Topics in Traffic Simulation and Travel Behavior Modeling

Tomer Toledo

Faculty of Civil and Environmental Engineering,

Technion – Israel Institute of Technology

Tel. 04-8293080

toledo@technion.ac.il

Traffic simulation models are used in a wide range of studies by both researchers and practitioners. Examples include the evaluation and design of traffic control and management systems, traveler information systems, study of work zones, impact of new sensor technologies, safety studies, environmental (emissions and noise) impact studies, testing of new technologies for which no prior operational experience exists, etc.

Modern traffic simulation tools are a very complex synthesis of a number of individual, but interacting, models. These models belong to two categories: models that capture traffic dynamics (such as speed and acceleration, lane changing) and models that capture travel behavior (such as route choice and response to travelers' information).

Students interested in the following avenues of research, encompassing the field of traffic simulation are sought:

- Development of new traffic simulation models and enhancement of existing models.
- Development, estimation and testing of driver and traveler behavior models, which will provide the core for traffic simulation models.
- Innovative tools and approaches to collection of the driving and travel data that are required for the estimation of these behavioral model.
- Development of methodologies and tools to facilitate and support the use of traffic simulation models, such as algorithms for efficient calibration of the model parameters and OD estimation of these models.
- Application of traffic simulation models to real-world traffic problems, and development and evaluation of new and innovative approaches to these problems.

Development/enhancement of simulation models

The number of traffic simulation models that are being developed has been growing steadily. However, there are still significant demands for new models and added functionalities in existing model that will address specific needs and applications. For example, the level of representation of public transportation systems, and therefore the applicability of available simulation models for planning and operations of transit services, both bus and rail systems, is limited. Similarly, the development of models of pedestrian movements as well as models that capture the presence of bicycles and other non-motorized modes and their interactions with automobiles is at early stages.

Driver and traveler behavior models

Driver and traveler behaviors are the most important components of traffic simulation models. The reliability of the simulation tool depends on the realism of the underlying behavior models. The specification of behavior models, and their estimation using real-world data is a challenging task, which requires the application of sound behavioral principles and advanced econometric techniques, such as the use of latent variables and classes to capture unobserved driver characteristics (e.g. aggressiveness, mental state etc.).

Innovative data collection methods

Development of driver and traveler behavior models requires detailed data on the movement of subjects in the traffic stream and their interactions with other vehicles. Increasingly, sophisticated data collection techniques, which involve GPS and cellular transmission technologies, and automated data reduction methods that apply image and pattern recognition algorithms are being developed and used. In addition to real-world data collection we employ driving simulators, which consist of a vehicle located in a virtual reality laboratory and equipped with various sensors, which measure variables such as speed, acceleration, engine conditions and so on. The virtual reality is created by a set of programmable computer-controlled displays that face the driver and show the outside "world" including the built environment, road facilities, signals and signs, surrounding vehicles and other objects. Within this laboratory environment, experiments and scenarios to collect hard-to-get data can be devised and the data gathered this way can be used in model estimation together with the available field data.

Methods to support the use of simulation models

The increasing popularity of simulation models, among both researchers and practitioners, raises several questions regarding their appropriate use, and in particular their calibration and validation. Calibration of traffic simulation models is not a trivial task. The main challenges are the following:

- The data usually available for calibration consists of aggregate measurements of traffic characteristics (e.g. counts, speed, occupancy), and does not support independent calibration of the various models a traffic simulator consists of. Instead, calibration has to be performed by comparing these measurements to corresponding measurements from the simulation model. The simulated measurements are the emergent results of the interactions among all the constituent models. The error of the simulation is then defined as a function of the difference between the observed and simulated measurements. It is an aggregate error, and cannot be decomposed to its individual sources.
- Most applications involve a fair amount of parameters. In many cases dynamic Origin-to-Destination (OD) flows are an important input and have to be estimated jointly with the parameters of the various models.
- Data may have measurement errors themselves (e.g. detector errors).
- Most simulation models are stochastic (Monte-Carlo). Therefore, the outputs of a single simulation realization can only be viewed as noisy measurements of the

output. Calibration and OD estimation methods that rely on the simulation output must recognize the simulation stochasticity and apply simulation optimization techniques. Moreover, gradient-based solution algorithms are inapplicable since reliable gradient information is very expensive to infer.

Application to real-world problems

Simulation models provide an ideal laboratory for testing. Simulation evaluation is not only a cost effective approach to answer *what-if* questions, but also reduces the possibility of an adverse or undesirable impact of a new design (by detecting it before it is implemented). Traffic simulation models may be applied in several areas of research:

Intelligent Transportation Systems: traffic simulation models are the only viable alternative to assist in the design and evaluation of ITS technologies. Some examples include adaptive signal control systems, ramp meters, incident detection algorithms, lane control signs and variable speed limit signs, toll plaza operations and traveler information and route guidance through in-vehicle technologies and variable message signs.

Safety: The application of traffic simulation models for safety studies is an emerging area of research. A major difficulty in safety studies is the lack of sufficient real-world data to draw statistically significant conclusions on the safety impacts of various transportation systems. Traffic simulation models may be used to collect safety indicators that would predict the safety impacts of a proposed design. Traffic simulation models may also be used to evaluate new driver assistance technologies, such as Automatic Cruise Control (ACC), early brake warning, and merging and intersection assistant systems.

Public transportation systems: Simulation models can be used as a laboratory for the evaluation of public transportation operations. Application examples include design and evaluation of control strategies (such as bus priority at traffic signals), development and evaluation of dynamic traveler information systems (such as real-time arrival information), analysis of electronic fare collection (EFC) systems and fleet management systems and technologies (such as automatic vehicle location).

Externalities: Prediction of traffic emissions and noise, and their environmental impacts requires very detailed traffic information, such as speed and acceleration profiles. However, these profiles are not readily available in the field, and generally depend on many site-specific factors such as congestion levels, road geometry etc. Thus, environmental analysis often relies on partial and inaccurate traffic inputs. Detailed traffic simulation models may be integrated or interfaced with emissions and noise models to provide better data. This will also allow for the design and evaluation of environmentally oriented traffic management and control, such as emission-based road pricing route guidance.