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**Computational Algorithms and Procedures for Microsimulation Models**

***Eric J. Miller***

*University of Toronto, Ontario, CANADA*

***Karthik C. Konduri***

*University of Connecticut, Storrs, USA*

1. **Background**

Microsimulation as a method for implementing detailed, disaggregate models of socio-economic behavior for policy analysis dates back to at least the 1970’s as modelers attempted to exploit the steadily increasing computational power of digital computers to undertake ever more detailed, “higher fidelity” analyses of socio-economic phenomena (Miller, 1996). In the past decade, as unprecedented computing power, advanced behavioral modeling methods and increasingly detailed datasets concerning spatial-temporal processes have become available, microsimulation has emerged not just as a common research tool but as increasingly best practice in operational planning models, as exemplified by operational models in New York (Vovsha, *et al*, 2002), the Netherlands (Arentze and Timmermans, 2004) and elsewhere. IATBR has played a seminal role in the evolution of the microsimulation state of the art through workshops and paper sessions focusing on this important topic dating back to at least the 1997 8th conference in Austin, Texas. The Jaipur Conference continued this tradition by holding a workshop on microsimulation methods, with a focus on “taking the pulse” of the current state of the art/practice and then discussing in detail the issues and challenges currently facing researchers and model developers as we continue to improved microsimulation methods and as we continue to move these methods into operational practice.

Two resource papers were presented during the workshop, followed by a discussion of some of the challenges and current/emerging issues with respect to microsimulation models. The first resource paper titled “Parcel-level Microsimulation of Land Use and Transportation: The Walking Scale of Urban Sustainability” by Paul Waddell (2010) presents a case for developing integrated microsimulation of land use and transport systems. In particular the resource paper stresses the need for integrated parcel-level microsimulation of land use and travel behavior and discusses advances that make this detailed spatial representation possible. The paper then identifies challenges and explores some future research avenues related to integrated land use and transport models. The second resource paper titled “Computational Algorithms and Procedures for Microsimulation Models” by Kay Axhausen (2012) provides a brief overview of MATSim - a toolkit that is used for large-scale agent-based transport microsimulations. MATSim is an integrated set of modules that simulate the different components of an urban system, including travel demand and traffic simulation with appropriate feedback mechanisms between the two. The paper also presented various challenges which need to be addressed for the state of the microsimulation art to move forward, including issues pertaining to the definition and use of equilibrium concepts in our models, travel behavior representation, and computation time.

1. **Summary**

Taking the two resource papers as its starting point, discussion within the workshop centered on the following four major themes.

**2.1 Role of Microsimulation**

A tremendous amount of progress has been made in improving the behavioral representation of individual agents within the microsimulation model systems. The agent-based frameworks employed in these microsimulation model systems support a very fine resolution of time and space. As a result, agents can now be simulated down to individual parcels and be tracked in the system on a second by second basis. However some researchers have raised concerns about whether such a fine representation of time and space is warranted for the policy questions that are being evaluated. Such detailed representations entail the use of complex modeling frameworks to accurately capture the behavior and constraints experienced by individual agents and also add significant computational burden.

Additionally, there is a lack of a theoretical framework which connects the policy questions with the level of spatial and temporal detail that is necessary. It may be the case that one needs to use microscopic/macroscopic hybrid frameworks that combine multiple layers of scales to represent the different components (land use, travel demand, traffic flow) of an urban system and therefore a detailed representation in each component of the urban system may not be reasonable. Also lacking is a good understanding of the nature of the variables to be used in the models and their stability at different temporal and spatial scales.

In addition to the level of detail in the spatial and temporal representation, one needs to also think about the role of microsimulation models. Are these models being used to model individual traveler behavior including the dynamic, time-varying nature of the travelers’ behavior, or are these models being used for forecasting purposes wherein the aggregate outcomes of individual agent’s decisions are used for policy analysis? A clear understanding of the role of microsimulation models will also define the direction in which future research efforts need to be dedicated.

**2.2 Behavioral Issues in Microsimulation**

We still do not have a complete understanding of all the factors that contribute to individuals’ travel behavior and underlying choice process mechanisms. Timmermans (2003) during his keynote address at the 10th International Conference on Travel Behaviour Research reviewed the current state of practice as it pertains to integrated land use and transport models. While noting that not much improvement has been made since 1970’s, he urged researchers to wake up and start addressing the fundamental issues. He emphasized the need to improve the behavioral realism in microsimulation models by reconciling the role that constraints play on the formation of individual activity-travel patterns. Also important in this context is the realistic representation of an individual’s opportunity space while making choices. The realistic representation of opportunity spaces not only has behavioral implications but also improves computational performance. One should also represent the dynamics in the individual’s activity-travel behavior with appropriate feedback mechanisms across components of the urban system namely land use, travel demand, and network traffic flow.

It is important to use appropriate approaches and frameworks to model the activity-travel choice dimensions of individuals. One of the most popular approaches used for modeling the individual choice dimensions is Random Utility Maximization (RUM), based on the theory of rational behavior. While the power of RUM-based models in a wide variety of applications is undeniable, situations exist in which rule-based (“computational process”) models and other non-compensatory-utility-based methods may be more appropriate, and it is important for microsimulation model systems to incorporate the “right” mix of models of process and decision-making for the problem at hand.

Considerable discussion occurred within the workshop concerning the role of equilibrium / model “stabilization” within microsimulation. While this issue clearly has technical aspects to it, the workshop discussion focused on its behavioral elements; i.e., under what circumstances is equilibrium a reasonable assumption? Feedback to “stabilize” model results also raises questions concerning the nature of the dynamics being modeled within the system, as well as the nature of the information which agents perceive and use in their decision-making. The two resource papers provided contrasting examples of approaches to this issue, with UrbanSim providing an example of a disequilibrium model of longer-term land use processes, while MATSim employs considerable feedback to “stabilize” its predictions of short-term activity/travel decisions. No general conclusions emerged from the workshop’s discussion of this issue, except to highlight the importance of this issue, the need to continue to investigate and discuss it, and the likelihood that different approaches are appropriate for different processes.

**2.3 Technical Issues in Microsimulation**

The “7 Sins” of Lee (1973) are always lurking in the background despite all the advances that we have experienced in the arena of microsimulation modeling. Microsimulation models today suffer from a number of technical issues and challenges. There continues to be a lack of quality data to estimate, calibrate and validate microsimulation models, especially with respect to “process data” concerning the dynamic, disaggregate observation of agents’ decision-making and decision-making processes over time. There have been advances in survey administration and monitoring techniques including the use of GPS, cellular phones etc. These techniques provide avenues for collecting rich data pertaining to activity-travel patterns. However, traditional techniques of collecting data including travel diary surveys etc. are still dominant because of the high cost of administering the advanced techniques and privacy concerns, among other issues.

Advances in computational speeds and programming languages have facilitated the development of more disaggregate models with behaviorally rich representations of activity-travel choices compared to the trip-based approaches. The models, however, are not without issues and challenges. In particular, despite significant computational advances, run times are typically still very high, with the computational complexity of many models exceeding the capabilities of single core/ single thread computers to process the model calculations within reasonable time limits. A number of approaches have been proposed in this context to reduce model run times. Different scales of spatial and temporal disaggregation are being tested to adequately answer the policy questions within reasonable run times. Scaling/sampling techniques offer a good solution to huge run times wherein the microsimulation model is employed to predict the activity-travel patterns for a sample of the population, with results then being expanded to represent the entire population. And much more extensive use of current and emerging multi-processor hardware and software to parallelize and multi-thread our model systems must be employed run times for complex, large-scale (i.e., urban region wide) microsimulation models are to be achieved.

**2.4 Opportunities for Collaboration (Getting Past “My Model”)**

Model development efforts should be aimed at working together as a community and getting past the “My Model” syndrome. This was also brought up in an earlier workshop at the 11th International conference on Travel Behaviour Research (Walker and Bush, 2006). There have been certain encouraging signs in the direction of cooperative model development efforts, with the adoption of open source software development paradigms to enable code development for microsimulation model systems. Examples include OPUS – Open Platform for Urban Simulation and MATSim – Multi-Agent Transport Simulation tool, TRANSIMS – Transportation Analysis and Simulation, among others. These are encouraging signs, but most of these efforts are limited to code development, which only comprises one component of cooperative microsimulation model development. Other components for cooperative development include setting up a data repository which can be used to host sample data sets; one can then readily use the data to compare across different modeling paradigms. Challenges in this context include the lack of appropriate mechanisms and infrastructure to promote cooperative model development, and the lack of an effective set of incentives to encourage cooperative research and development interactions.

1. **Future Directions**

The field of microsimulation models has seen a number of advances in recent years. Despite this notable progress, the two workshop papers identified several important research questions that continue to challenge the field. In particular, much work needs to be done to clearly identify the role of microsimulation in understanding and modeling the urban transportation system under various policy scenarios. Secondly there is a need to improve our understanding about the activity-travel behavior choices of individuals, especially in terms of understanding and reconciling the different spatial, temporal, and resource constraints to which individual agents are subjected. It is also important to enhance our understanding of the underlying choice process mechanism and use appropriate mathematical frameworks to model these choices. Thirdly there are a number of technical challenges pertaining to improving data collection techniques and data quality for model estimation and validation, in employing computation techniques and identifying methodologies to reduce run times, in enhancing our understanding of the factors affecting activity-travel choices, and in characterizing uncertainty within our models and hence achieving a better understanding of the statistical properties of model outputs. Finally the transportation community will benefit from moving away from the concept of “My Model” and move towards a co-operative model development environment which can allow for innovating and sharing methods and data in a more systematic framework. Some progress in this regard is already underway in terms of collaborative efforts to integrate various model systems, such as TASHA with MATSim (Hao, *et al*, 2010), UrbanSim with AMOS and MALTA (Pendyala, *et al*, 2009), and MATSim with UrbanSim (Nagel, 2008).

Microsimulation modelers will continue to face interesting times in the coming years, which will be filled with both tremendous opportunities and considerable challenges as we continue to advance the state of the art and operational practice in this critical methodological field.

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