to the following geographical extension.

Configuration module (ConfMod) stores all the required parameter and directory settings in XML format for the other modules, which allows for a central configuration management and an easy maintenance of the functionality. In practice, every module that is switched active in FEATHERS communicates with the configuration module in order to obtain its specific settings.

Data module (DatMod) provides access to the data required for all the other modules. Generally, it consists of two types of data: supply data and demand data. The supply data mainly refers to the environment data in terms of transportation performance which might potentially influence the travel demand and travel behavior in the study area. It includes the zoning system data, the land use data and the fundamental transport system information. The demand data consists of the activity-travel diaries or schedules that describe the demand for the execution of activities at certain locations as well as the resulting demand for transportation.

Population module (PopMod) manages all persons and corresponding households data characterized by a number of attributes, which are essential for the simulation of travel demand and travel behavior at the individual level. For the case of the Flanders region of Belgium, due to privacy reason, a synthetic population is adopted by applying the Iterative Proportional Fitting (IPF) algorithm based on a collection of Flemish population data.

Schedule module (SchedMod) is committed to predict individual activity-travel schedules for the target population based on a rule-based decision tree scheduling algorithm. This algorithm consists of a sequence of 26 decision trees, which are consulted from the ALBATROSS (A Learning BAsed TRansportation Oriented Simulation System) model and tailored for the Flemish situation by using the chi-squared automatic interaction detector (CHAID) based induction method[8,9].

For the detailed description of the above four and the remaining five modules, as well as the interaction of these modules, we refer to Kochan, 2012[7].

3. Extension to BB zoning system

In order to apply the FEATHERS framework at the BB zoning system, some input data currently derived from the Subzone zoning system have to be re-prepared or updated accordingly. Thanks to the FEATHERS modular-based structure, we can focus only on some particular modules related to data and leave the others as they are. More specifically, for this study, three parts of the data sets need to be processed. They are the environment data, the activity-based schedule diary data, and the synthetic population data, among which the first two are contained in the *DatMod* while the third one belongs to the *PopMod*. The detailed data processing procedure is described as follows.

3.1. Environment data processing

As introduced in the previous section, the environment data set involves the context of the study area and the factors which might potentially influence the travel demand and travel behavior in the study area. It mainly consists of information on the zoning system, the land use system, and the fundamental transportation system.

The zoning system describes the hierarchical structure of a zoning system. The current FEATHERS framework is operational at the Subzone zoning system, which is composed of three layers, i.e., Superzone, Zone, and Subzone. Each zone at a lower level (more detail) belongs to one and only one zone at a higher level (less detail). In order to apply the FEATHERS framework at the BB level, we thereby establish a BB zoning system, which also contains three geographical layers, but they are Zone, Subzone, and BB. Again, each zone at a lower level corresponds to one higher level zone.

The land use system offers the available sector-specific data at different levels of the zoning system, which are used as indicators of availability and attractiveness of facilities for conducting particular activities, such as the total number of employee in each Subzone. Now, when the BB zoning system is considered, the sector-specific data have to be transferred to the BB level, which we obtain from the 2009 year based socio-demographic data in Belgium.

Finally, the fundamental transportation system provides the availability and performance of the transportation system between every two zones in the study area, such as the travel distance and travel time with respect to different transport modes. All these data are represented by a set of Level of Service (LOS) matrices in the FEATHERS database. However, some of these data are not directly available for the BB level. Taking the car mode as an example, due to the fact that travel demand is highly dependent on the time of the day, the free-flow and the congested (morning-peak and evening-peak) travel time between every two Building Blocks have to be recorded, which however, are not available in the current database. To obtain this information, we apply the network skimming tool in TransCAD to compute the travel distance and travel time for every two BBs based on the Flemish road network. More specifically, the Flemish road network provides all the road links with attribute values regarding travel distance and travel time. Thus, by identifying the travel path connecting every two BB centroids (based on the shortest travel time for example), the total travel distance and the free-flow travel time between every two BBs can be calculated. Moreover, after running FEATHERS based on these data, we generate the predicted activity travel patterns of each person, based on which the time-dependent OD matrices can be derived. Then, by performing traffic assignments, the congested travel time of each network link (8 a.m. to 9 a.m. for morning-peak and 5 p.m. to 6 p.m. for evening-peak) can be simulated. Thus, the congested travel time with respect to both the morning-peak and evening-peak between every two BBs can be estimated.

3.2. Activity-based schedule diary data processing

To apply the activity-based model embedded in the FEATHERS framework, the basic schedule diary data of travel activities over a specified time period are required. The schedule diary data should cover the demographic (e.g., age, gender), socio-economic (e.g., income, work status), activity (e.g., beginning time, duration and the location of the activity), household (e.g., number of cars, age classification of children), travel information (e.g., transport mode, origin and destination of the journey), as well as the interrelationship between the multitude of facets of activity profiles on an individual level. To this end, a trip-based survey called OVG (Onderzoek VerplaastingsGerdarg Vlaanderen) was used to collect data for the Flemish study area, which was conducted through 8.800 persons selected based on a random sample from the national register by means of a face-to-face interview primarily.

Based on the OVG travel survey, the schedule diary data for the Subzone zoning system were obtained and grouped into six data sets, i.e., Activities, Cars, Households, Journeys, Lags, and Persons. To obtain the schedule diary data for the BB zoning system, the basic information on persons, households or journeys at the Subzone level can continue to be used without any problem, such as the age of the person, the number of the household members, and the duration of the journey. However, the location IDs used to mark up the occurrence place of activities or journeys need to be refilled in corresponding to the IDs of the BB layer.

3.3. Synthetic population data processing

A large number of personal and household data are required for travel demand forecasting using the FEATHERS framework. However, due to the privacy protection or limited by the high cost constrains, it is very hard to acquire and apply the individual data directly in Belgium. Therefore, a synthetic population technology[10,11] was introduced to provide an alternative data source for the FEATHERS framework. In application, to estimate the target joint distributions for Flanders in 2007, the socioeconomic census (conducted in 2001) joint distributions were updated using the IPF (Iterative Proportional Fitting) algorithm based on the population marginal data of 2007 for Flanders. To obtain the synthetic population data for the BB zoning system, similar to what we did to generate the schedule diary data, the basic information of persons (e.g., age, gender, work status and driving license) and households (e.g., number of household members, household income, number of cars) at the Subzone level is not necessary to change, but the location IDs need to be replaced by the BB IDs.

4. Results and discussion

After updating the database system, the attributes and parameters accommodated in the *ConfMod* can be calibrated and the decision trees in the *SchedMod* can be reconstructed. Then, the FEATHERS framework can be applied to predict the travel demand in Flanders using the BB zoning system. In this section, we present the results based on this extended zoning system, using a 50% of the full population of Flanders, and they are further compared with the ones based on the Subzone zoning system.

Table 1 lists the observed average daily number of activities, trips, as well as distance travelled of each person based on the two zoning systems. As can be seen, the values of the first two variables are exactly the same for both two zoning systems. It is logical because there is no relation between the unit of geography and the number of activities or trips, as long as the study area is the same. However, the unit of geography does influence the variable of distance travelled. It can be explained by the fact that when a more detailed geographical level is taken into account (here from Subzone to BB), the distance travelled with respect to those trips happened inside each Subzone, which cannot be tracked using the Subzone zoning system, can now be counted in when the BB zoning system is under consideration. In the last row of Table 1, we can see that a different value of the average daily distance travelled per person has been derived based on the BB zoning system.

Table 1. Result comparison between BB zoning system and Subzone zoning system.

	BB zoning system	Subzone zoning system
Average daily number of activities per person	3.987	3.987
Average daily number of trips per person	2.928	2.928
Average daily distance travelled per person (km)	45.913	44.447

Next, to show the predicted results from FEATHERS based on the two zoning systems, we take Hasselt city as an example. Fig. 1 illustrates the distribution of attracted daily number of trips in Hasselt city at the Subzone level and the BB level, respectively. Given the fact that approximately four times more zones are considered at the BB level compared to the Subzone level (93 BBs vs. 23 Subzones), it can be clearly seen that more detailed travel demand data and distribution can be obtained using the BB zoning system, Such a zoning system is therefore more suitable for certain research that has to take the precision into account, such as site selection.

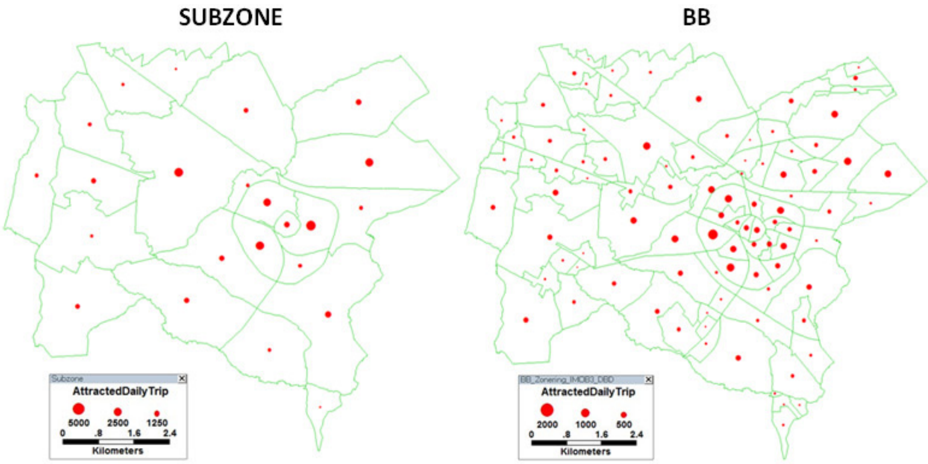

Fig. 1. Distribution of attracted daily trips in Hasselt city based on two zoning systems.

To further compare the results based on these two zoning systems, we aggregate the predicted number of trips of all the BBs belonging to the same Subzone. Thus, the results obtained based on the two zoning systems can be compared at the same level. Fig. 2 shows the attracted daily number of trips in Hasselt city at the Subzone level using both two zoning systems. A high similarity of the results can be found with a Pearson correlation coefficient of 0.962 (if whole Flanders is under consideration, the correlation is also high with the coefficient of 0.951). Such a result verifies on the one hand the transferability of the FEATHERS framework from the Subzone zoning system to the BB zoning system, and on the other hand the correctness of the extension procedure we performed in this study.

5. Concluding remarks and future research

In this paper, we investigated the transferability of applying FEATHERS - an activity-based micro-simulation modeling framework - to a more disaggregated zoning system, which in this study is from the Subzone zoning system to the Building block zoning system for the Flanders region of Belgium. In doing so, several data sets need to be re-prepared or updated from the original ones. They are the environment data, the activity-based schedule diary data, and the synthetic population data. Thanks to the modular-based framework of FEATHERS, it facilitated the extension by allowing us to only focus on some particular modules related to the above data sets and maintain the others unchanged. Based on the data for the extended zoning system, we applied the FEATHERS framework to predict the travel demand in Flanders, and the results were compared with the ones from the Subzone zoning system. The high similarity of the results verified the transferability of the FEATHERS framework from one zoning system to another. Meanwhile, the differences existed in the results (such as the value of distance travelled) implied the correctness of the extension procedure we performed, and also the necessity of such an extension.

Future research will focus on the application of FEATHERS based on this extended BB zoning system for some practical applications such as parking site selection, land use, teleworking, etc. In addition, to further improve the prediction accuracy of the model, some fundamental transportation system information at the BB level, such as the congested travel time between every two BBs in the study area that was estimated by using TransCAD network skimming in this study, would be updated when the real values are available.

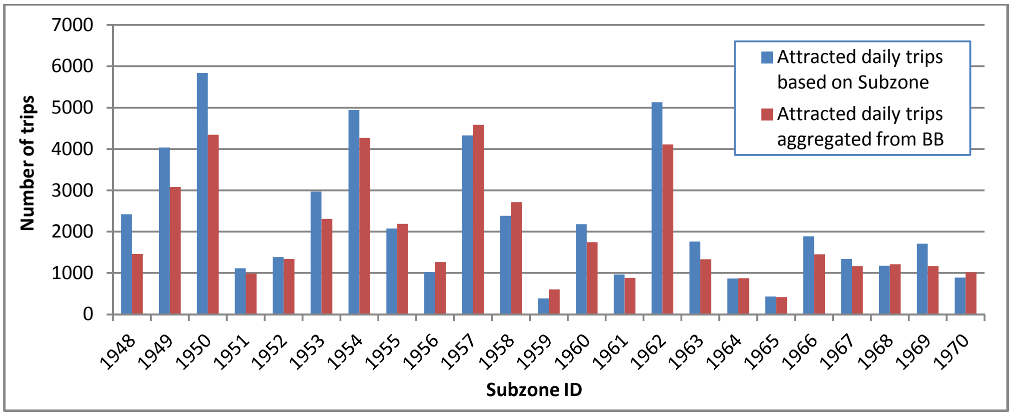

Fig. 2. Comparison of the predicted number of trips in Hasselt city at the Subzone level.

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