Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 8 (2015) 168 – 180

Transportation Research Procedia

www.elsevier.com/locate/procedia

European Transport Conference 2014 – from Sept-29 to Oct-1, 2014

A Population Simulator and Disaggregate Transport Demand Models for Flanders

Michiel de Bok[a]*, Gerard de Jong[a], Jaap Baak[a], Eveline Helder[a], Cindy Puttemans[b], Kurt Verlinden[b], Dana Borremans[c], René Grispen[c], Joris Liebens[c] and Marthe Van Criekinge[c]

[a]Significance, Koninginnegracht 23, 2514 AB The Hague, the Netherlands
[b]MINT, Hendrik Consciencestraat 1b, 2800 Mechelen, Belgium
[c] Verkeerscentrum, Department MOW, Flemish Authorities, Lange Kievitstraat

---

Abstract

The Fourt Generation of Strategic Passenger Transport Models for Flanders are being developed to meet three objectives. It includes a Population Simulator to generate reliable population inputs for a disaggregate demand model, the demand model is based on disaggregate tour-based mobility demand model, which also includes a departure time choice model to improve the sensitivity to increasing congestion and congestion charging. Finally the model is updated to the base year. This article describes the development of the population simulator and mobility demand model. The population simulator simulates the demographic evolution of the Flemish population from 2001 to the new base year 2013 and subsequently for a given year in the future. The disaggregate choice models in the mobility-demand model are are estimated on the OVG and OWoWi surveys. The presented demand models are being implemented in a microsimulation application. In effect, the passenger transport model is sensitive to changes in the composition of the population and infrastructure developments.

Selection and peer-review under responsibility of Association for European Transport

Keywords: mobility behaviour, transport demand models, microsimulation, discrete choice, Flanders

---

* Corresponding author. Tel.: 31-70-312-1541; fax: +31- 070-3121531.
E-mail address: debok@significance.nl

Selection and peer-review under responsibility of Association for European Transport
doi:10.1016/j.trpro.2015.06.052

1. Introduction

The Flemish Authorities use five provincial passenger transport models as a planning tool to support decision making on middle to large scale infrastructure projects, public transport schemes, land use plans and general mobility policy measures. The provincial models are continuously updated and currently the fourth generation is under development. This fourth generation is developed to meet a broad set of objectives and purposes: at first, the overall transport model needs improvement of all sensitivities in order to meet upcoming evaluation requirements. This includes flexible implementation of all choices on tour level with integrated destination, time and mode choice, as well as the inclusion of attributes on individual and household level explaining the global sensitivities. In this process, the dependency of observed origin-destination data from census data as a structural component of the model needs to be alleviated. Moreover, a make-over of both base and reference forecast years is necessary, as well as an update of both networks and assignment techniques.

The fourth generation strategic passenger transport models for Flanders is currently under development and will qualify as disaggregate tour-based models, meaning that most of the submodels refer to round trips. Both home-based and non-home-based tours are distinguished and also the distinction is made between primary and secondary tour destinations. In application of the model system, these choice models are applied at the level of individual persons using discrete micro-simulation instead of sample enumeration on a prototypical sample (Daly, 1998), which is common practice in most existing tour-based models. For this purpose, the fourth generation models include a newly developed population simulator that simulates the evolution of the size and composition of the population over time.

First the paper will present the origin, development and applicability of the Flemish strategic passenger transport models (Section 2). The paper will present an international review of the work done in transport on dynamic population simulators and a description of the new population simulator for the Flemish situation (Section 3). It will also present the tour-based demand model (Section 4). The functionalities in the demand model and process of model estimation are illustrated by discussing the estimation results for the mode/destination/time-of-day choice models and some key results (e.g. elasticities) of a selection of choice models. Finally, the paper concludes with a discussion and outlines further research (Section 5).

2. The Flemish strategic passengertransport models

2.1. Provincial traffic models version 3.6.1

At this moment, the Flemish Authorities use the five provincial traffic models version 3.6.1 (Verkeerscentrum, 2013) for the preparation and support of decisions on large scale infrastructure projects or transport policy measures. These traffic models are frequently and successfully applied in planning studies of large scale infrastructure projects. Some examples are the study on the environmental effects on planning level (Plan-MER) for a completion of the bypass around Antwerp (Verkeerscentrum, 2014) and for the enlargement of the bypass around Brussels (Verkeerscentrum, 2010), as well as a study on the strategy on mobility and transport in the region of the airport of Zaventem (close to Brussels). Most of the applications deal with a rather more operational level than a strategic one. Therefore the provincial traffic models, where the study area is more or less the province, are built with detailed zones (2000 to 3000 zones per model), a rather fixed commuting pattern based on the population census 2001 and an assignment with junction modelling.

The provincial traffic models version 3.6.1 have base year 2009 and forecast year 2020. Their network and zoning system covers Belgium and a part of France, the Netherlands and Germany. These models are based on classical four-step traffic models, but contain a lot of detailed data and further developments, such as a supply-demand equilibrium, a combination of techniques for the production-attraction, etc.

On the real strategic level, a passenger transport model for the whole of Flanders version 1.1 was built in the late nineties. It was used for a study on the strategy on traffic policy in Flanders (the first design 'Mobiliteitsplan Vlaanderen'). This strategic model at the level of Flanders was not developed further and is outdated at the moment.

2.2. Towards the fourth generation

The provincial traffic models are continuously in development. The first generation of these models was developed in the mid-nineties and was almost purely synthetic. In the second and third generation empirical patterns for commuting and mobility to school were available thanks to the population census of 1991 and 2001.This empirical information improved the provincial traffic models a lot. Synthetic models such as gravity models can for instance not reproduce the atypical asymmetric mass-commuting patterns to Brussels, after all.

Besides this empirical information, an update of the socio-economic data was performed, new and more advanced model techniques and parameters were implemented and a calibration with recent traffic counts was performed regularly. All of this resulted in 2012 in the robust and reliable provincial traffic models version 3.6.1.

There is a need for new development of these traffic models: firstly the population census will not take place any more in Belgium. This means that the census of 2001 will remain the most recent data on total commuting patterns that exist and thus that the demand models have to be estimated on other data than the census data. Secondly, the increasing congestion and possible congestion charging in the future, require a departure time choice model (or a model for a shift in departure time) and hence a new structure of the demand model. Moreover, the traffic model had become so detailed and complex while computational techniques have become so powerful, that going from a zone-based model to an agent-driven model should be considered. Thirdly, the base year has to be updated, a new forecast scenario has to be made and the model for Flanders on a real strategic level needs to be updated.

This all means that the next model will be a new traffic modelling tool with a different structure, new model techniques and new parameters with new socio-economic data and networks for a new base year as well as for a new forecast year. Because all possible aspects (techniques, parameters, data base year, forecasts) will be different, it will be called a fourth generation traffic model.

The structure of the strategic passenger transport models version 4.1 will be completely different from version 3.6.1. However, there are some restrictions for the development, besides solving the problems mentioned above. Firstly, the new traffic models have to be transparent and well documented. Secondly, all parameters have to be estimated on the most recent travel surveys (OVG 3-4 and OWoWi) for Flanders. And last but not least, the models have to be flexible at the operational scale: some sub-models such as trip generation and distribution (or tour frequency and destination choice) will have the option to be 'frozen' or turned off in model applications.

The fourth generation strategic passenger transport models will consist of five provincial traffic models and one strategic traffic model with as study area Flanders (the latter is called Flemish strategic passenger transport model).

In the meantime, a fourth generation strategic freight model is being developed (see paper 'A time-period choice model for the Strategic Flemish Freight Model based on Stated Preference data'), which will deliver the truck matrix as an input to the assignment of cars and trucks to the road network.

3. The Population simulator

3.1. Short review on population simulators

The introduction of micro-simulation of individuals with all their personal and household-related properties requires a full and detailed description of the population with all its attributes. In former applications, a range of population synthesizers have been developed, all aiming at reproducing demographic data, both in base years as in forecasts. Well documented applications include CEMSELTS in the CEMUS model, PopGen in the SimAGENT model, DEMOS 2000 and I-DUM in ILUTE (Sundarajan and Goulias, 2003; Bowman, 2004; Morand et al., 2010; Müller and Axhausen, 2010; Ravulaparthy and Goulias, 2011). In the applications that have been applied in various regions over the world a shift can be observed from applications that use fitting techniques to combine marginal demographic data according to known distributions over attributes (population synthesizers) towards applications that use direct simulation of demographic changes (population simulators). As such, these population simulators often model demographic transitions between discrete states, where underlying attributes or properties do influence probabilities of these transitions. Typically, approaches such as change rates, proportional hazards or the classical logit-formulation are implemented in order to model these transitions.

After assessment of data-availability and opportunities regarding the micro-simulation implementation of the next generation Flemish model, it was decided to adopt the simulation approach in the demographic module as well instead of falling back on the more synthetic approach of fitting marginal demographic data. A major contributor to this decision lies in the available state-description of the full Belgian population based on the census of 2001. This dataset gives a detailed description of a base year population including inter-personal relations, personal status, … Although this starting point is somewhat outdated, it still provides a full and consistent data framework that can be used to 'grow' upon via demographic simulation. A second reason to move to a population simulator is the growing feeling that demographic state-data can yield better explanations by modelling the actual underlying mechanisms: transitions like birth, marriage, divorce, death, entering the educational or professional market, migration, … result in the overall description of the demographic data for a given period. A better understanding of these transitions can be reached by taking interactions of properties into account, for example: higher education tends to give better chances in the job market but also to a higher age when entering it; marriage leads to a higher probability of having children and possibly migration to different housing areas. Moreover, through iterative simulation the history of transitions becomes part of the descriptive models, as many transitions depend on duration of certain states.

The developed application therefore is set up as a population simulator, and is referred to as the PopSim-module of the 4th generation Flemish strategic transport models.

3.2. Scope and structure

PopSim aims to iteratively grow a full demographic dataset on a yearly basis, using transition modelling for every single individual, describing both households and family members in detail on key attributes and keeping track of historical changes. In doing so, PopSim manages two linked datasets on both households and individual family members for the whole country of Belgium, and operates over a period ranging from base-year 2001 to 2060. The starting point consists of an enriched census dataset for 2001. PopSim uses the year 2013 as a reference anchor-point: simulation from 2001 to 2013 is trained against observed marginal and demographic distributions. Beyond 2013, PopSim forecasts yearly demographic transitions.

Transitions occur on an individual level or on household level where appropriate in case the decision to change state is carried out jointly over family members. The main transitions that are modelled are birth, death, changes in personal status and relation to other family members, as well as migration or more general, reallocation, as reflected in the diagram. Due to interaction between individuals, both the reallocation and part of the relationship module are carried out on the household level.

Internal transition models contain dynamic parameters, so they can vary over years as is observed in reality and known to the model user. In this context a scenario module is incorporated in PopSim, where a set of parameters can be modified to test different forecasts or policy schemes in the application. For example the participation in higher education at university level or on the job market can vary by gender and age across scenarios, or the age of job retirement can be increased. In this way, PopSim can measure impacts on demographic compositions according to different views on the main future social evolutions.

In addition, corrective actions can be taken after each year of simulation: if required, a set of marginal or distributions may be introduced to PopSim that will be exactly met after the concerned simulation year. Given the stochastic nature of iterative simulation, small deviations will arise between PopSim results and observed reality. These corrective actions are pragmatically required for PopSim runs starting from 2001 towards anchor year 2013, in order to meet exact demographic figures, but can also be desirable to align PopSim results for future years with other predictions or global scenarios.

PopSim results are exported on different levels. Standard output contains the two datasets on households and individual family members with all details and history for the final simulation year. Intermediate datasets are optional. Additionally, a yearly summary of descriptive demographic statistics is reported, in order to give insight in the overall evolution of the demographic composition regarding age, relationships, education and job participation, … Optionally the demographic data can be exported in different formats on zonal aggregated levels, to be used in other types of models or applications. Finally, PopSim allows for a subset of households to be selected for whom all yearly transitions, or the absence thereof, and their yearly state is reported. This allows the PopSim user to obtain a detailed view on the proceedings of PopSim on the lowest level, and monitor the plausibility of the simulated transitions.

3.3. Model Specification

PopSim combines a set of transition models that simulate the choice of an agent, be it an individual or a household, to alter demographic states. Each model formulates a probability for a transition, based on a set of driving characteristics applicable to the agent, and previous history of transitions. Simulation requires a stochastic approach so every agent's decision is drawn from a statistical distribution according to the respective probabilities. In order to guarantee robustness and consistency random seeds on the agent's level are used by PopSim: every agent will behave in a stable way across transitions across simulation years. Behaviour over all agents follows the required distributions for each transition. In order to facilitate the corrective process of PopSim, where optionally strict targets are to be met, the clear-cut yes or no approach towards an agent's transition, is expanded: pools of agents are set up per transition model containing agents that had higher or lower probabilities for the specific transition but did not randomly draw so. Whenever a small absolute correction on the transition model for a simulation year is required, the required modifications are drawn from these pools.

It is clear that different transitions do interact with each other. Therefore the setup of the actual sequence of transitions is important, for example swapping transitions birth and death does result in small variances in the results. It is in fact the resolution step of the simulation, in this case for each individual year, that determines the impact of different sequences. Ideally PopSim runs on a daily or even hourly basis, but this requires unpractical runtimes. As such, a sequence is worked out that poses as few limitations and conditions as possible, without needing to go into feedback loops between transitions. In any case, PopSim models transitions for all agents in sequence, this improves interaction between agents in a much more efficient way than an approach where each agent's transitions are modelled in sequence.

Both the birth and death model are rate-based models incorporating different attributes like gender, age, education level and person and relation status. Detailed datasets are available for the design of dynamic model parameters over time, and sound expectations on trendlike evolution for future years are available. These models do incorporate geographical variances between regions and even municipalities, showing for missing model drivers like for instance ethnicity or others. Alternative approaches with hazard-based models have been tested, but are still outperformed by the rate-based models.

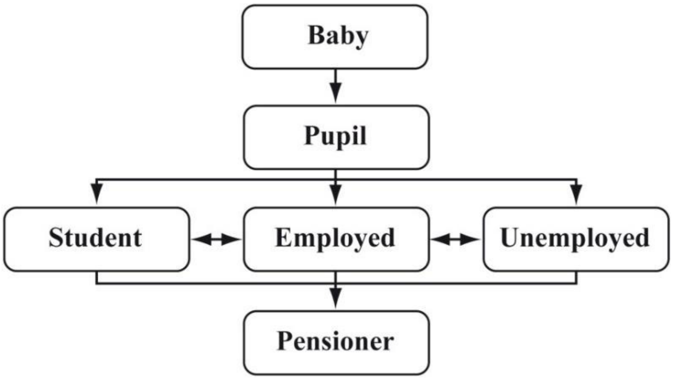

Fig. 1: Transitions between states of person status

The person status distinguishes between different states for a family member consisting of: child under the custody of an adult, an adult who is a student, employed or unemployed and a pensioner. Different transitions do exist between these states, but not all transitions are possible, as illustrated in the diagram. For each state, a substate is defined. For example for pupil the grade and type of school is simulated, taking the possibility of lagging behind in school career into account. Basic transitions simply use age and current regulations, children at the age of 6 mandatory start their school career at primary level, and can only leave school from the age of 18. Other transitions are more elaborate. After the mandatory education until 18, the agent can choose between higher studies, employment or remaining unemployed. For these transitions, hazard models are formulated, calculating probabilities for transitions based on duration of current state, gender, age, education level, household situation, … Specific data for model estimation is, however, sparse or fragmented. Overall data on population state is available, often with useful distinction between age or gender or more, but insights in the actual transition itself are lacking. Therefore, a set of calculations is needed to reset the state data into transitions, sometimes requiring simple behavioural assumptions. As an illustration, data on participation in higher studies at university or similar, is available by age and gender, as well as data on grade retention and even dropping out of studies. However, it is not possible to cross these different datasets, although it is clear that for example retention and dropping out do interact. Moreover, little data can be found fully linking the data on higher studies with household characteristics, education level, former education history in secondary school, … Fragmented insights do exist, and these factors are introduced in the hazard formulation, but a larger set of longitudinal data on an agent-basis would offer a stronger basis for model estimation.

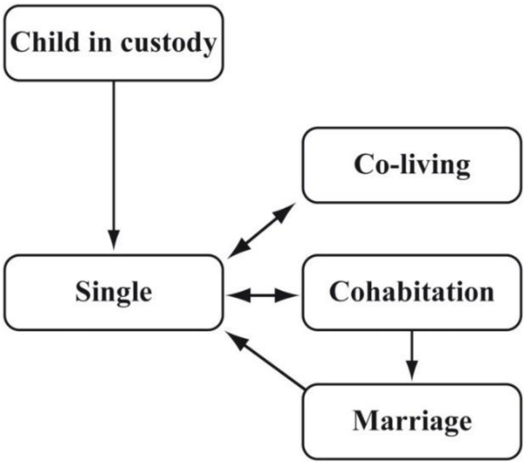

Fig. 2: Transitions between states of relation status

The relation status of a person describes how the agent is linked with other persons. The first state refers to a child in custody, and in PopSim this limits the agent's decisions but links with the choices that are made by the parent. At the age of 18 a moving out choice is set up, where the agent turns from a child in custody towards a single and active independent adult, who can participate in other relations and ways of forming households. Three forms of households are introduced, with cohabitation and marriage intertwined in a cycle. A separate form of co-living is available, covering all forms of household that combine single agents without mutual intimate relationship. Unlike cohabitation and marriage, this form of household can span more than two singles on the same level.

Similar to previous models, most transitions are formulated as hazard-based mechanisms. Transition from child towards single passes via a moving out module, taking education, age, gender, family situation and characteristics of parents into account. This transition is irreversible, in case a single moves in again with a previous household and parents, the state switches to co-living. Singles have the possibility to enter a relationship via a similar model using, again, age, gender, history of previous relations and person status. An opposite transition is formed by a divorce mechanism, similarly formulated with use of age, but also age difference between partners, person state, children in custody and history of previous relations. Marriage is considered to be the more classic and formal cohabitation, this transition is modelled by a rate-based process. Again, the sequence of transition choices is important, as to giving the possibility of carrying out more than one relation transition in a simulation step. Practically, all the splitting up and divorce transitions are carried out in a first stage, so to allow for a larger set of singles to form other relationships. Data to estimate the models similarly is extracted from state data on number of household types, officially reported divorces and marriages, … Again little data can be found covering all characteristics and implied transitions, from fragmented studies and reports a set of sensitivities can be deduced that enhance PopSim with the required interactions.

An important part of the relation model is formed by the agent-matching module that combines singles who decided to go into a relationship. An internal optimization module is constructed, scoring all possible partners via attributes like age, age difference, distance between key locations of the agents as well as gender. The matching module does not strictly divide between male and female but allows for intra-gender relationships, using gender-difference between agents as an attribute-level. This two-sided process is the most elaborate and time-consuming part of PopSim, so a set of relaxations are introduced that correspond with the observed behavioural mechanisms. The process does not look for optimal solutions but will allow for suboptimal choices, which means that for every agent a threshold utility will suffice without the chosen partner to be the best in the total population. Moreover, in this same context the total process is divided over a set of separate calculation processes, greatly decreasing the size of the problem to be solved. In the concept of distance between agents a set of anchor locations is introduced, augmenting the attractiveness of partners that share geographical location like school, work, family, … Model estimation remains a difficult task, as overall datasets are lacking, and the partner choice mechanism remains a mystery for all people involved. As such a set of parameters is designed that mimic expected behaviour and does result in marginal sets of relations as observed in reality. Possibly a larger longitudinal survey can broaden the insights, but it is clear that this choice module will remain largely dependent on simple random selection since the amount of attributes for partner choice lie beyond the scope of PopSim.

The reallocation module handles the choice of residence for households or singles that need a new address. The need for reallocation can be a choice by the agent, deciding to move between houses, or can be the result of a change in relation state that leaves the agent without an address, like moving out of custody from the parents, but also as a result from a divorce. The former choice is modelled by a hazard-based mechanism that uses age, household type, duration since last reallocation and changes in person status to trigger the need for reallocation. Reallocation to new addresses itself follows a somewhat similar two-sided optimization process that uses availability of housing as balancing factors. PopSim does not include a real estate bidding market, but uses observed migration patterns between provinces and municipalities as proxy-utilities for the process. This allows for the integration of immigration and emigration as well, removing the limitations of a simulated population as a closed market. Practically though it implies that PopSim takes a more synthetic fitting approach to the reallocation compared to the other transition models. The results however do logically follow observed and expected patterns of migration between regions, and this is preferred for the role of PopSim.

3.4. Implementation, current applications and further work

The PopSim application was conceived from scratch and programmed as a stand-alone application. As a whole, the design and setup follows an open and modular approach. The core of PopSim is a flexible and efficient data model that allows for easy maintenance of both persons and households, combined with an iterative mechanism that guides the developer in introducing transition models. All technical aspects and procedures that handle the dynamic parameters, required absolute corrections, parallelization of procedures, exporting and reporting of results, robust bookkeeping of random seeds, …, are built in at a low level. Thus, this modular setup provides a simple toolbox for testing different types of transition models without the developer needing to take care of technical issues, or at least as little as possible.

At this moment PopSim handles a whole dataset for Belgium, starting off with more than 10 million inhabitants and about 4 million households in 2001. Where applicable, this starting dataset is enriched with a synthetic form of history since internally PopSim does heavily use actual duration of states for transition modelling. In practice the whole population datasets do rapidly increase in size and complexity during consecutive iterations, and it is noticeable that PopSim needs more time to handle simulation years further in the future: where in the first set of years PopSim takes about 5 minutes to complete calculations for one year, calculation times go up to about 20 minutes per year for the period 2020 and beyond.

Currently PopSim in its operational version is used to finalize the population description for 2013, the baseyear for the 4th generation model in Flanders, only requiring some fine-tuning of the dynamic parameters and modification files. In parallel, datasets that describe global trends in demographics are recoded to PopSim input so to prepare simulation up to 2030 and 2040, in order to comply with guidelines set out in overall scenarios. It is envisaged to expand these evolutions into a wider set of scenarios that represent different assumptions on socio-demographic evolutions.

The current version of PopSim is delivering promising and powerful results, however it is clear that certain transition models can be greatly improved by reconsidering the use of more attributes and, more important, interaction with other transitions. It needs to be assessed whether the setup of a post-longitudinal survey that would assemble the transitions for a panel of persons over the last decades, could offer the required data to better adapt to the notion of transition modelling.

As an add-on, PopSim expands final year simulation data with 2 extra modules. A first one enriches the resulting population on household level with average income data, based upon available distributions linked to specific household characteristics. A similar second module adds car ownership data, again deducted from other available characteristics. Both modules limit to expanding the state data, and are not part of any iterative transition model. In further work it is foreseen to integrate both modules internally in the transition simulation framework.

In a same context plans are developed to integrate work and school location for all family member within the PopSim system, rather than falling back on destination choice modelling in the final traffic model. It remains to be assesses whether this approach, linking work and school location as geographical anchor points, provides sturdier results, from which other choice models on secondary non-home based tours can start.

Technically it is expected that a solid review on the accumulation of historical data for all agents within the datamodel, which is the main cause for slower performance, could alleviate PopSim by surgically removing useless information during and in between iterations. It seems however that current performances are not an immediate concern.

4. The mobility demand model

The Flemish transport demand model version 4.1 will consist of disaggregate tour-based models that are implemented in a discrete micro-simulation. The passenger transport model will apply these demand models in an iterative procedure with the assignment models for cars and public transport.

4.1. Structure of the mobility demand model

The mobility demand model will consist of various modules based on discrete choice models. The choices that are modelled include:

- Tour frequency (TF) model for primary destinations;
- Tour frequency (TF) model for secondary destinations;
- Mode/destination/time-of-day (MDT) model;
- Destination choice for secondary destinations.

The choices are being modelled at the person level, where the person has the choice between six modes (car driver, car passenger, train, regional public transport (bus, tram and metro), cycling and walking). For the destination choice, the person has the choice between 6756 zones and the time-of-day choice distinguishes 11 time periods. These 11 periods are defined as periods of one hour in and around the two peak periods and the period before the morning peak period, between the peak periods and the period after the evening peak hour.

All modules differentiate between adults and children (<18 years). For the modules where the number of observations for children is too small to give useful estimation results, the models are being restricted to adults only. Where the number of observations allows for it, the separate models are being developed for different purposes for the tours. The different purposes are defined as follows: work, business, education, shopping (split between household shopping and other shopping), leisure and 'other' for the home-based trips. Additionally, we define as work-based purposes: work-based business and work-based 'other' destinations. For some purposes the respondents are divided according to their occupation (for instance, there is a separate education model for students).

4.2. Choice data for estimation of demand models

The demand models have been estimated on the Flemish “Onderzoek Verplaatsingsgedrag” (OVG) surveys v3.0-4.4 carried out between October 2007 and August 2012. Only for household shopping and other shopping, we used the "Onderzoek Woon-Winkelverplaatsingen” (OWoWi), carried out in November 2006. In the latter survey, 6164 households were asked to list the shopping trips they made during a full week. This resulted in a data base of shopping trips made by 16009 individuals. These individuals listed among other things their modes of transport on the shopping trip and the kind of items purchased. The latter is being used to differentiate the trips into the household shopping and other shopping categories. Table 1 gives an overview of the number of observed tours in the datasets, on average workdays and in weekends.

Table 1: : number of observed tours split by purpose used for estimating the demand models. Source: OVG and OWoWi.

	home-based					work-based		shopping*	
	Work	business	education	leisure	other	business	other	household	other
workday	2538	388	1485	1731	748	59	62	7595	2376
Week end	196	60	40	1541	625	1	1	2399	1023

* shopping data only contain observations on weekdays and Saturday

4.3. Specification of the mode/destination/time-of-day choice model

To illustrate the functionalities in the model we will discuss the mode/destination/time-of-day (MDT) model in more detail. Before we discuss the estimation results we will present the specifications for the MDT-model.

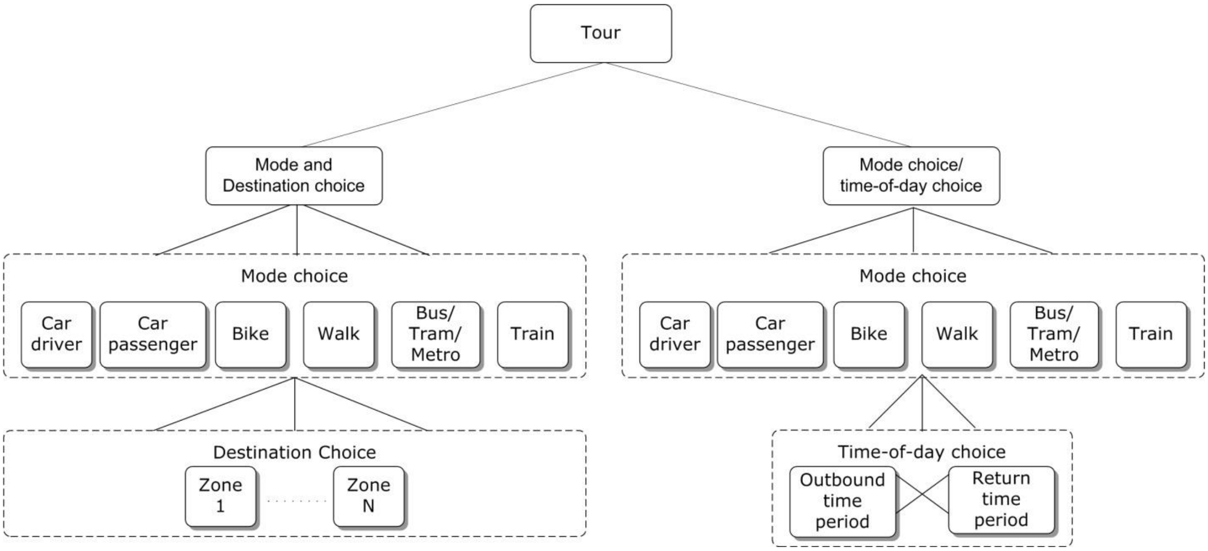

Fig. 3: Schematic representation of the mode/destination/time-of-day choice model

The MDT model is structured as a joint-logit model, which allows multiple choice dimensions in one model. It simulates choices at three levels simultaneously: mode choice, destination choice and time-of-day choice. For estimation purposes, the three-level model is structured as two parallel models that partly overlap: a two-level logit model for mode/destination choice for the chosen time period, and a two-level mode/time-of-day choice for the chosen destination. Both models have their time, cost and mode specific parameters in common and these are estimated simultaneously.

The mode/destination model includes zonal characteristics of the destination zones as size variables to account for the attractiveness of this zone for a particular purpose. For example, both the number of employees and the number of inhabitants of a certain zone add to the attractiveness for the zone for the home-work trips. Parking costs are also included as destination specific utility attributes (for some travel purposes). Furthermore it could be likely that in urban destinations it is easier to find a proper destination for the secondary destination. So, for tours that include a secondary destination, additional utility parameters were included to test if urban destinations are preferred for the main tour when the tour is combined with a secondary destination.

The mode/time-of-day choice model includes alternatives at the level of mode specific outbound- and return period combinations. The time specific utility parameters include outbound- and return specific constants, and measures that capture the fit between total required time to conduct the planned activities including travel time, and the time span of the outbound- and return period combinations.

For the mode choice alternatives we tested in a nested logit structure whether the alternatives are correlated in a higher-level hierarchy for car-, public transport or slow modes. For some mode-groups we found significant nest coefficients.

4.4. Example of estimation results

The estimation process of the simultaneous mode/destination/time-of-day choice models involves a systematic comparison of different assumptions on the model specifications. This procedure included optimisation of different elements of the model specifications, such as identification of the optimal cost functions (linear versus linear-logarithmic costs), alternative availability constraints, size functions, zone specific parking costs parameters, and persontype- and mode-specific interaction-terms. The selection of the cost function is somewhat arbitrary: different cost functions yield similar elasticities (see Table 2), and the linear-logarithmic cost functions was selected based on small differences (a time elasticity for public transit of -1.49 is more likely than -1.60).

The identification of optimal specifications leads to different results for each travel purpose. It is beyond the scope of this paper to describe the full estimation procedure but we will discuss the end result for the mode/destination/time-of-day model for commuting tours.

Table 2: Time and cost elasticities for commuting tours, for two alternative cost functions.

	linear cost function		linear-logarithmic cost function	
	time elast	cost elast	time elast	cost elast
Car driver	-0.23	-0.22	-0.19	-0.24
Train	-1.03	-1.97	-1.01	-2.00
Bus/Tram/Metro	-1.60	-0.79	-1.49	-0.87

In Table 3, the result for the mode/destination/time-of-day model for weekdays/adults/commuting is shown. The coefficients CD, CP, TRN, BTM, CY and WLK are mode specific constants for car driver, car passenger, train, regional public transport, cycling and walking respectively. Here, walking is chosen as the reference. Intra_X is a dummy for intrazonal destinations for mode X. B_timX is the time coefficient for travel with mode X. B_logcost is the linear-logarithmic cost coefficient. Earlier attempts to estimate this coefficient in the MDT model resulted in a counterintuitive positive value. Therefore, the coefficient was fixed at the value resulting from the mode-destination model for commuting travels. CD_0cars and CD_2pcars indicate the probability that car driver is chosen as mode when the household has 0 or 2-or-more cars respectively.

TmSpn indicates how the length of the chosen outbound and return time period compares to the total of the travel time and time spent at work. TmSpnEx indicates the likeliness that a period combination is chosen when the total of the travel time plus the time spent at work is larger (or smaller) than the maximal (or minimal) timespan contained within this period combination. The OutXX and RetXX coefficients are the alternative specific constants for outbound period and return period of XX. Here, the outgoing period 03 and return period 09 are chosen as reference, since they are in the morning and evening rush hour respectively. Ret01 and Ret02 are fixed at -12, since there were no observations of trips returning early in the morning. BTM_fem and WLK_fem indicate that women are more likely to take regional public transport or walk to work. CP_occu4 indicates that people with occupation ‘other’ are more likely to be a car passenger on their way to work. The significant and positive parameter sec_urb shows that urban destinations are preferred if the commuting tour will be combined with a secondary destination. Sizework and Sizepop are the size variables. They show that the number of inhabitants adds less to the attractiveness of a certain region for work purposes than the number of jobs. However, they both contribute significantly.

Table 3: Estimation results mode/destination/time-of-day choice model for commuting purposes

Variable	Coeff. (t-stat.)
CD	0.6495 (2.8)
CP	-5.287 (-21.6)
TRN	-0.8808 (-2.9)
BTM	-1.563 (-5.4)
CY	0.8968 (3.8)
WLK	0 (*)
INTRA_CD	0.8810 (4.9)
INTRA_CP	4.179 (7.2)
INTRA_TRN	0 (*)
INTRA_BTM	0 (*)
INTRA_CY	0.5739 (2.6)
INTRA_WLK	1.488 (6.3)
B_timCD	-0.05942 (-58.4)
B_timCP	-0.04440 (-19.5)
B_timTRN	-0.01736 (-17.2)
B_timBTM	-0.01166 (-19.5)
B_timCYC	-0.04218 (-27.6)
B_timWLK	-0.03439 (-11.5)
B_logcost	-3.408 (*)
CD_0cars	-2.678 (-7.9)
CD_2pcars	1.128 (14.8)
BTM_fem	1.250 (7.4)
WLK_fem	0.9398 (5.0)
CP_occu4	4.999 (8.7)
TmSpn	-1.843 (-21.3)
TmSpnEx	-0.2765 (-6.8)
Out01	-1.888 (-20.0)
Out02	-1.053 (-15.3)
Out03	0 (*)
Out04	-0.4342 (-7.7)
Out05	-2.111 (-21.1)
Out06	-1.976 (-23.6)
Out07	-3.731 (-14.9)
Out08	-4.101 (-11.8)
Out09	-3.145 (-12.2)
Out10	-3.517 (-10.5)
Out11	-3.018 (-9.8)
Ret01	-12.00 (*)
Ret02	-12.00 (*)
Ret03	-4.460 (-6.2)
Ret04	-4.220 (-8.2)
Ret05	-4.171 (-9.9)
Ret06	-1.096 (-13.0)
Ret07	-1.236 (-13.3)
Ret08	-0.08530 (-1.3)
Ret09	0 (*)
Ret10	-0.5232 (-7.1)
Ret11	-0.4445 (-5.8)
sec_urb	0.3302 (2.0)
SizeWork	1.000 (*)
SizePop	-1.765 (-22.1)
ThetaDum	1.000 (*)
Observations	4650
Final log (L)	-25976
D.O.F.	42
Rho^2(0)	0.297
Rho^2(c)	-0.014

5. Discussion and further research

5.1. Discussion

The paper presents the development of the fourth generation strategic passenger transport models for Flanders. Tour-based models can be considered as a logical step in the evolution from a traditional trip-based model to an activity based model (Shiftan and Ben-Akiva, 2011). For a comparison of existing trip-, tour- or activity based models see for instance Bhat et al. (2004) or Shiftan and Ben-Akiva (2011). Tour-based models simulate tour activity patterns that include the number of tours per day, and for each tour the primary destination, possible secondary destinations, and mode choice. These models have been developed since the late 80's for several European regions: for instance The Netherlands (Ministry of transport and public works, 1992), Stockholm (Algers et al., 1995).

The presented approach is based on disaggregate tour-based choice models in a microsimulation application. We argue that this approach has a large overlap with activity based models, in particular as a result of the microscopic implementation. The presented approach makes the strategic transport model sensitive to a wide range of policy measures, which are sometimes attributed specifically to activity-based models. Given the recent interest in disaggregate activity-based transport planning models we will position the applicability of the model relative to activity based models. We will do so by explaining how the analysis of specific policy measures, that are generally attributed to activity-based models in a large part of the transport planning literature, are represented in the tour-based approach that we adopted.

Activity timing modifications, such as shop opening hours or flexible work start times (Khorgami, 2013; Bowman and Ben Akiva, 2001). The presented approach includes time-of-day choice and optimises the outgoing and return leg of a tour simultaneously. To include flexible work hours or shop opening scenarios, the time-period specific constants can be adjusted in a similar manner as in activity based models. Adjusting these parameters is not trivial, but applies to any approach. However, the presented tour-based approach does not account for scheduling tours on a day- or week bases, which is possible in various activity-based models.

Effectiveness of congestion pricing in reducing peak-hour demand (Khorgami, 2013; Bowman and Ben Akiva, 2001). Congestion pricing affects costs (first order) and peak-hour travel times (second order) in the simultaneous (destination) mode and time-of-day model. Thus, congestion pricing may change the travellers chosen outbound and/or return leg, and thus the peak-hour demand. The tour models have a strong empirical basis, being estimated on large travel surveys, providing a robust time- and price sensitivities.

Motivate substitution of out-of-home activities with in-home activities, such as access to the internet and on-line shopping (Bhat et al., 2004). This is not represented explicitly in the demand model but this is not a limitation of the tour-based approach itself. Such a substitution functionality can be included within the tour-based framework, provided there is relevant data available to calibrate substitution patterns from out-home to in-home activities.

Effectiveness of land use policies on activity planning (Khorgami, 2013). The demand models are sensitive to land use policies at different levels. Land use attributes, such as urbanisation levels, affect car ownership, tour frequencies and mode choice. The destination choice model includes zonal population and employment variables as size variables and apply urban density as choice parameter for tours in which multiple activities are combined ('secondary destinations').

Over-all the most significant difference between the presented tour-based approach and activity-based approaches is the scheduling of all activities and tours on one day, and between household members. The presented approach generates tours in which one or multiple activities are combined, and lacks interdependencies between tours and household members. However, it is fair to consider if the increased behavioural realism of such functionalities outweighs the practical applicability of the model (Shiftan and Ben-Akiva, 2011), but a linkage between tours, and possible optimisation with other household members is an issue that will be further explored as a possible extension of the fourth generation demand model.

5.2. Further research

Besides the presented mode/destination/time-of-day models for commuting purpose, all demand models for each travel purpose are estimated. These include models for tour frequency and models for secondary and tertiairy destination choice. Currently, the implementation of these demand models in the microsimulation framework is ongoing.

After implementation, a second round of estimations of the demand models will take place. These estimations will first of all be based on level-of-services derived from the new networks, and network assignment models. Secondly, the choice models will be further integrated by including logsums from the mode/destination/time-of-day models into the tour frequency models. These logsums are a behavioural-form accessibility measure, and add another important policy sensitivity to the demand model: the simulation of induced demand in case of improved accessibility.

Acknowledgements

The work reported in this paper follows from a research project for the Flemish Authorities (Verkeerscentrum, Department of MOW). Any interpretation or opinion expressed in this paper are those of the authors and do not necessarily reflect the view of the Flemish Authorities.

Bibliography

Algers, S., A. Daly, P. Kjellman and S. Widlert, (1995). Stockholm Model System (SIMS): Application, 7th World Conference of Transportation Research, Sydney, Australia, 1995.

Bhat, C. R., J. Y. Guo, S. Srinivasan, and A. Sivakumar. Comprehensive Econometric Microsimulator for Daily Activity-Travel Patterns. In Transportation Research Record: Journal of the Transportation Research Board, No. 1894, Transportation Research Board of the National Academies, Washington, D.C., 2004, pp. 57-66.

Bowman, JL (2004) A comparison of population synthesizers used in microsimulation models of activity and travel demand, working paper.

Bowman, JL, Ben-Akiva, M.E. (2001) Activity-based disaggregate travel demand model system with activity schedules. Transportation Research Part A, Vol. 35, pp.1-28.

Chingcuanco, F and E.J. Miller (2012) The ILUTE Demographic Microsimulation Model for the Greater Toronto-Hamilton Area: 1 Current Operational Status and Historical Validation. Paper presented at TRB annual meeting 2013.

Daly, A. (1998) Prototypical Sample enumeration as a basis for forecasting with disaggregate models, PTRC proceedings, Transport Planning Methods, Vol.1.

Khorgami, S. (2013) A new approach to generation of household activity travel pattern: a modelling framework and study results. Paper presented at European Transport Conference, Frankfurt

Ministry of Transport and Public Works (1992) The National Model System for Traffic and Transport, Outline report for the Transportation and Traffic Research Division, The Hague: Hague Consulting Group.

Morand, E., L. Toulemon, S. Pennec, R. Baggio and F. Billari. (2010) Demographic modelling: the state of the art. SustainCity Working Paper 2.1a, Paris. 408.

Müller, K. and K.W. Axhausen (2010) Population Synthesis for Microsimulation: State of the Art. Presented at the Swiss Transport Research Conference, Ascona.

Ravulaparthy, S. and K. Goulias (2011) Forecasting with Dynamic Microsimulation: Design, 409 Implementation, and Demonstration. UCTC-FR-2011-07, University of California 410 Transportation Center: Santa Barbara.

Shiftan, Y., and M. Ben-Akiva (2011) A Practical Policy-Sensitive, Activity-Based, Travel-Demand Model. The Annals of Regional Science, Vol. 47, No. 3, pp. 517-541.

Shiftan, Y., M. Ben-Akiva, K. Proussaloglou, G. d. Jong, Y. Popuri, K. Kasturirangan, and S. Bekhor. (2003) Activity-based Modeling as a Tool for Better Understanding Travel Behaviour. presented at the 10th International Conference on Travel Behaviour Research, Lucerne, Switzerland.

Sundarajan, A. and K.G. Goulias. (2003) Demographic Microsimulation with DEMOS 2000: design, validation and forecasting. In Transportation Systems Planning: Methods and Applications, Eds. K. G. Goulias, CRC Press, Boca Raton, Ch. 14.

Verkeerscentrum (2010) Mobiliteitsstudie noordelijke Ring om Brussel, Mobiliteitsstudie versie 3.1, juli 2010. Available at:
http://www.verkeerscentrum.be/verkeersinfo/studies/mobiliteit-ring-brussel-noord-2010-101007

Verkeerscentrum (2013) Opbouw van het Multimodaal Model (MM) versie 3.6.1 – Gedetailleerde beschrijving modelprocessen, Dossiernummer 12006, Versie 3.2, 24/04/2013. Available at:
http://www.verkeerscentrum.be/extern/VlaamseVerkeersmodellen/ProvincialeVerkeersmodellen/Versie3.6/Opbouw_MM_versie3.6.1.pdf

Verkeerscentrum (2014) Deelrapport Doorrekeningen Oosterweel Plan-MER fase 4, Dossiernummer 11217, Versie 3.2, 15/01/2014. Available at:
http://www.verkeerscentrum.be/verkeersinfo/studies/oosterweel-planMER-fase4-140219, and:
http://www.verkeerscentrum.be/verkeersinfo/studies/oosterweel-planMER-fase3-130530