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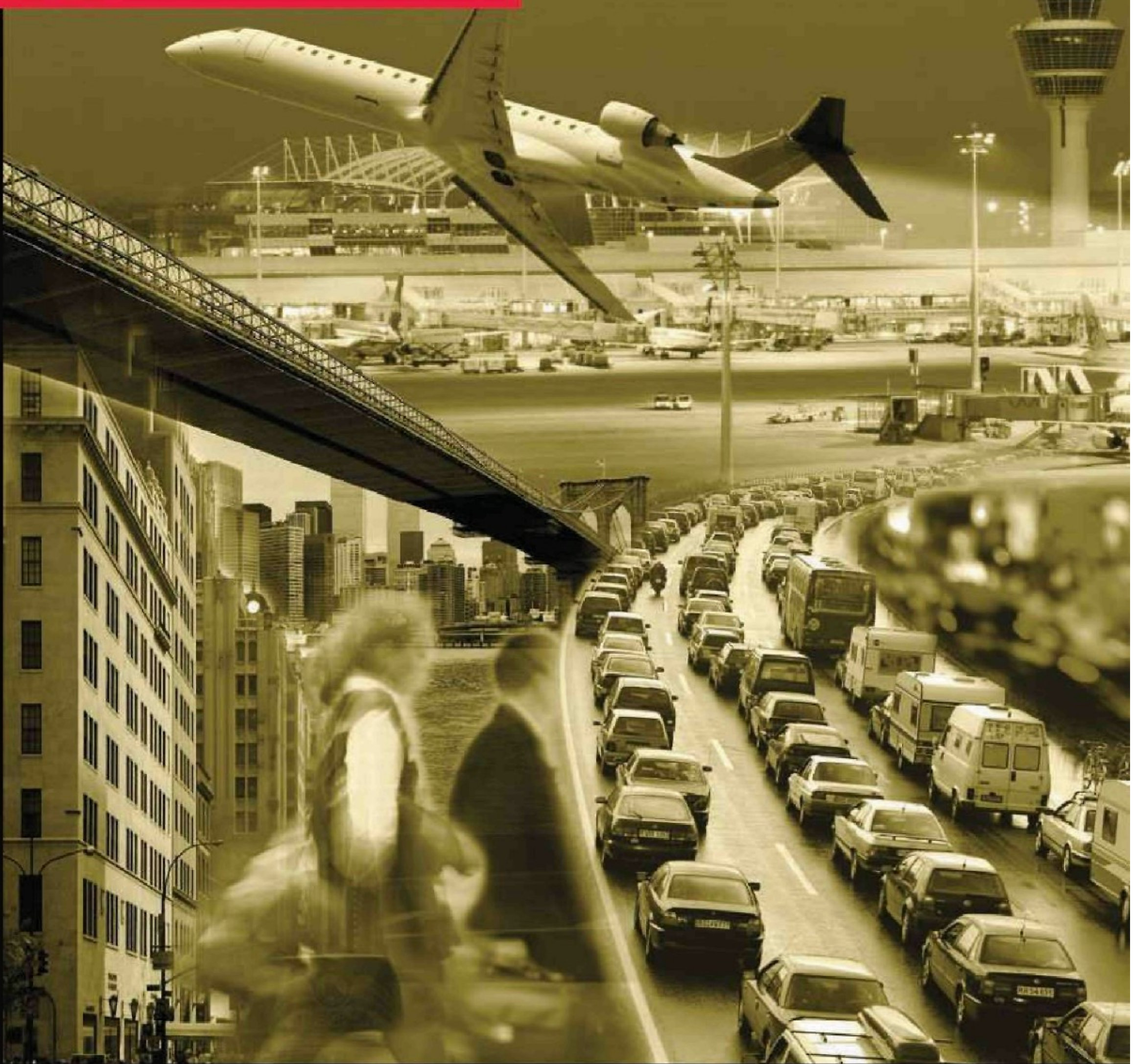

Routledge Handbook of Transportation

Edited by Dušan Teodorović

THE ROUTLEDGE HANDBOOK OF TRANSPORTATION

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Dušan Teodorović

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FOREWORD

Since the first organization of human societies and the division of labor, the transportation of persons and goods had an essential role in the progress of human civilization, contributing to and gaining from the technological and societal evolution. For thousands of years, transportation was taking place on surface paths and roads as well as on waterways. It is only in the last couple of centuries where railways were introduced, and even more recently when air transportation entered the scene. While for thousands of years transportation was almost exclusively serving trade and other professional activities, an initially timid, but eventually dramatic increase of recreational transportation needs has been observed over the last centuries. Today, transportation in developed countries accounts for some 6 percent of the GDP and some 13 percent of the family budget on average. On the other hand, the societal, environmental and personal cost of transportation has also grown enormously. There are 1.24 million road traffic deaths worldwide every year. Transport is the second largest sector in terms of emissions, releasing 22 percent of global CO_2 emissions in 2011. The fast emissions growth of the transport sector was mainly driven by emissions from the road sector, which increased by 52 percent since 1990, accounting for about three-quarters of transport emissions in 2011. Global transport fuel demand is expected to grow by nearly 40 percent by 2035. These statistics generate rightly questions about the rationality of the evolution of transportation, particularly in the last decades, the most severe of these questions concerning the usage of (typically one-person occupancy) cars in large metropolitan areas.

The interrelated evolution and continuous expansion of transportation means, infrastructure and needs would not have been possible without the parallel gathering, development and enhancement of skills, techniques and experiences, which eventually evolved in the interdisciplinary area of Transportation Science. Transportation is the main subject of study for myriads of students at corresponding divisions, departments and universities at all higher education levels, as well as the subject of intensive research activity at industrial firms, consultants, universities and research institutions around the globe. Transportation Science encompasses the design, planning, operation, assessment of all transportation modes, both separately and in appropriate multimodal combinations, and covers a broad variety of aspects, spanning from traffic flow theory to human factors and economics. The Transportation discipline has close ties and indeed overlaps with many other scientific disciplines, a non-exhaustive list comprising fluid mechanics, simulation, dynamic systems, optimization, metrology, automatic control, communications, computer science, psychology and economics. Thus, progress in each of these disciplines may be reflected in corresponding advancement of Transportation Science as well, and this is a first engine and source for innovation in the area. A second and more important motivation for innovation and improvements are the difficulties and problems appearing in transportation practice due to the steady demand and infrastructure expansion, shifting objectives, priorities and emerging needs. This calls for close cooperation of agencies responsible for the planning and operation of Transportation systems with agencies addressing Transportation research, something that, like in other disciplines as well, is not always achieved in the best possible way.

Transportation typically involves discrete entities, i.e. vehicles or particles. In some cases, e.g. in aspects of road traffic, it is reasonable and helpful to view the transportation system in an aggregate way, as a particular continuous fluid on traffic networks, while in other cases (e.g. a rail system), the significance of each transportation vehicle must be reflected in the analysis and considerations, leading to discrete mathematical representations (e.g. the scheduling task). When the density of transportation particles within a transportation infrastructure is low, planning and design may be static and focus mainly on safety. As the density of particles increases, network efficiency concerns must also be considered, and the related methods and tools have to consider dynamic aspects of the transportation process as well. Even higher concentration of vehicles may lead to congestion, i.e. a situation where the transportation infrastructure is degraded due to excessive queuing and spillback phenomena, leading to accordingly excessive delays, fuel consumption and environmental impact. As a matter of fact, increasing demand or exogenous events may lead to such situations at specific locations and time periods on all transportation modes. This calls for the development of appropriate methods and means to protect the infrastructure from the detrimental degradation. Intelligent Transportation Systems (ITS) is a relatively new domain, boosted by recent technological advances in communication, computing and control, aiming at optimizing the performance of transportation systems and mitigating congestion phenomena.

This *Handbook of Transportation* gathers contributions from virtually all areas and modes of Transportation, with focus on recent developments. The Editor, Professor Dušan Teodorović, has done an excellent job in the selection of subjects and experienced authors for each included subject. The volume will be valuable for students, researchers and engineers interested in particular transportation subjects, but it can also be consulted or read to gain a global overview of the many different aspects of the transportation domain and to discover, except for the differences, also many similarities among different subjects and modes. I believe that this work will have its own contribution to transportation education, research and, last but not least, to a more efficient, safe and environmentally friendly transportation system in the years to come.

Markos Papageorgiou

THE ROUTLEDGE HANDBOOK OF TRANSPORTATION

The *Routledge Handbook of Transportation* offers a current and comprehensive survey of transportation planning and engineering research. It provides a step-by-step introduction to research related to traffic engineering and control, transportation planning, and performance measurement and evaluation of transportation alternatives.

The *Handbook of Transportation* demonstrates models and methods for predicting travel and freight demand, planning future transportation networks, and developing traffic control systems. Readers will learn how to use various engineering concepts and approaches to make future transportation safer, more efficient, and more sustainable.

Edited by Dušan Teodorović and featuring 29 chapters from more than 50 leading global experts, with more than 200 illustrations, the *Routledge Handbook of Transportation* is designed as an invaluable resource for professionals and students in transportation planning and engineering.

Dušan Teodorović is Professor at the Faculty of Transport and Traffic Engineering, University of Belgrade, Serbia, and Professor Emeritus of the Virginia Polytechnic Institute and State University, USA. Dr. Teodorović received a Ph.D. degree in engineering from the University of Belgrade and has worldwide academic experience. His primary research interests are in operations research and computational intelligence applications in transportation engineering. Dr. Teodorović has been elected a member of the Serbian Academy of Sciences and Arts and the European Academy of Sciences and Arts.

CONTENTS

4. Modeling the Operational Performances of the ATC System

General

The above-mentioned performances of different components of ATC system can be modeled using analytical, simulation, and optimization models. In general, the capacity of airspace, ATC sector based on the ATC controller's workload, the A/G communication link, air route network, and ATFM operations and processes have been under focus (Bertsimas and Patterson, 2000; Janić and Tosic, 1991; Odoni, 1987; Péter, T. and Szabó, Z., 2012; Vranas, 1994). Here, the analytical model for estimating the ATC sector capacity based on the ATC controllers workload is presented (Janić, 1997).

Model of the ATC Sector Capacity

The models for estimating the ATC sector ("ultimate") capacity are commonly based on estimation of the ATC controller's workload generated by executing the main ATC tasks/activities such as monitoring air traffic on the radar and other (CDIT) screens, decision-making, and executing the control tasks, all under given conditions (EEC, 2003; Janić, 1997). Monitoring screens enables the ATC controller to memorize the current air traffic situation in the sector by using his/her internal "mental" model and store it into the short-term memory. This is then used together with information exchanged with pilots via the A/G/communication link and that with the air traffic controllers from neighboring ATC sectors for creating and carrying out control tasks. It is commonly assumed that the ATC controller cannot simultaneously monitor screens and carry out control tasks, which appears crucial for modeling the ATC sector capacity in the given context. Assuming that the ATC controller operates as at the channel serving demand consisting of the control and monitoring tasks, his/her workload can be expressed by the workload coefficient as follows:

$$\rho = \rho_m + \rho_c = 1.0 \tag{1}$$

where

ρm is the workload coefficient due to monitoring screens; and

ρc is the workload coefficient due to performing control tasks.

Equation 1 implies the ATC controller's maximum workload during a given active period of time (for example, 42 min of 1 hour (EEC, 2003)).

The workload coefficient ρ_m in equation 1 can be estimated as:

$$\rho_m = \frac{t_1^*}{t_1^* + t_2^*} \tag{2}$$

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