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Handbook of Transportation Science

by Vincent W. Yao

Over the past decades a substantial amount of theoretical and empirical research has been done across different domains of transportation, including engineering, public policy and economics. Much of this research has been synthesized into a systematic handbook that examines the scientific concept, methods and empirical investigation of the emerging and evolving field of transportation science. *Handbook of Transportation Science* is more focused on properties and characteristics that transcend individual modes of transportation and collectively define the science of transportation. For this purpose, the book is structured to elucidate the properties on a subject-by-subject basis, rather than by mode. The 18 papers included in this handbook are written by prominent scholars on each subject in an effort to explore the scientific nature and state-of-the-art practice of the field. They are sorted into five subjects: human elements in transportation, flows and congestion, spatial models, routing and network models, and economic models.

Section one has discussions on research on human elements or decisions in transportation. On a daily basis, individuals are presented with a handful of transportation choices, and the decision is determined either by environment or by human elements. In the paper by Ben-Akiva and Bierlaire (Chapter 2), theoretical and practical aspects of discrete choice models are reviewed, such as logit, nested logit, generalized extreme value and probit models, as well as more recent developments like hybrid logit and latent class choice models. As an illustration, different models are applied to estimate the departure time and route choice. These decisions are imbedded within the broader context of how we plan and organize our travel activities in the paper by Bhat and Koppelman (Chapter 3). The methods in activity-based travel analysis not only include discrete choice models but also other models that accommodate non-discrete choice variables in activity modeling. The latter methods have merged more recently because of the need to model travel as part of a larger activity-travel pattern and involve relatively non-traditional methodologies such as duration analysis and limited-dependent variable models. Evans (Chapter 4) provides a very thorough review of issues related to transportation safety. Because more than 94% of the transportation fatalities are accounted for by road traffic, the chapter focuses on the factors influencing road traffic safety to find approaches to reduce harm from traffic crashes. These factors include engineering and road user factors. The fatality rate also differs by driver age.

The second section deals with the relationship between travel time and traffic flows, which is an important basis for congestion theory. Both papers show how congestion originates on transportation networks and how vehicles, travelers and shipments interact as they travel across the network. Hall (Chapter 5) considers transportation queueing to have evolved in its own distinct direction, compared to queues in communication or production. He includes examples of vehicular flow on highways, signalized intersections, transit and trucking, aircraft and airports, and railways. The effective models used to address the queueing problem in bulk service are economic order quantity (EOQ) and economic production quantity (EPQ) models, which have been used for many years in transportation and manufacturing to optimize cycle lengths, load size and batch quantities. Cassidy's paper (Chapter 6) is devoted to methods of measuring traffic stream properties and of predicting how these properties evolve over time and space. Certain emphasis is given to flow

restriction or bottlenecks, and to the estimation of their capacities because traffic streams are often impacted by these restrictions.

At a more microscopic level, vehicle flows and trajectories depend on how their speed and direction are controlled. Loannou and Bose (Chapter 7) discuss automated techniques for controlling trajectories, how to implement those techniques and the benefits they obtain. The chapter begins with vehicle longitudinal and lateral dynamics models, followed by discussions on longitudinal controllers for heavy vehicles, vehicle-to-vehicle communication designs and sensor requirements that are needed to ensure sage and proper operation of automated vehicles. Chapter 8 by Papageorgiou covers control at the more macroscopic scale of regulating flows, which is typically executed by conveying messages to vehicle operators. These controls include isolated intersection control, fixed-time coordinated control, freeway traffic control, and route guidance and driver information.

Section three on spatial models covers the historical core topics of transportation science: continuous-space models (Chapter 9) and transportation location (Chapter 10). The continuous-space approach in Puu and Beckman's chapter has been used extensively as an explanatory tool for optimal network design, both with respect to physically constructed networks and operational networks. It draws from spatial economic theory and continuum models in physics. The chapter on transportation location by Daskin and Owen also addresses system design, largely from the perspective of placing discrete facilities, such as terminals and points of production. Among classical location models, there are three classes of objectives typically used in modeling: minimizing the number of selected facilities, maximizing the number of covered demands and minimizing the maximum demand-weighted distance between facilities and demand sources, subject to different constraints. More recently, attempts have been made to address the limitations like multiple objectives, stochastic inputs, dynamics decisions, vehicle route considerations and interaction of the network with facility locations.

Section four focuses on routing and network models, represented by the assignment of traffic to different networks, or of persons/shipments to vehicles and terminals, and the sequencing of stops along routes. Florian and Hearn (Chapter 11) formulate the network equilibrium and pricing models, both deterministic and stochastic, followed by subsequent applications and validations. However, some of the basic premises of the formulation of these models such as the additivity of link costs to form the cost of a path, and the static analysis of average flows during a selected time period, open the way to the study of more complex models. The recent interest in temporal or dynamic network equilibrium models is already attracting the attention of many researchers. The following four chapters are discussions of different aspects of routing assignments. Chapter 12 by Bodin, Maniezzo and Mingozzi emphasizes local street routing (the street routing and scheduling problem or SRP), represented by vehicle tours that can be accomplished within the span of a single day. Chapter 13 by Crainic is on routing freight over long-haul networks, represented by tours that travel from city to city and last more than a day. The author points out that both intelligent transportation systems (ITS) and the electronic business way of interacting with customers and partners have already been impacting how transportation firms plan and operate. Chapter 14 by Barnhart and his coauthors covers the airline (cockpit) crew scheduling on longhaul networks, with a focus on the personnel constraints that dictate feasible tours. The newly-added chapter by Hall (Chapter 15) extends the networks section by addressing supply chains, distribution networks and logistics. The chapter emphasizes the consolidation of trade-off between waiting cost and transportation cost to minimize the total logistics costs, and the availability and usage of information in supply chain management.

The final section of the book focuses on transportation economics. Ryzin and Talluri's paper (Chapter 16) reviews the recent developments of revenue management (RM), how transportation companies can use pricing to maximize their returns on investment. All the RM problems are implemented with disciplined processes and systems. The chapter is focused on the core methodology for use in the airline industry (and related industries like hotels) during the last 25 years. Rietveld and Nijkamp in Chapter 17 present a framework for predicting patterns of development, in light of

transportation services and infrastructure. The four stage model, one of the most comprehensive approaches for travel demand forecast is revisited, which includes trip generation, trip distribution, modal choice and route assignment with new perspectives. The final chapter by Arnott and Kraus covers transportation economics in general, with emphasis on pricing, markets and public policy. Models presented include a traditional highway pricing and investment model, a highway bottleneck model, and models for mass transit. This chapter illustrates principles of transportation economics regarding demand, supply and regulation with the ultimate objective of efficient allocation of scarce resources.

Overall, this book is a comprehensive reference for transportation researchers. Most chapters are written by authors who have contributed substantially to that subject and are derived from papers or books they have published over the years. Therefore, without downloading tons of original papers, readers can find important developments in the discipline of transportation science over the time. For instance, with my economics background, I was only familiar with section one and five, which are on various limited dependent variable models, human behavior and transportation economics. Without spending too much time, I learned the major developments on topics of scheduling problems for different modes by reading five papers in section four. The interested reader may choose to read papers of his or her interest, but it would be valuable to read all of the papers because they provide current research in the entire field. In general, each chapter is very well written and easy to understand. I recommend it as a desk tool for most transportation professionals.

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