

Preface

Networks permeate our daily lives, underpinning our economies and societies and provide the infrastructure for business, science, technology, social systems, and education. Transportation networks give us the means to cross physical distance in order to see clients and conduct business, as well as to visit colleagues and friends and to explore new vistas and expand our horizons. They enable manufacturing processes through the supply of the necessary input components and the ultimate distribution of the finished products to the consumers.

Communication networks, in turn, allow us to access and to share data within our communities and across regions and national boundaries and to inform others as well as to be informed. Energy networks help to fuel not only transportation networks but in many settings also communication networks. They provide electricity to run the computers and to light our businesses, oil and gas to heat our homes and to power vehicles, and water for our very survival.

Financial networks supply businesses with the resources to expand, to innovate, and to satisfy the needs of consumers. They allow individuals to invest and to save for the future for themselves and for their children and for governments to provide for their citizens and to develop and enhance communities.

The advent of the Information Age with the increasing availability of new computer and communication technologies, along with the Internet, have transformed the ways in which individuals work, travel, and conduct their daily activities, with profound implications for existing and future networks. Moreover, the decision-making process itself has been altered due to the addition of alternatives and options which were not, heretofore, possible or even feasible. The boundaries for decision-making have been redrawn as individuals can now work from home or purchase products from work. Managers can now locate raw materials and other inputs from suppliers through information networks in order to maximize profits while simultaneously ensuring timely delivery of finished goods. Financing for their businesses can be ob-

tained online. Individuals, in turn, can obtain information about products from their homes and make their purchasing decisions accordingly.

The reality of today's networks include: large-scale nature and complexity, increasing congestion, alternative behaviors of users of the networks, as well as interactions between the networks themselves, notably, between transportation and telecommunication networks. The decisions made by the users of the networks, in turn, affect not only the users themselves but others, as well, in terms of profits and costs, timeliness of deliveries, the quality of the environment, etc.

In this book, we lay out the theory of *supernetworks* in order to formalize decision-making in the Information Age. "Super" networks are networks that are "above and beyond" existing networks, which consist of nodes, links, and flows, with nodes corresponding the locations in space, links to connections in the form of roads, cables, etc., and flows to vehicles, data, etc. Supernetworks are conceptual in scope, graphical in perspective, and, with the accompanying theory, predictive in nature.

In particular, we seek to capture, within a unifying framework, decision-making facing a variety of economic agents including consumers and producers as well as distinct intermediaries in the context of today's networked economy. The decision-making process may entail weighting trade-offs associated with the use of transportation versus telecommunication networks. The behavior of the individual agents is modeled as well as their interactions on the complex network systems with the goal of identifying the resulting equilibrium flows and prices.

This book provides the conceptual, analytical, and computational tools for the study of supernetworks. The approach is rigorous and of sufficient generality and detail to give added insight into the behavior and structure of large-scale, interacting and competitive network systems, consisting of numerous agents and alternatives.

This book consists of four parts, with a total of twelve chapters. The first part provides an introduction, discusses the origins of supernetworks, and lays the foundations for their study. Part II then focuses on multitiered supernetworks with applications to supply chain networks with electronic commerce and financial networks with intermediation. Dynamic versions of the models are studied using a multilevel network perspective. Part III turns to multicriteria network equilibrium models and addresses such relevant topics in the Information Age today as: telecommuting versus commuting decision-making, teleshopping versus shopping decision-making, as well as location and transportation decision-making. Part IV describes new directions for supernetworks by providing extensions and syntheses of some of the earlier material in this book.

The intended audience for this book includes students, researchers, and practitioners in economics and business, in computer science, in engineering, and in operations research and management science, who are interested in the

formulation, qualitative analysis, application, and computation of complex network systems in the Information Age.

The writing of this book was made possible by the support of several National Science Foundation (NSF) grants. In particular, the authors acknowledge support under NSF Grant No.: IIS-0002647. The first author also acknowledges support under NSF Grant No.: CMS-0085720 and NSF Grant No.: INT-0000309. The authors would like to thank Dr. Suzi Iacono, Director, Computation and Social Systems Program at NSF, for support in this endeavor.

Anna Nagurney would also like to thank Dr. Mark Suskin, Program Manager, Western Europe Program, Division of International Programs, and Dr. Miriam Heller, Program Director, Information Technology for Infrastructure Systems at NSF for support. She also thanks Dr. Rick Adrion, Division Director of Experimental and Integrative Studies, Directorate for Computer and Information Science and Engineering at NSF and Professor of Computer Science at the University of Massachusetts at Amherst for encouragement and supportive conversations.

In addition, Nagurney would like to thank Mr. John F. Smith, Jr., the Chairman of the Board of General Motors, for his support through the John F. Smith Memorial Fund at the Isenberg School of Management at the University of Massachusetts at Amherst.

The writing of this book was initiated while Nagurney was visiting the Royal Institute of Technology (KTH) in Stockholm, Sweden, during the summer of 2001. The hospitality of the host institution and, in particular, the Division of Transport and Location Analysis and the Department of Infrastructure and Planning at KTH are warmly appreciated. The support of Swedish academic colleagues and collaborators, notably, Professors Lars-Goran Mattsson and Lars Lundqvist in this endeavor is recognized.

Dong thanks the Department of Management at the Hong Kong Polytechnic University for giving her the opportunity to visit. In particular, she would like to thank Professors Gerald Fryxell, Edwin Cheng, and Hong Yan for support.

The authors acknowledge the collaborations with Professor Ding Zhang of the State University of New York at Oswego and with Professor Patricia L. Mokhtarian of the University of California at Davis. The first author also thanks Professor Kitty Hancock of the Department of Civil and Environmental Engineering at the University of Massachusetts, Amherst and Dr. Frank Southworth of the Oak Ridge National Laboratory in Tennessee for their collaborations.

The authors acknowledge Professor Ladimer S. Nagurney of the University of Hartford for his technical assistance and Christopher Sullivan and Jose Cruz for their library and web-based research and for their reading of various parts of the manuscript.

The authors are grateful to their families for traveling with them in order

to allow for the writing and completion of this book. Anna Nagurney thanks her husband, Ladimer, and daughter, Alexandra, for their support while in Sweden. She also acknowledges the outstanding housing arrangements in Stockholm provided by the Wenner Gren Centre Foundation, which enabled the establishment of new friendships and renewal of old ones with researchers and their families from around the world. June Dong thanks her husband, Ding Zhang, and their children, Alex and Alena, for their support while in China.

The authors are indebted to their home institutions, respectively, the Isenberg School of Management at the University of Massachusetts at Amherst and the School of Business at the State University of New York at Oswego for supportive work environments. The second author thanks SUNY at Oswego for granting her the sabbatical leave.

Finally, the authors acknowledge the contributions of the pioneers of the Internet, since without that network, the writing of this book would have been not only substantially more time-consuming but also not nearly as enjoyable.

Parts of the material in Chapter 9 are forthcoming in “Urban Location and Transportation in the Information Age: A Multiclass, Multicriteria Network Equilibrium Perspective,” A. Nagurney and J. Dong (2001a), *Environment & Planning B*. Parts of Chapter 10 are forthcoming in “Spatial Economic Networks with Multicriteria Producers and Consumers: Statics and Dynamics,” A. Nagurney, D. Zhang, and J. Dong (2001), *Annals of Regional Science*. Parts of Chapter 11 have appeared in “Bicriteria Decision Making and Financial Equilibrium: A Variational Inequality Perspective,” J. Dong and A. Nagurney (2001), *Computational Economics* **17**, 29-42. Parts of Chapter 12 have appeared in “Paradoxes in Networks with Zero Emission Links: Implications for Telecommunications versus Transportation,” A. Nagurney and J. Dong (2001b), *Transportation Research D* **6**, 283-296.

The authors acknowledge Pion Ltd., the publisher of *Environment & Planning B*, Springer Verlag, the publisher of *Annals of Regional Science*, Kluwer Academic Publishers, the publisher of *Computational Economics*, and Elsevier Science Ltd., the publisher of *Transportation Research D*, for the use of the above material in this book.