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## Preface

The goal of this book is to provide a comprehensive, in-depth, and state-of-the-art summary of the important aspects of transportation analysis and modeling and simulation. The term modeling and simulation refers to computer simulation, with an emphasis on modeling real transportation systems and executing the models. A recent White House report identified computer modeling and simulation as one of the key enabling technologies of the twenty-first century. Its application is universal. For this reason, the book strives to motivate interest in transportation analysis and modeling and simulation as well as to present these topics in a technically correct yet clear manner. This required making some carefully considered choices in selecting the material for this book.

First the fundamentals of modeling are described, as they represent the largest portion of transportation analysis. In addition, the mathematical background describing real transportation systems is introduced on a basic level as well as on a more advanced one; and its correspondence to the respective modeling methodologies is described. Secondly, the most interesting simulation systems are presented at the language and logic level, and their use is described in several case studies. However, a textbook cannot describe all of the available simulation systems in detail. For this reason, the reader is referred to specific supplemental material, such as textbooks, reference guides, user manuals, etc., as well as Internet-based information which addresses several simulation languages. Thirdly, a variety of actual applications are presented which have been conducted during a long period of collaboration with Prof. Bernard Schroer, Ph.D., University of Alabama in Huntsville (UAH), USA.

This book was developed for use by senior and graduate level students in applied mathematics, operations research, computer science, and engineering and business informatics and to serve as the primary text for a course on Transportation Analysis, Modeling and Simulation, held annually at Clausthal University of Technology.

The material in the book can be difficult to comprehend if the reader is new to such an approach. This is also due to the fact that transportation analysis/modeling and simulation is a multidisciplinary domain, founded in computer science, engineering, mathematics, operations research, etc. The material may not be read and comprehended either quickly or easily. Therefore, specific case studies have been embedded with related topics to help the reader master the material.

It is assumed that the reader has some knowledge of basic calculus-based probability and statistics and some experience with computing.

The book can be used as the primary text in a course in various ways. It contains more material than can be covered in detail in a quarter-long (30-h) or semester-long (45-h) course. Instructors may elect to choose their own topics and add their own case studies. The book can also be used for self-study; as a reference for graduate engineers, scientists, and computer scientists for training on the job or in graduate school; and as a reference for transportation analysis and modeling and simulation practitioners and researchers.

For instructors who have adopted the book for use in a course, a variety of teaching support materials are available for download from <http://www.springer.com/978-1-4471-5636-9>. These include a comprehensive set of Microsoft PowerPoint slides to be used for lectures and all video-recorded classes.

The book is divided into six chapters which can be read independently or consecutively.

Chapter 1, Computational Foundation in Transportation and Transportation Systems Modeling, covers the classification of models used for multimodal transportation systems and introduces transportation and transportation systems for the movement of passengers or freight and how to analyze their behavior. A transportation case study planning a seagate harbor expansion by a dry port is introduced.

Chapter 2, Transportation Models, contains a brief overview of the use of models in the transportation sector, the several types of models used in transportation planning, the specific evaluation methods used, queuing theory to predict queuing lengths and waiting times, and the methodological background of congestion, graph theory, and bottlenecks. Finally a ProModel-based case study for a four-arm road intersection is introduced.

Chapter 3, Traffic Assignments to Transportation Networks, introduces traffic assignment to uncongested and congested road networks; the equilibrium assignment, which can be expressed by so-called fixed point models where origin-to-destination demands are fixed, representing systems of nonlinear equations or variational inequalities; and the multiclass assignment based on the assumption that travel demand can be allocated as a number of distinct classes which share behavioral characteristics. The case study involves a diverging diamond interchange (DDI), an interchange in which the two directions of traffic on a nonfreeway road cross to the opposite side on both sides of a freeway overpass (or underpass).

Chapter 4, Integration Framework and Empirical Evaluation, is an introduction to computer simulation integration platforms and their use in the transportation systems sector. It provides, in addition to an overview of the framework architectures, an introduction into ontology-based modeling and its integration into transportation; the workflow-based application integration in transportation; and detailed case studies for a marine terminal traffic network simulation, an airport operation simulation, a highway ramp control simulation, and vehicle tracking using the Internet of Things paradigm.

Chapter 5, Simulation Tools in Transportation, gives an overview of transportation simulation tools including continuous systems simulation tools, such as

block-oriented and equation-oriented simulation tools, and discrete-event simulation tools. Some of the many available simulation software packages are described with a focus on those used for the case studies in this book. Finally, a ProModel-based case study for a maritime transportation analysis is introduced.

Chapter 6, Transportation Use Cases, introduces, from a general perspective, critical issues in the design, development, and use of simulation models of transportation systems. Case studies in Chap. 6 include real transportation projects such as the McDuffie Coal Terminal at the Alabama State Docks in Mobile, the Container Terminal at the Port of Mobile and its intermodal container handling facilities, and an analysis of the operation of an intermodal terminal center before the design of any planned expansion is finalized. A case study on port security inspection is included due to the increased security requirements for the operation of seaports. The objective of the simulation is to evaluate the impact of various inspection protocols on the operation of the container terminal at the Port of Mobile. The objective of the Interstate Traffic Congestion case study is to determine the congestion point as traffic increases and to evaluate adding additional lanes at congestion points. Tunnels are an important solution for the transportation infrastructure, e.g., for crossing a river such as the Mobile River in downtown Mobile, Alabama. Besides the maritime transportation sector, the aviation domain also calls for innovative solutions to optimize their operational needs. Thus the first of the two aviation case studies focuses on passenger and freight operations at Hamburg Airport to estimate the maximum numbers of passengers and freight that can be dispatched to identify potential opportunities in process optimization with regard to the expected growth in passenger and freight numbers. In the second aviation case study, an Italian airport transportation operation conducted by an international student team is introduced to demonstrate how an international group of students can be motivated to conduct an innovative, advanced project in a very complex area of concentration in modeling and simulation.

Besides the methodological and technical content, all chapters of the book contain comprehensive questions from the chapter-specific area to help students determine if they have gained the required knowledge, identifying possible knowledge gaps and conquering them. Moreover, all chapters include references and suggestions for further reading.

I would like to express my special thanks to Prof. Bernard Schroer, Ph.D., University of Alabama in Huntsville, USA, for our long collaboration on research-oriented projects in transportation analysis and modeling and simulation; to Prof. Jerry Hudgins, Ph.D., University of Nebraska-Lincoln, USA, for his great support in working at the University of Nebraska-Lincoln on computer modeling and simulation; to Prof. Dr. Thomas Hanschke, Chairman of the Simulation Science Center at Clausthal-Göttingen (SWZ), Germany, for electing me as a member of the Simulation Science Center Clausthal-Göttingen; to Prof. Louis G. Birta, Ph.D., University of Ottawa, Canada, for inviting me to contribute this book to the series, *Simulation Foundations, Methods and Applications*, he is editing; to Patricia Worster, University of Nebraska-Lincoln, for her excellent assistance in

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Finally, I would like to deeply thank my wife, Angelika, for her encouragement, patience, and understanding during the writing of this book.

This book is dedicated to my parents, Wilhelm and Hildegard Möller, whose hard work and belief in me made my dreams a reality.

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