Preface

This provides an overview of latest state-of-the-art research about spatial-temporal micro-simulation methodologies for human mobility, grounded on massive amounts of big data of various types and from various sources (e.g. GPS, mobile phones, and social networking sites). One of the applications explored in this book is the forecasting of nationwide consequences of a massive switch to electric vehicles, given the intertwined nature of mobility and power distribution networks. Many scientists have already pointed out that the goal of the social sciences is not simply to understand how people behave in large groups but to understand what motivates individuals to behave the way they do. If this fundamental insight can be gained, it certainly is a large step forward towards the solution of this important challenge; it can help us to better understand the dynamics of our society and, in the longer run, have an impact on overall societal well-being. In a nutshell, this book will help achieve some very novel objectives in the field of data-mining, transportation sciences, and its applications. Some of these objectives include:

1. **Big data challenges:** Big data coming from mobile call records, GPS trackers, and social networking sites (e.g. Facebook), along with microscopic energy consumption, land-use, road network, and public transport level-of-service data pose an enormous challenge in terms of data storage, integration, management, and privacy.

2. **Big data joined with behavioral motivation leading to truly novel social science laws:** Big data needs to be merged with behaviorally rich activity-travel diaries, generating a novel data-driven theory that enables us to analyze mobility demand from the individual point-of-view, not neglecting the behavioral and contextual situation of the individual.

3. **The behavioral sensitivity of the individual as the core entity in the novel simulation standard:** Agent-based reality mining of big data is combined with behavioral sensitivity of the agent, accounting for changes in human behavior when circumstances change, either due to control (e.g. policy actions to prevent peak loads in the power network) or due to general trends (e.g. the use of electric vehicles).

4. **A novel standard for evaluation and benchmarking:** The massive amounts of big data can be used to estimate origin-destination matrices, setting a novel, better, and more detailed standard for evaluating, validating, and benchmarking agent-based micro-simulation models.

5. **An issue of scalability:** Computational power needs to be enhanced by orders of magnitude using state-of-the-art advances in high-performance fine-grain parallel computing systems, addressing scalability problems resulting from the behavioral theory extraction from big data and from the adoption of this theory in a nationwide simulation environment of electrification of road transport.
The ability to understand dynamics of human mobility is crucial for tasks like urban planning and transportation management. The rapid growth of large spatio-temporal datasets gives us the possibility to develop more sophisticated and accurate methods and algorithms going towards a complete view on mobility. Private and public institutions have recognized mobility data as a source of information to assess the lifestyle, habits, and demands of citizens in terms of mobility. Chapter 1 provides an overview of a few approaches to extract mobility profiles of individuals from two important examples of big data sources: the GPS traces of vehicles and the GSM traces of mobile phones. The key of all the methods presented is that from the analysis of the individual histories it is possible to derive better information about the collectivity. Similarly, the pervasiveness of mobile devices and location-based services produces as side effects an increasing volume of mobility data, which in turn creates the opportunity for a novel generation of analysis methods of movement behaviors. Chapter 2 relies upon the same amount of big data but focuses on the specific problem of predicting future locations, which is aimed at predicting with a certain accuracy the next location of a moving object.

An activity-based approach, which estimates an individual induced traffic demand derived from activities, has been applied for traffic demand forecast research. The activity-based approach normally uses different types of input data: daily activity-trip schedule and population data, as well as environment information. In general, for privacy reasons, population data is made available only as aggregated frequency distributions; furthermore, that data is snapshots that apply to a specific moment in time. Therefore, it is indispensable to develop disaggregation and evolution simulation methods to population data. A synthetic population technique that provides a solution to this problem is presented in chapter 3.

Over the last decades, the trip-based approach, also known as the four-step model, has been playing an unrivalled role in transportation demand research in Korea. It has been used to predict changes in traffic volume resulting from new transportation policy measures and has allowed benefit-cost analyses for new infrastructure provisions. It has been increasingly difficult for the trip-based model to anticipate individual responses to new transportation policy inputs and infrastructure provision as the society becomes personalized and diversified. Activity-Based Modeling (ABM) approaches, predicting travel demand derived from individual activity participations, were introduced to complement the trip-based approach in this regard. Chapter 4 provides some deep insights on using an activity-based approach for a real world scenario (i.e. Seoul city). Similarly, chapter 5 demonstrates the feasibility of applying an integrated micro-simulation model of activity-travel demand and dynamic traffic assignment for analyzing the impact of pricing policies on traveler activity-travel choices. From a market’s point of view, the realistic example presented in both of these chapters show strong valorisation potential of the approaches used.

Proper, accurate, and on time data collection is an important challenge for transportation scientists. For example, the underreporting of road accidents has been widely accepted as a common phenomenon. In many developing countries this remains a critical problem as inappropriate information regarding road accidents does not provide a base to analyse its root causes. Chapter 6 shows various features of a unique data collection mechanism along with the discussion of some success stories where the collected data has contributed significantly to improving road safety conditions.

Travel Demand Management (TDM) consists of a variety of policy measures that affect the transportation system’s effectiveness by changing travel behavior. Although the primary objective to implement such TDM strategies is not to improve traffic safety, their impact on traffic safety should not be neglected.
Chapter 7 explains that activity-based transportation models provide an adequate range of in-depth information about individuals’ travel behavior to realistically simulate and evaluate TDM strategies. The main advantage of these models is that the impact of applying a TDM strategy will be accounted for, for each individual, throughout a decision making process instead of applying the scenario to a general population level.

The increasing expressiveness of spatio-temporal micro-simulation systems makes them attractive for a wide range of real world applications. However, the broad field of applications puts new challenges to the quality of micro-simulation systems. They are no longer expected to reflect a few selected mobility characteristics but to be a realistic representation of the real world. In consequence, the validation of spatio-temporal micro-simulations has to be deepened and to be especially moved towards a holistic view on movement validation. Chapter 8 paves the way for a novel, better, and more detailed evaluation standard for spatio-temporal micro-simulation systems. The chapter collects and structures’ various aspects that have to be considered for the validation and comparison of movement data.

In the next chapter, the issue of validation is explained further because in the specific case of activity-based models of travel demand, a micro-simulation approach is adopted, thereby inevitably including a stochastic error that is caused by the statistical distributions of random components. As a result, running a transport micro-simulation model several times with the same input will generate different outputs. In order to take the variation of outputs in each model run into account, a common approach is to run the model multiple times and to use the average value of the results. The question then becomes: What is the minimum number of model runs required to reach a stable result? Chapter 9 provides details on systematic experiments that are carried out by using FEATHERS, an activity-based micro-simulation modeling framework currently implemented for Flanders (Belgium). Six levels of geographic detail are taken into account, which are building block level, subzone level, zone level, superzone level, province level, and the whole Flanders. Three travel indices (i.e. the average daily number of activities per person, the average daily number of trips per person, and the average daily distance travelled per person) as well as their corresponding segmentations with respect to socio-demographic variables, transport mode alternatives, and activity types are calculated by running the model 100 times. The results show that application of FEATHERS at a highly aggregated level only requires limited model runs. However, when a more disaggregated level is considered (the degree of the aggregation here not only refers to the size of the geographical scale but also to the detailed extent of the index), a larger number of model runs is needed to ensure confidence of a certain percentile of zones at this level to be stable.

Over the last decade, traffic simulation frameworks advanced into an indispensable tool for traffic planning and infrastructure management. For these simulations, sophisticated models are used to “mimic” traffic systems in a lifelike fashion. In most cases, these models focus on a rather technical scope. Human factors, such as the drivers’ behaviour, are either neglected or estimated without any proven connection to reality. Chapter 10 presents an analysis of psychological driver models in order to establish such connection.

Chapter 11 describes the authors’ continued efforts and experiences with the development, calibration, validation, and application of a regional agent-based traffic model of a medium-sized metropolitan area with the goal of shedding light on the challenges, lessons learned, and the opportunities of regional agent-based transportation models. Specifically, the chapter highlights efficient procedures for identifying network coding errors and describes how one might go about validating and calibrating such complex models so as to achieve a good match between the model’s simulated results and the field counts.
Modeling activities and travel for individuals in order to estimate traffic demand leads to large-scale simulations. Most current models simulate individuals acting in a mutually independent way except for the use of the shared transportation infrastructure. As soon as cooperation between autonomous individuals is accounted for, the need for agent-based simulation emerges. Chapter 12 presents a novel agent-based model for the carpooling application.

The last series of chapters in this book relate to the rise in both development and usage of electric vehicles all around the world. This rise has influenced not only the transportation infrastructure but also has an impact on the electricity grid. Chapter 13 provides an overview of electric power systems. The purpose is to describe the structure and operation of the power system and its evolution to the new smart grids.

Battery-electric and plug-in hybrid-electric vehicles are envisioned by many as a way to reduce CO₂ traffic emissions, support the integration of renewable electricity generation, and increase energy security. Electric vehicle modeling is an active field of research, especially with regards to assessing the impact of electric vehicles on the electricity network. Chapter 14 presents a framework for electric vehicle modeling that provides strong capabilities for detailed electricity demand modeling. This model is built on an agent-based travel demand and traffic simulation.

As mentioned earlier, electric mobility is becoming an option for reducing greenhouse gas emissions of road transport and decreasing the external dependence on fossil fuels. However, this new kind of mobility will introduce additional loads to the power system, and it is important to determine its effects on it. An application related to electric mobility and its impact on the electric grid from Flanders region is presented in chapter 15.

Similarly, chapter 16 presents a coordination algorithm for charging electric vehicles that can be used for avoiding capacity problems in the power distribution grid and for decreasing imbalance costs for retailers. Since it is expected that the fraction of electric vehicles will exceed 50% in the next decades, charging these vehicles will roughly double the domestic power consumption, and not all parts of the grid are expected to be able to provide the required power. Therefore, this chapter is quite interesting for the stakeholders from the power industry to be able to manage the future needs.

Last, but not the least, chapter 17 assesses the impact of different technical solutions and their impact on the ability of a fleet of plug-in hybrid-electric vehicles to drive in electric mode as much as possible. The technical solutions covered in this chapter to attain this objective include: charging at low and medium power; charging at home, at work, and at other locations; and using fleets with small, medium, and large battery sizes. The driving behavior of the fleet is modeled using an availability analysis based on statistical data from Flanders and The Netherlands.

This book is mostly based on the work performed within the European FP7 project called Data Science for Simulating the Era of Electric Vehicles (DATASIM) (www.datasim-fp7.eu). Many researchers are working on the problems defined above in the framework of this project. However, it would be difficult for any small group of people to cover such a broad topic with the appropriate depth and expertise. In order to tackle this challenge for this book, we, the editors, looked to our colleagues from within and outside the DATASIM project consortium to find experts from the domain in question. You can see that the list of authors has grown quite large and contains a good mixture of academics, consultants, and people from the industry. We are very fortunate to have received contributions from the knowledgeable
authors in this book, and we are extremely grateful for this. We applaud the efforts of our contributors, partners, advisory board, reviewers, and all the others who helped us make this book a success. We all hope to see the important research work presented in this book used in our everyday lives soon!

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