

Microsimulation: Workshop report of the 8th IATBR Conference, Austin, September 1997

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Abstract

This report discusses the results of the Workshop on Microsimulation held at the 8th IATBR conference at Austin, Texas in September 1997.

Keywords

Microsimulation; Workshop; IATBR Conference; Austin, Texas; September 1997

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1. Introduction

Microsimulation approaches are the potential workhorses for the application of complex and dynamic models of travel and activity behaviour. The goal of the workshop was to take stock of how close we are to this goal and what issues need to be addressed on the way to this goal. The discussion was based on the resource paper by Miller and Salvini (1997), which set the scene and defined *microsimulation* in the context of travel behaviour research as an approach for exercising a set of *disaggregate behavioural models over time*, which implies the status of the disaggregate entities, e.g. persons, is updated and their actions performed resulting in a consistent evolution of the system state and in individual trajectories/profiles for each entity. The authors highlighted that current technologies bring us closer to the promise of microsimulation as a standard tool for analysis and forecasting, but that there are still substantial difficulties, which need to be addressed.

2. Status in simulation models of travel behaviour research

The discussion of the workshop highlighted that a number of new technologies (in particular agent-based computing, non-linear system theory or the advances in computing power) have improved the ease of development and application of microsimulation models, but that they still have not found widespread application in their full form in the modelling of travel behaviour, which is in marked contrast to traffic flow simulation where such models are dominant (see excursus below).

The sample-enumeration tools, associated with disaggregate modelling systems, are the most widely applied tools, although their lack of *real-time* and *activity-location* interaction between the simulated units and their lack of an explicit time axis puts them outside the definition provided above. Well known examples are the Dutch National Model (Gunn, van der Horn and Daly, 1988 or Van der Hoorn and van Hoek, 1989), the work of Zumkeller (1989) or the tool VISEM (Fellendorf, Haupt, Heidl and Scherr, 1997).

In recent years models have been formulated, which try to integrate the time axis and the real-time interactions in a consistent way, e.g. ORIENT/RV (Axhausen, 1990), Eurotopp (Axhausen and Goodwin, 1991) or DYNASMART (Mahmassani, Hu and Peeta, 1994) among others. The most important of these is TRANSIMS (Barrett et al, 1995), which is intended as a replacement of the standard UTPS-approach in the USA. TRANSIMS provides an iterative

scheme to ensure the macroscopic consistency between the demand for travel and the performance of the network, which is evaluated using a microscopic flow simulation. This leaves the possibility for microscopic inconsistencies, but makes the approach applicable for large scale planning studies. Housing market models have been able to achieve this consistency in a slightly less complex environment than the activity-travel-regime (for a review see Wegener, 1994).

Excursus: Simulation of traffic flow

The problems of operating and designing multi-lane single-direction carriageways of motorways stimulated early on an interest in the simulation of motorway traffic flow (May, 1990) first in the US, then in Europe and elsewhere (Leutzbach, 1988). The purpose of this excursus is neither a historical review (for this see May, 1990 or Leutzbach, 1988) nor an overview of currently available models (for recent reviews see Algiers, Bernauer, Boero, Breherent, Di Taranto, Dougherty, Fox and Gabard, 1997 or Reiter, 1997), but a discussion of their general structures and problem areas, in particular in relation to the state-of-the art in simulation models of travel behaviour.

The motorway context allowed a relatively simple conceptualisation of the drivers, their vehicles and their environment due to the absence of other types of road users, an uniform and mostly disturbance-free environment custom-made for the motor vehicle and few flow interruptions. The core of the conceptualisation was and is the driver-vehicle unit and a set of rules and models describing the choice of the driving speed and of lateral position, implying rules for acceleration and deceleration, overtaking and interaction with surrounding vehicles. For simplicity the rules are generally specified:

- Only for the immediate neighbours of the driver-vehicle unit considered at any one time (cars in front and behind, which equals a maximum of $2 * \text{number of lanes cars}$).
- The models are time-stepped treating each driver-vehicle-unit in a given order of precedence. Time steps of one second are the norm.
- The models assume that there are only n positions available in the cross-section, with $n = \text{the number of lanes}$.
- There are no interactions with on-coming and crossing traffic and with merging or demerging traffic only at on- and off-ramps.

This framework was then transferred to other environments, where some, but not all of these assumptions had to be relaxed: multi-lane rural roads with on-coming traffic influencing overtaking (e.g. Brilon, 1976; Leutzbach, Brannolte and Schmidt, 1989; Okura and Matsumoto, 1990; Pursula and Siimes, 1993; Botha, Zeng and Sullivan, 1993), urban traffic with crossing traffic and signal control (Leutzbach and Wiedemann, 1986 or Khasnabis, Karnati and Rudraraju, 1996) interaction with guidance and control systems, e.g. radio-based direction guidance, in-car dynamic route guidance, variable speed control etc (among many others Emmerink, Axhausen, Nijkamp and Riedveld, 1995; Hu and Mahmassani, 1995 or Reiter, 1994). The modelling idea was also transferred to other types of vehicles, such as bicycles (e.g. Wiedemann and Zhang, 1989), planes and trains (e.g. among many others VISION (British Rail), TRANSIT (Siemens) or SIMU VII (TU Braunschweig), or applications such as Reid, Sicking and Paulsen, 1995; Venglar, Fambro and Bauer, 1995 or Buck, 1992), as well as to pedestrians.

The core of each model remains the description of the choice of speed by each simulated unit and the choice of lateral position in conjunction with the rules specifying the response to the various control systems modelled. Within the speed-choice context, four main modelling traditions can be distinguished in the literature:

- Implementation of *continuous car-following models*, which describe the desired distance between any two vehicles as a function of their distance, their relative speeds and, sometimes, their relative accelerations. Assuming that a desired maximum speed is known the acceleration/speed for the next time step is then calculated to fit the desired distance. A well known example among many is Gipps' car-following model (Gipps, 1981), which has also been implemented widely in operational models. Well known implementations of such approaches are the FHWA models FRESIM, and NETSIM or AIMSUM2 (Barcelo and Ferrer, 1994)
- Implementations of the *psycho-physical spacing model*, which relates acceleration and deceleration to the speed- and distance-differences detectable by the driver (Leutzbach and Wiedemann, 1986; Fellendorf, 1993, Benz, 1994)
- *Cellular automata*, which simplify the description further providing only discrete positions along the roadway axis and across the cross-section and only discrete speeds, trading simplicity for speed of calculation (e.g. Nagel and Schreckenberg, 1992). Nagel (1995), for example, specifies his model of single-lane flow completely as follows:
 - 1) **Acceleration:** If the velocity v of a vehicle is lower than (uniform) v_{\max} and if there is enough room ahead ($v \leq \text{gap} - 1$), then speed is increased by one.
 - 2) **Slowing down (due to other cars):** If the vehicle ahead is too close ($v \geq \text{gap} + 1$), then speed is reduced to gap

- 3) **Randomization** (which is applied after rule 1 or 2): With probability p , the velocity of each vehicle (if greater than zero) is decreased by one.
- *Mixed micro- and macroscopic models*, which maintain individual driver-vehicle-units, but use aggregate relationships for the calculation of speeds, such as DYNEMO (Schwerdtfeger, 1984) or Integration (Bacon, Lovell, May and Van-Aerde, 1994).

A further alternative are discrete event frameworks, which calculate variable time-steps until the next change in behaviour (e.g. Taale and Middelham, 1997).

It should be noted, that the last two alternative do not allow meaningful disaggregate analyses of driver behaviour or interactions, as their base models are either too crude (cellular automata) or not disaggregate (mixed models). Certain other aspects, for example route choice if included in the model, can be meaningfully traced and analyzed on an individual level.

The models of lane-choice and overtaking are rule-bases of differing complexity, depending on context and degree-of-realism sought. Further rule-bases to describe the interaction with traffic control and traffic information are easily implemented, but generally difficult to validate.

The available commercial models (see Algiers et al., 1997) are intended for smallish networks with a concurrent number of simulated vehicles in the low thousands, which is completely suitable for the normal tasks to which they are put: analysis of specific freeway sections or parts of signalized urban networks. In both cases the work involved in the aggregate validation of the model and the acquisition of the detailed description of networks and flows prohibits larger networks. Due to the expensive specialized data required a new validation of the disaggregate rules and assumptions is hardly ever undertaken during an application. The default parameters are accepted and may be fine tuned. The inclusion of complex rule-bases for interactions with control and information systems makes a disaggregate validation even less likely in a typical application.

The commercial models respond in their development to the pressures of their market place, which currently is mostly interested in the simulation of various high-tech driver support, traffic control or traveller information systems. These development enrich the range of applicability of the models, but do not challenge the basic framework set out above. The rather non-commercial work on pedestrians and bicyclist and traffic flow in less-developed countries has shown that the lane- and immediate vicinity orientation of nearly all current models also limits the description of the driver-vehicle-unit. The incorporation of more explicit models of the

exact choice of lateral position and of the strategic and tactical driving decisions can expand the behavioural core of the models, while requiring a much richer description of the drivers and their plans in comparison to the currently blindly responding simulated drivers. Still, this expansion of behavioural complexity could until now not be justified for real-life applications, although congested urban networks with interactions between car, trucks, trams, busses, cyclists and pedestrians might do so in the future.

The second major development direction of the current model generation is their transfer to large networks with 100,000's of concurrently simulated driver-vehicle units for both planning and real-time control applications: simulation of a whole urban area including detailed simulation of emissions production and distribution (e.g. TRANSIMS (Barret et al., 1995) or DYNEMO (SIMTRAP, 1997)), simulation of complete motorways networks of large-scale regions (e.g. the Ruhr-Region or Scottish Midlands) (PLANSIM-T (in Algers et al., 1997) or PARAMICS (McArthur, 1995), or the optimization of traffic control for large networks using simulation to evaluate different control strategies in real-time. A variety of directions are currently pursued to achieve the necessary computational speeds and behavioural realism. Parallel computers are one approach of speeding up the calculation. The more important approaches concern the reformulation of the model to simplify the conceptualisation of the driver-vehicle units and their interactions: e.g. cellular automata or mixed microscopic/macroscopic models.

The relative success of this microsimulation tradition is based on the relative simplicity of modelling task at hand, the lack of credible alternative tools, which could address the same questions and the relatively simple starting conditions and relatively low validation requirements¹. The progress in this area is important, as fully fledged microsimulation models of travel behaviour require a model of traffic flow to ensure consistency between the time-space regime and the experiences of the individual travellers and to allow for time-space specific interactions, such as parking search or response to traveller information systems.

¹ In many cases only the reproduction of known macroscopic speed-flow relationships

3. Issues and challenges

While the implementation of microsimulation models of travel behaviour is making progress on the well established basis of consumer choice theory and its extension to dynamic processes, as well as on the new results about network learning, there are a range of issues, as identified by the workshop, which need attention.

Microsimulation models of travel behaviour have ambitious scales in time and space and scope in their coverage of human choices. Next to the practical problems of the large amounts of computing time required and file storage required for the intermediate outputs, the main conceptual problem for the user is to maintain the understanding of how the model reacts, in particular for the various nested rule structures, which make this rather difficult. In the face of this challenge the workshop suggested to separate the definition of the "agents" and of their "processes" as strictly as possible and to document the model and the application as comprehensively as possible.

A single run of a microsimulation model of travel behaviour is a challenge in itself, especially as the run needs to be prefaced with the creation of a consistent starting solution against which any policy might be tested. A bigger challenge is the necessary and proper experimentation to remove the effects of the random-number seeds, which are known to have potentially substantial impacts in microsimulation models of all kinds. Researchers in the field will have to adopt best practises in experimental design, if they want to keep the effort manageable and if they want to obtain valid results.

Given these difficulties the workshop concluded that microsimulation models should be applied only, if their specific strength are called for: description of system evolution over time, modelling of interactions in time and space, complex non-linear decision rules, non-equilibrium situations.

4. Research directions

The workshop was not able to cover the whole range of possible issues in its definition of research directions, but could only focus on a small number. The following were identified

- Development of tools for the construction of consistent scenarios out of individual - not necessarily - internally consistent building blocks

- Execution of proper experiments with the scenarios, i.e. construction of experimental designs, conduct of sufficient simulation runs, extractions of required results from each run and proper statistical meta-analysis (response surface regressions etc.)
- Correct integration of flow simulation and higher level traveller choices in the context of traffic control, road side information and in-vehicle and pre-trip information systems.
- Formulation of models of environmental learning (updating of mental maps) and of the process of abstracting by which travellers generalize from the specific to the general, e.g. how experiences become general expectations about the performance of types of environments and services.
- Experimentation with the formulation of discrete rule systems and their comparison with choice models or non-linear classifiers, such as neural networks or fuzzy neural networks.
- Analysis of the meaning and identification of equilibrium and steady state for such models and of the paths they describe (true system evolution vs iterative convergence)
- Analysis of the general stability of such systems and of the effects of the dimensionality of the choices considered and described.

The number and difficulty of the research problems indicates that large scale application of microsimulation models as a matter of fact is some way in the future. Still, the workshop felt that even now microsimulation models offered the best tool available to test and explore research hypotheses through their formulation as rules and their animation in simulation models (see also Axhausen, 1991).

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