There can be no doubt that the economic globalization of the last decades and the growing need for flexibility in modern enterprises have transformed freight transport and turned it into a major public policy and corporate domain. Freight transportation research has reflected this evolution and is quite justifiably attracting ever closer attention.

Transportation is not just the product of social and economic activity. Good and reliable transport remains a sine qua non for sustained economic growth. Since production and consumption of goods and services are usually physically separated, the distance between the two needs to be bridged by means of at least one mode of transportation.

Similarly, relocating production activities, often from high-cost to low-cost countries, can only be achieved through better, cheaper and more extensive transportation services. The other side of the picture is that an unrestrained expansion of passenger and freight transport will create substantial negative externalities such as air pollution, congestion, accidents and damage to infrastructure. Consequently, if the relevant policies remain absent, the social costs of mobility may exceed the benefits.

Quite a number of international organizations, including the World Bank, IMF, UNCTAD, OECD and many others, have acknowledged the need for effective transport policy. However, implementing and, as the case may be, adjusting such transport policy is not a straightforward proposition. Continuous monitoring and effective insights are required to afford decision-makers the ability to successfully design and pursue transport policies while responding adequately to new challenges. Despite prolific research on passenger transport in the 1970s and 1980s, the pace of economic globalization since the 1990s has caused researchers and policymakers to shift their primary focus to freight transport.

As the late Professor Marvin Manheim emphasized in quite a few of his publications and in his opening address to the 8th World Conference on Transport Research (Antwerp, 1998), effective and sound resolutions for such issues require a new and broader transport analysis. This book aims to contribute to such an analysis by presenting the insights of a wide and international range of experts with a view to pushing forward frontiers in freight transport modelling. Hence it is intended for transport researchers in general and for those working on freight transport modelling in particular. It guarantees value added for experienced researchers and doctoral students alike. Moreover, the link with transport policy and management will be of interest to transport decision-makers in both government and industry.

In order to capture the complexity of freight transport systems, researchers have proposed a wide array of models. Gerard De Jong et al (2004) characterized such models as consisting in one or more mathematical-empirical relations designed to describe and explain the behaviour of a transport system. Ultimately, by taking into account that any transport system is subject
to exogenous shocks and/or policy measures, these models can provide insight into possible future evolutions in freight transport.

Small and Winston already asserted in 1999 that freight models must also represent special characteristics of transport markets, most importantly the interactions within or involving the transport system. Ideally, a whole range of important factors such as localization, trade issues, destinations, infrastructure, shipment and parcel size, timing and frequency of shipment, quality of service, transportation mode, routing, costing and inventory holdings, as well as possible interactions with passenger transport, should be entered into the equation.

To complicate matters further, due attention must be paid to the dynamic nature of transport systems. Some decisions need to be taken consecutively and require harmonization in order to optimize the transport and logistics chain. Others are to be taken simultaneously and may involve a high degree of interaction. Finally, freight transport models must allow for a considerable time lag between a decision and its implementation.

Thus far, the majority of freight transport models that have been put forward deal with specific topics and tend to be designed to deal with a limited number of interactions. The main constraint on the development of more elaborate freight transport models is the limited availability of data, especially at the level of individual firms.

Looking back at past decades, the modelling of freight transport demand has evolved from a non-structural, aggregate engineering approach that is conventionally used for traffic management and routing decisions to a structural, disaggregate approach. The aggregate models utilize global data on shippers and shipments to identify general relations resulting from underlying behavioural assumptions. The more sophisticated models rely on flexible functional forms and test such traditional restrictions as homogeneity, economics of scale and separability. With new empirical methods and growing availability of firm-level data, transport modellers have turned their focus on more behavioural disaggregated analyses.

In the literature, one can find various examples of both aggregate and disaggregate freight transport modelling. There are a number of studies providing extensive overviews of the state of the art in freight modelling (see for example Tavasszy, 2006). Three important fields are identified: the modelling of the relationship between transportation and economic activity, logistic decision-making and processes, and the linking of traffic flows and networks.

As Small and Winston (1999) have quite rightly pointed out, ‘economists have primarily, though not exclusively, focused on mode choice’. Over the past two decades, transport researchers have clearly broken with this tradition, as evidenced in this book.

**Content of the book**

The book consists of three parts. The first part deals with freight transport modelling from a global (international) point of view. Part two considers freight modelling from a regional perspective. The final part concentrates on the local/urban level.
The global section encompasses four chapters. The opening contribution, by Hilde Meersman and Eddy Van de Voorde, discusses the relationship between economic activity and freight transport. By applying stability and cointegration tests, the authors show that gross domestic product (GDP) is not the best indicator for modelling this relationship in the long run. There are several reasons for this. Some have to do with the changeable composition of GDP, others have to do with the altered relationship between freight transport and economic activity due to the globalization of the economy, policies aimed at decoupling freight and economic activity, and changing business behaviour (time-based competition, labour vs. transport costs, …). All this makes reliable long-term aggregate forecasting of freight transport on the basis of GDP very difficult indeed. A number of alternatives are suggested for estimating a reliable relationship between freight and well-chosen relevant indicators of economic activity. The general conclusion is that more specific disaggregate approaches are needed that are based on detailed microeconomic underpinnings of the behaviour of shippers and freight transport companies.

Ennio Cascetta, Vittorio Marzano, Andrea Papola and Roberta Vitillo discuss Multi-Regional Input-Output (MRIO) models for freight demand simulation at national level. They specify a model with elastic trade coefficients and a multimodal freight supply model on a European geographic scale. From the demand side, an elastic trade coefficient MRIO model is presented and some relevant macroeconomic feedbacks are discussed that are incorporable into the model. From the supply side, a critical review is presented of the complexity of the multimodal freight networks and the corresponding modelling requirements. From a practical standpoint, the implementation of an MRIO model at European level is reported, describing in particular both the database and the supply model for the calculation of transport impedances required by the trade coefficient model. Finally, the authors present some simple applications of the implemented MRIO model with elastic trade coefficients, before drawing conclusions and outlining some research suggestions.

In their contribution to freight choice analysis and market research, Moshe Ben-Akiva and Gerard de Jong start from the observation that most freight transport models applied by national, international and regional authorities ignore important aspects of logistics decision-making, such as the choice of shipment size and the use of consolidation and distribution centres. At the same time, these models often assume transport (mode) optimization at the aggregate zone-to-zone level, for which in reality no agents exist. The Aggregate-Disaggregate-Aggregate (ADA) freight model system tries to overcome these limitations by modelling the generation of trade flows and assignment to networks in an aggregate way, but simulating the logistics decisions at the level of individual firm-to-firm flows. The disaggregate part of the system is the logistics model, where shipment size and transport chain choice (including the use of transhipment centres) are determined by minimizing the total logistics cost. Most countries lack commodity flow surveys that include this information, but the disaggregate logistics model can also be calibrated to more aggregate data on the mode shares by commodity and aggregate zones. Models relying on the latter approach have been developed in Norway, Sweden and Flanders, and are under development in Denmark and for the European Union.
Terry Friesz, Amir Meimand and Bo Zhang model the dynamic shipper-carrier problem as a differential Stackelberg game. The shippers act as followers operating under the Cournot-Nash behavioural assumption while competing on the sale of a homogenous product in several markets. They choose their strategies simultaneously by maximizing their respective utility functions while assuming their competitors’ strategies are fixed. The leader in this problem is a transportation company referred to as the carrier who seeks to maximize its objective function while considering the followers’ reactions. The authors show that the differential Nash game describing the shippers’ competition may be articulated as a differential variation inequality (DVI). The DVI is then reformulated as a nonlinear complimentarily problem (NCP) to characterize the follower’s Nash-Cournot equilibrium by the implicit solution of a system of equations. This allows the shippers’ response to the carrier’s policy to be embedded into the carrier’s problem as a set of nonlinear constraints. The penalty method is then used to reduce the number of explicit constraints and finite-dimensional time discretization is employed to approximate the model as a mathematical program that may be solved by the multi-start global optimization scheme found in the off-the-shelf software package GAMS when used in conjunction with the commercial solver MINOS. They also present a small scale numerical example with two followers and four markets.

Part two of the book is comprised of eleven chapters on freight modelling at a regional level. The development of the disaggregate logistics choice model is the subject of the contribution of Moshe Ben-Akiva, Denis Bolduc and Jay Q. Park. They begin with a choice model based on the assumption that a shipper attempts to minimize the total logistics cost that includes transportation as well as order and inventory costs. They estimate their basic choice model using revealed preferences data from a US market research survey and extend this basic model in a number of ways. They apply recent developments in discrete choice analysis to better capture unobserved heterogeneity among shippers and to introduce into the model specification new variables that measure the perceived service qualities to the alternative modes. These extensions are then shown to be more powerful when the revealed preferences data are augmented with stated preferences data collected in the same survey. The results obtained by combining revealed and stated preferences data are shown to be superior to those obtained from revealed preferences only.

Michel Beuthe, Christophe Bouffioux, Cathérine Krier and Michel Mouchart present a systematic comparison of four methodologies for separately analyzing individuals’ stated preferences relative to the choice of alternative solutions of freight transport. These are defined by the monetary cost and five qualitative attributes: frequency of service, transport time, reliability, carrier’s flexibility, and damages/losses. As the data consist of alternatives rankings, the models applied are somewhat unusual in the field, at least in transportation analysis: conjoint analysis, UTA-type multi-criteria analysis, rank-ordered conditional logit, and neural network analysis. This chapter applies the above four models, some of them with non-linear utility functions, to the individual rankings of nine firms’ transport managers in diverse sectors of industry. The alternatives submitted to their judgment are conceived according to an orthogonal fractional factorial design. Each estimation methodology is
adjusted and specified to suit the specific data. Over this small set of individual firms, each method applied shows that cost is the most important factor in individual choice-making for seven out of the nine transport managers. Reliability is often more important than transport time, even though its relative importance varies from case to case. The other factors may play a significant role in some cases. These outcomes are mostly coherent with the earlier results obtained at an aggregate level. The two better-performing methods are the multi-criteria and the neural network analyses, which both involve non-linear partial utility functions.

Gernot Liedtke, Stefan Schröder and Li Zhang assert that, in order to analyze the impacts of policy measures aiming at influencing the behaviour of various logistics actors (such as road pricing instruments, regulation and market interventions), it is necessary to model decision-making in logistics explicitly, including the emergence of spatiotemporal logistics structures. This would be similar to activity-based models for passenger transport that deduce the spatiotemporal movement patterns of individuals from their planning problems. Such types of models consider the complex reactions of individuals coherently and allow for a deduction of individual welfare changes. Multi-agent systems allow for the modelling of the local interactions of these actors. The authors’ overview describes some models dealing with the emergence of spatiotemporal structures in freight transport by integrating optimization methods and coordination mechanisms. Three modelling efforts are presented: the first model is on the formation of regional logistics agglomerations; the second concerns the formation of tours at a national level; and the third relates to the formation of transport chains and vehicle utilization. Together, they provide an outlook on the prospects of integrating optimization methods and coordination mechanisms in a multi-agent system.

Lorenzo Masiero and Rico Maggi deal with accounting for the discrepancy between the willingness to pay (WTP) and the willingness to accept (WTA) in discrete choice models. A key input in cost-benefit analysis is represented by the marginal rate of substitution which expresses the willingness to pay or its counterpart, willingness to accept, for both market and non-market goods. The consistent discrepancy between these two measures observed in the literature is suggestive of the need to estimate reference-dependent models that are able to capture loss aversion by distinguishing the value attached to a gain from the value attached to a loss according to reference-dependent theory. The authors propose a comparison of willingness-to-pay and willingness-to-accept measures estimated from models with both symmetric and reference-dependent utility specifications within two different freight transport stated-choice experiments. The results show that the reference-dependent specification outperforms the symmetric specification and they prove the robustness of reference-dependent specification over datasets designed according different attributes levels ranges. They also demonstrate the policy relevance of asymmetric specifications, illustrating the strong implications for cost-benefit analysis in two case studies.

François Combes, Kees Ruijgrok and Lori Tavasszy start from the observation that, on theoretical grounds, it is already widely accepted that the choice of shipment size influences the choice of mode. However, due primarily to a lack of data, there have been few attempts to empirically test the quality of this relationship. The authors propose a model for the choice of transport mode in which the costs of transport follow the logic of economics of shipment size
choice. They specify a discrete choice model where the generalized cost depends on transport
distances, mode abstract values of time and continuous shipment sizes. The model is
estimated on observations of about 10,000 individual shipments from the French ECHO
survey. The results show that mode choice is strongly consistent with the economics of
shipment size choice.

Hanno Friedrich and Andreas Balster deal with supply-chain risk analysis with extended
freight transportation models. The analysis and management of supply-chain risks has indeed
become more important in a world with globally integrated production networks in which
extreme events seem to occur more frequently. But transparency, in particular for the overall
economic, production and logistics system, is lacking. The authors discuss the possibility of
using approaches from freight transportation analysis to analyze consequences of supply-
chain risks on overall logistics and freight transportation. A literature review shows that there
is a research gap for these models, especially for the analysis of short and medium-term
impacts of risks (days to weeks). An overview of possible reactions of economic actors to
risks and challenges of modelling these risks recommends that such models should be
explanatory, and that they should map time explicitly and probably be specific to sectors and
countries.

Tomer Toledo et al studies the decision-making process and the factors that affect truck
routing. The data collection involved intercept interviews with truck drivers at three rest area
and truck stop locations along major highways in Texas, Indiana and Ontario. The
computerized survey solicited information on truck routing decisions, the identity of the
decision-makers, the factors that affect routing and sources of information consulted in
making these decisions. In addition, Stated Preferences (SP) experiments were conducted, in
which drivers were asked to choose between two route alternatives. The data was used to
study the identity of routing decision makers for various driver segments and the sources of
information used both in pre-trip planning and en-route. A random effects logit model was
estimated using the SP data. There are significant differences in the route choice decision
making process among various driver segments, and these decisions are affected by multiple
factors beyond travel time and cost. These factors include shipping and driver employment
terms, such as the method of calculation of pay and bearing of fuel costs and tolls.

Edoardo Marcucci reviews a set of articles, based on stated preferences techniques, focusing
on logistics managers' preferences for freight transport attributes with the intent of assessing
the quality of knowledge acquired through applied research, as well as its reliability and
transferability. The review indicates that there are some evident shortcomings in the way
research has been performed so far, but, at the same time, there appears also to be a high
potential if corrective actions are taken. In particular, substantial improvements could be
attained by: clearly defining research and reporting protocols; defining and circumscribing
who has to be interviewed in the different freight contexts studied; reporting the contractual
relationships governing freight movements; reporting freight details (e.g. volume, value,
weight); motivating the attribute selection method used. There is a need for systematizing
procedures and reporting in applied research by introducing a much higher level of detail and rigor, both in defining the object of measurement and in the experimental design protocols employed.

Megersa Abate and Ole Kveiborg discuss a central aspect of freight transportation, i.e. capacity utilization, in the context of empty running of commercial freight vehicles. They provide an overview of the literature on these topics and distinguish between two types of contribution according to their analytical approach and origin of research. The first approach looks at utilization based on economic theories, such as the firms’ objective to maximize profitability, and considers how various firm and haul (market) characteristics influence utilization. The second approach stems from the transport modelling literature and its main aim is to analyze vehicle movement and usage in a transport demand modelling context. A strand of this second group of contributions is the modelling of trip-chain and its implications in terms of capacity utilization. A key lesson to be learned is that it is important to take into account the commercial activity that initiates vehicle movements in evaluating performance. There is room for further enhancement of the modelling exercise by incorporating information regarding the operator in order to provide a stronger behavioural basis for the vehicle movements and utilization analysis.

The purpose of Inge Vierth’s contribution is to demonstrate how freight transport time savings) and reduced variability in transport time are valued in CBA and to discuss alternatives. The author suggests a structure where the benefits of transport time savings are related to the reduction of transport resources required, capital tied up in goods while transported, and goods users‘ opportunity costs. The benefits of less variability in transport time are due to the reduction of transport resources required for a given service and users‘ opportunity costs. Normative and behavioural approaches are applied to determine the value of transport time savings (VTTS) and the value of reduced variability in transport time (VTTV). The VTTS definition differs between countries. Different VTTS and VTTV constructions make the transfer of results difficult. It is found that the savings in transport resource costs can be calculated with the aid of engineering formulae, provided that the VTTS is limited to the capital tied up in the goods, where market-based approaches can be used, and VTTS(O). The incorporation of VTTV in CBA requires further development of the valuation methods. The use of information on the trade-off between transport costs and inventory costs is one promising approach.

Siri Pettersen Strandenes deals with freight transport pricing models. Freight transport prices typically increase proportionally with distance and with weight or size. Trade models traditionally apply iceberg transport costs, where the value of the good transported is reduced upon arrival by a percentage of the initial value, to reflect transport and other trade costs, whereas freight charges in transport and logistics models reflect physical characteristics such as weight and distance. The author shows that non-linear pricing models can be applied to build priority pricing schemes where shippers pay a surcharge for priority handling of their cargoes. Basing point pricing and unified delivered prices commonly used in freight transport pricing imply spatial price discrimination. Yield management developed by passenger airlines upon deregulation of the airline industry in the USA has spread to air cargo. The EU’s
recent prohibition on liner conferences makes yield management more probable also in container shipping.

The final part of this book focuses on the local/urban level and includes six chapters. The main objective of José Holguin-Veras et al. is to provide a comprehensive overview of empirical findings and models that focus on urban freight tours (UFTs). Freight demand modeling researchers and practitioners are cognizant of the need to explicitly model UFTs, and are collecting data and developing models that account for UFT. There are some obvious limitations. The data collected are small and, in most cases, are unable to provide a comprehensive view of UFTs, while the models developed are still in need of significant improvements. Some of the more pragmatic approaches, such as simulations and hybrid models, are likely to require enhancements in their behavioural foundations, as they rely on assumptions that are not always validated. On the other hand, the most theoretically appealing models—such as those based on spatial price equilibrium—still require computational improvements to make them ready for real-life use.

Francesco Russo deals with modelling behavioural aspects of urban freight movements and presents the main behavioural aspects of urban goods movements and the approach to modelling them. The movements in question are generated by the restocking and purchasing decisions of retailers and consumers in an urban context. A general model system to structure and interconnect all the choices, with relative decisions, is presented in the form of a wide-meshed grid in which researchers and practitioners may introduce specific models presented elsewhere, or calibrated ad hoc in a real urban context. The system considers the four main vehicle movements: push and pull, generated by end-consumers and retailers. It also considers a commodity model where the quantity choice model is discussed with its relative implications in the main decisional level for each decision-maker. The advancements relative to the alternative set model and the choice within the set are proposed, with reference to push and pull movements, opening up possibilities for future researches. Due consideration is given to: new discrete choice model; dynamic choice and presence of ITS; dispersion of taste. This chapter attempts to build a bridge between the transport paradigm and the shopping-restocking process and supply planners by means of an integrated and updated outlook.

The contribution of Romeo Danielis, Elena Maggi, Lucia Rotaris and Eva Valeri starts from the assumption that adopting a supply chain approach is crucial to understanding how urban freight distribution works and how urban transport policy alternatives may impact on supply chain performance. In accordance with a recent strand in the literature, this chapter aims at: characterizing the urban supply chains; discussing how an urban supply chain can be modelled, which role actors play and how the coordination issue can be handled; showing how transport choices, in particular between own-account or third-party transport operators, are dealt with in each urban supply chain and by each actor; and analyzing how urban supply chains are affected by the many proposed freight transport policies. Although much progress has been made in this field, with regard to both modelling and empirical analysis, it emerges that further advances are needed in relation to both the ex-ante and the ex-post evaluation of the private and social efficiency of the different urban supply chains and how they are impacted by local authorities’ transport policies.
Rosário Macário recognises that the diversity of problems associated with urban logistics prevents the organization of urban logistics with a single solution. Diversity of urban profiles and of business models must be successfully matched to solve that complexity. This rational serves as the basis for designing a future Master Plan for urban logistics, which might be used by local authorities to regulate their territory and to implement measures that enable inducement of better behaviour by the economic agents who take part of the urban supply chain. Therefore a “3-step approach” methodology has been followed. The first step comprises the definition of “Logistic Profiles”. The second step encompasses the evaluation of different logistics solutions based on different criteria in terms of their suitability for serving different logistics profiles. The third step consists in modelling the changes which will occur if the solutions are implemented. This approach is validated by modelling a first pilot area in Lisbon.

Agostino Nuzzolo and Antonio Comi first classify city logistics measures that city administrators can use to reduce the negative impacts of urban freight transport, in relation to planning (i.e. strategic and tactical/operational). The focus then shifts to models developed to support the assessment of tactical and operational measures. The assessment procedures require the simulation of freight transport demand and hence the estimation of freight vehicle origin-destination (O-D) flows. These O-D flows can be obtained from the simulation of delivery tours. Therefore, this chapter presents a system of models that is able to simulate delivery tours using an aggregate approach. Such models allow one to capture actors’ choices that can be influenced by tactical and operational measures. They were calibrated and tested on the basis of surveys conducted in the inner area of Rome, where more than five hundred truck drivers were interviewed.

The chapter by Jaume Barceló, Jesús Arturo Orozco and Hanna Grzybowska deals with making real-time fleet management decisions under time-dependent conditions in urban freight distribution. The design and evaluation of City Logistics applications requires an integrated framework in which all components can work together. Therefore, City Logistics models should account for vehicle routing applications and fleet management models also capable of dealing with the dynamic aspects of traffic flows in the underlying road network, namely when ICT applications are taken into account. The authors develop a methodological proposal based on an integration of vehicle routing models and real-time traffic information. In the computational experiments conducted, a dynamic traffic simulation model is used to emulate the actual traffic conditions, providing, at each time interval, estimates of the traffic state on each link of the road network used, by a real-time fleet management system, in order to determine the optimal dynamic routing and scheduling of the fleet.

Acknowledgements

This book is dedicated to the memory of Prof. Marvin Manheim.

In a book we edited in 2008, Prof. Werner Rothengatter (2008), former chairman of the World Conference on Transport Research Society (WCTRS), characterized Prof. Manheim as “a
most pro-active thinker, always trying to be some steps ahead of the present reality and to anticipate the most important drivers of future development”. Prof. Rothengatter (2008) rightly stated that Marvin Manheim may be regarded as the spiritus rector of modern activity-based freight modelling and logistics.

Prof. Manheim understood that human beings as individuals or in organizations may accelerate processes, but that they can also act as barriers to development. Bringing people together to form global and worldwide networks is therefore a productive way of reducing barriers, of fostering social cohesion and of enhancing economic progress. Marvin Manheim applied this idea to various fields. Hence it is no coincidence that he was also a founding father of the World Conference on Transport Research (WCTR) and its Society (WCTRS). The development of WCTRS illustrates Marvin Manheim’s notion that sustainable networks have to be most flexible and adaptive to new developments. No rigid centrally-steered hierarchies, but autonomous working groups of highly motivated and committed individuals, collaborating in a truly international spirit.

In 2008, Marvins’s wife, Mary Beth Watson-Manheim (2008), wrote: “Twenty-five years ago, the first sentence in Marvin’s textbook stated: ‘We live in a world of rapid change’. Throughout his career, he never stopped probing and searching for new models of the changes he envisioned across multiple disciplines and problem settings, with a relentless focus not only on theory but also on translating the theory into practical applications. Those who knew Marvin were also influenced by personal qualities, which were interwoven through his research and teaching. Marvin was an inveterate teacher, he was creative, an integrator and a visionary, often seeing connections not immediate obvious to most people. The ability to integrate can also be seen in the communities of colleagues he developed, and the sheer enjoyment he found in debating and discussing ideas, while also savouring food and wine with friends and colleagues”.

We sincerely hope that this book will contribute in a profound way to the scientific knowledge of and research into freight transport modelling, in the spirit of Marvin Manheim.

To conclude this introduction, the editors would like to extend their sincere thanks to all those who contributed to the publication of this book. First and foremost, we are grateful to the various authors. They did a great job. We also thank all the referees for their indispensable and much appreciated assistance. Finally, our gratitude goes to all those who contributed logistically to ensuring the success of this publication.

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