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# **INTEGRATED LAND-USE AND TRANSPORTATION MODELS: BEHAVIOURAL FOUNDATIONS**

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INVESTOR IN PEOPLE

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Balancing family and work is never easy, and this book could only increase this tension, especially as the editors were often on different continents. Our heartfelt thanks to our spouses and children, and to our employers, l'École Supérieure d'Aménagement du territoire et de Développement régional of Université Laval, and the Department of Geography and Environmental Studies, Wilfrid Laurier University, for their generous understanding.

## INTRODUCTION

It may seem odd to see a book with the words “behavioural foundations” come from a group of authors that includes scarcely anyone with a traditional behavioural background. If anything, we would like this to serve as an invitation to set us straight – we believe something isn’t quite right with the behavioural assumptions going into the gamut of land-use and transport models, and we’d like to get the ball rolling on some innovative and creative new solutions.

In this vein, we brought an international group of modellers, data-designers, geomatics experts policy analysts, and some behavioural scientists, to Quebec City in 2002. We asked them to unplug their computers and share ideas under the broad topic of “The Behavioural Foundations of Integrated Land-Use And Transportation Models: Assumptions and New Conceptual Frameworks”. This Colloquium was a landmark event in a major research programme on those behavioural foundations that had been underway since 1999 in a network of six (later eight) Canadian universities, with the collaboration of eight (later ten) institutions in six other countries<sup>1</sup>. Known as the PROCESSUS<sup>2</sup> Network, it overlapped and built upon the work of the ILUTE<sup>3</sup> Consortium, founded by Eric Miller of the University of Toronto in 1994 to pursue collaborative research on major simulation models for urban areas.

The behavioural research programme, consisting of 20 linked projects, was made possible by unprecedented funding for this class of urban problems through a Major Collaborative Research Initiative grant from the Social Sciences and Humanities Research Council of Canada, by an important synergy with the spatial sciences through project funding from the GEOIDE network (Geomatics for Informed Decisions), supported by the Network of Centers of Excellence Programme of the Canadian federal research councils, and by additional financial support from the Ministère des Transports du Québec for PROCESSUS’ empirical and database work in the Quebec City region.

It was at the Québec Colloquium that most of the chapters of this book were presented in a preliminary form. They were selected for the book with a view to establishing an open forum to share our experiences and to plot our course. Our overriding objective for both the research programme and the book was to question the behavioural foundations of ILUTE-type models, and to determine how such decision-support tools could help Canadian cities plan a future in

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<sup>1</sup> The Canadian members were Université Laval (network host), the University of Toronto, the University of Calgary, Université de Québec/INRS-Urbanisation, Culture et Société, Wilfrid Laurier University, McMaster University, McGill University and St.Mary’s University. The international collaborating institutions were Imperial College, London (UK), the University of Westminster (UK), Göteborg University (Sweden), L’École Navale de Brest (France), IVT-ETH, Zurich (Switzerland), Massachusetts Institute of Technology (USA), Boston University (USA), Georgia Institute of Technology (USA), the University of Sydney (Australia) and The Urban Transport Institute (Australia).

<sup>2</sup> PROCESSUS Network: PROCesses of behaviour underlying Equity and Sustainability in Systems of Urban access and their Simulation. Réseau PROCESSUS : PROcessus Comportementaux Essentiels aux Systèmes d’accès Urbain durables et équitables et à leur Simulation

<sup>3</sup> ILUTE: Integrated Land-Use, Transportation and Environment, a framework for modelling.

which the access that they offer to activities and services is environmentally sustainable, healthy and equitable. By behavioural foundations, we mean any framework or set of assumptions concerning the mechanisms and processes of human behaviour and decision-making over time, space and across multiple actors. As shown throughout the papers in this book, these may be adopted from a variety of disciplines, such as from: economics (e.g. random utility maximization), geography (e.g. space-time prisms), psychology (e.g. decision-making processes/rules), sociology (e.g. social networks, family dynamics), and others.

The behavioural foundations are explored in the context of land-use and transportation decision-making in built environments – by individuals, households, and businesses. These range in scale from daily decisions of households concerning what to do, where and when to do it, and by what travel mode, to longer term decisions concerning residential choice, vehicle holdings or land consumption by business entities. For it is the summation of all these individual micro-level decisions that culminates in the aggregate flows of traffic and urban growth, and has important implications for the environment, equity and sustainability.

Why are the behavioural foundations so important? Put simply, this class of model is only as good as the behavioural assumptions upon which it is based. One of the major uses of integrated urban models is to forecast human behavioural changes in response to emerging policy, technologies, and growth scenarios. Many of these, such as travel demand management policies or growth in telecommunications, inherently invoke changes at a micro decision-making level: if the behavioural mechanisms for these changes are not incorporated in the model, how much faith can you put in their output?

This book contributes in three key thematic areas, covered with varying degrees of overlap by all the authors: (I) conceptual issues and approaches; (II) key behavioural components and related data needs; and (III) operational modelling issues and advances.

Much of the material comprising the conceptual theme resulted from a challenge to those who normally focus on operationalising models through mathematical formulation and computer simulation: they were asked to clearly identify and communicate the underlying bases and assumptions of their models and approaches. We felt it was critical to establish the open forum with researchers who can offer new concepts, theories, frameworks, and data collection methods that could potentially enhance or question these bases. Surely, if we are to solve the emerging problems in our field, we need to make it accessible and understandable to a wide range of disciplines, and encourage intense collaboration.

Many of the papers in this volume explore new data collection tools that offer the potential to address past assumptions about the key behavioural components more empirically, and provide a basis for fundamentally new model types. For example, computerized surveys have emerged that can interactively prompt and track aspects of behaviour that are difficult to capture on paper, such as the sequence of data entries. At the same time, in-depth household interview methods have been extended, for example to engage respondents in interpreting the room for manoeuvre that they perceived to have been present when organising themselves and others in time and space during a recently observed week of activities. Stated preference/adaptation

surveys and retrospective recall have evolved to more thoroughly explore future and past response scenarios. Other tools, such as Global Positioning Systems (GPS) and 3-D visualization, are being used to reduce respondent burden and to potentially provide an opportunity for more in-depth exploration of other issues. In all, a shift in focus from observed outcomes alone (e.g. trip patterns, aggregate goods flows) to the inclusion of underlying decision processes is accruing.

The operational model development issues stemming from these behavioural foundations touch on a longstanding criticism of behaviourally rich disaggregated modelling approaches: the challenge of accounting for all the behavioural mechanisms and causal effects that are present. Rather than recoil at the apparent complexity, this book demonstrates how we can embrace the challenge, conceptualize the issues, and offer new solutions. Some of these capitalize on recent technologies such as Geographic Information Systems (GIS), agent-based simulation, and distributed computing, while others extend and integrate the established and the new, such as “hybrid” models and the proposed interdependence of sub-models within an ILUTE “suite”.

In all, this book was intended as an opportunity for the authors to openly expand their ideas, without a requirement for empirical support at this stage (although this is often provided where available), thus allowing many questions to emerge and creative approaches to be suggested. This serves both to stimulate and challenge other researchers, and provide an important basis for students and younger researchers to launch new projects – something that we feel is critical to forming a basis for substantive growth in the field.

The *conceptual issues and approaches* theme opens with contributions from two leaders in the field (Axhausen and Miller) who provide their latest perspectives on emerging approaches to understanding travel behaviour. In particular, Axhausen provides both a general introduction to travel behaviour issues and their historical evolution, highlights the most prominent issues and conceptual approaches (activity generation, activity spaces, scheduling, projects, etc.), and introduces several new focal areas for future research (e.g. social networks). Eric Miller, a recognized leader in the development of urban simulation models, takes a much more applied approach, providing a detailed sketch of how such concepts could be translated into analytical modelling advances and the challenges involved. The presentation is particularly comprehensive as travel decision making is treated as derived from the wider notions of activities, projects, schedules, and resources/budgets, all within a household multi-day context.

Roorda *et al.* take up the challenge posed by Axhausen and Miller with respect to activity scheduling behaviour, and take a specific look at the many assumptions that are often made when it comes time to model, and what new types of data could be used to address, expand and/or avoid such assumptions. For example, when activities and trips are inserted into an existing schedule, assumptions are made concerning how various activities may be modified as a result, and suggestions for exploring the validity of these assumptions using empirical data made.

Ramadier *et al.* complete the conceptual theme with a review of social psychological theories of the dynamic relationship between an individual in her social setting and the built

environment. They present a conceptual framework intended to guide survey methods that can observe the rules and heuristics with which agent-based models could more realistically represent the decisions that underlie spatio-temporal behaviour. A key implication for data collection is that rules can best be observed functioning in a two-stage “negotiation” cognitive process that is upstream from activity and travel patterns, a notion that fits well with the interplay of household, person and project “scheduler” roles proposed in the Miller chapter. They also argue for new efforts to simultaneously measure spatial and temporal flexibility, both as it is perceived, and as it may be inferred from executed activities.

The four chapters in the section on *behavioural components and data needs* expand on many of the key issues related to the representation of activity/travel decision-making that are put forth in the first chapters. McCray *et al.* focus on the adequacy of data collection methods to capture the articulation between what people do in time and space and what else they might do – and especially in the case of disadvantaged groups, those desired activities for which access is too costly or personally disquieting. In their wide-ranging chapter, they examine the implications of the evolution of activity patterns (including their extension into cyberspace), and the challenges of making surveys inclusive of all groups, including those that are hard to reach, such as the urban poor. To keep up with the phenomenological changes, and to overcome the selection biases that may accompany some types of survey methods, they conclude that flexible multi-instrument packages are often indispensable, especially at the specification stage of new model development. They give three case examples of such methods, two of which were guided by the conceptual approach in the Ramadier *et al.* chapter.

The Jotisankasa and Polak chapter gives a thorough review of recent efforts to incorporate in travel behaviour models a dimension that is often absent: the mechanisms of traveller learning. They develop in-depth the example of the cognition of travel time (including the effects of departure time) and route choice. They compare modelling approaches with and without updating mechanisms for perceptions of network attributes, and examine other aspects of learning. The chapter identifies six modelling issue areas in which research is needed to more fully incorporate learning mechanisms into integrated land-use and transport models: the learning component, choice modelling, habitual choice, choice set formation, data collection methods, and the evolution and convergence of the systems.

One of the key components that is changing the dynamics of activity scheduling is the rapid diffusion of mobile telephony. Richardson and Seethaler present a portrait of this phenomenon from several countries, including some characteristics of users and uses. They describe their efforts to find data on the interaction between mobile phone use and travel, which is too recent a development to have been covered, for example, by national travel surveys. As an interim measure, they used an Australian national time-use survey to compare a number of characteristics of the use of land-line phones and of tripmaking, including durations and temporal profiles of both for different population groups. This provides some leads for future analysis and some principles for new types of data collection.

To conclude the data discussion theme, Stopher describes a number of experiments to simulate household travel data. These methods start from suitable demographic data sources, and

employ parameter distributions from travel surveys that are carried out in other geographic areas, but which support comparable demographic definitions. Such simulations are attractive cost-savers. He presents statistical evidence that, with some cautions, useful datasets can be developed, and through the microsimulation of households, the datasets can be projected into the future, assuming that underlying distributions of travel characteristics remain stable. Research into a number of enhancements are suggested, including the introduction of random components to make the variance of characteristics of expanded households more realistic, the simulation of trip tours rather than trips, and the Bayesian updating of the simulations.

The chapter by Buliung *et al.* opens the set of four papers on *modelling issues and advances*. It moves the focus more directly on to integrated land-use and transportation models, including a thorough historical review, tying in how emerging travel behaviour approaches (dealt with in previous chapters) and geocomputing technologies are being incorporated into such models and their expansion. They pay particular attention to the need for interfaces that can be readily understood by model users who are not GIS experts. Ray and Claramunt subsequently demonstrate how a distributed computing environment offers a new avenue for the simulation of dynamic systems, and the exploration of the underlying properties and behaviour of large real-world systems. Despite remarkable recent increases in computing power, they illustrate from an example of passenger flows in an airport that multi-agent simulations can easily push the limits of memory and processing of a single computer. Distributed computing platforms seem well suited to future extensions of such simulations, especially those incorporating the complexity of collaboration between agents.

Hunt and Abraham follow with a chapter devoted more exclusively to the structure of land-use models, emphasizing how the many system elements (businesses, households, etc.) behave and interact. Their approach to simulating markets for goods, services, labour and space involves allocating flows between zones using nested logit models, according to exchange prices and transport (dis)utilities. It has been applied not only to urban regions, which are the main preoccupation of ILUTE frameworks, but also to larger geographies, namely the American states of Oregon and Ohio.

The book ends with a chapter by Bolduc *et al.* that explores recent extensions of econometrics to represent idiosyncratic aspects of choice processes, and to allow for apparently irrational decisions. They describe the development of Hybrid Choice Models (HCM) that build on basic Random Utility Theory, but include key elements of the cognitive processes believed to underlie choice, including aspects of history and context, the formation of perceptions, heterogeneity and unobserved constraints. Until recently, HCM methods have been demonstrated only on small-scale models with two or three alternatives: their chapter explores the application of HCM to large scale models with numerous dimensions and flexible formulations of the choice process, such as would be needed for urban simulations.

In an ideal world, all disciplines would truly collaborate together, surveys would have 100% response rates, all data would be shared, all models would be open source, and behavioural assumptions would not be needed (since the models would capture all aspects of them!). But questions remain. How will we know if we are on the right track? How far off are models that

that would reasonably satisfy the behavioural standards/frameworks outlined in this book? How will we know we got there? We encourage everyone to keep asking these questions, and look forward to future stages of the work, including the second International Colloquium to be held in Toronto in 2005.

Sean T. Doherty

Martin E.H. Lee-Gosselin