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Transportation Science Special Issue on Freight Transportation and Logistics, Part I

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Freight transportation and logistics systems and activities are the lifeblood of human society and modern economies. The goal and challenge of the organizations setting up and operating these complex systems is to simultaneously achieve the highest levels of operation efficiency, customer satisfaction, economic profitability, and market competitiveness. This is increasingly compounded by the social challenge of reducing the energy consumption, environmental footprint, and, particularly in cities, the impact of transportation and logistics operations on congestion and the quality of life of the people. An intense, rich and ever growing operations research and transportation science research field is answering these challenges, yielding contributions of significant scientific and practical importance. The series of *ODYSSEUS International Workshops on Freight Transportation and Logistics* has emerged as one of the foremost scientific forums for this research field. The fifth workshop, which took place in May 2012 in Mykonos, Greece, ignited the interest to call upon the scientific community for a special issue of *Transportation Science* on the topic.

The call has been answered enthusiastically. Following a thorough refereeing process, we selected a first group of 11 papers making up this issue. A second group will appear later this year. The selected papers present original, cutting-edge contributions illustrating, through methodological developments and innovative, insight-provoking applications, the diversity and richness of problems encountered in the modeling, planning, and management of freight transportation and logistics systems. A number of trends are noticeable, in particular, proposing integrated models that provide the means to address simultaneously issues traditionally associated to different levels of planning; increasing the level of modeling detail of system components and operations within network-wide problem formulations; explicitly considering the uncertainty inherent in most decision-making and operational processes and exploring methods to efficiently address

the resulting formulations; and proposing new system and service designs, particularly for operations within cities. Algorithmic developments enrich the selected papers, proving efficient means to address the particular problems at hand, as well as stimulating insights for further work. Exact and meta-heuristic solution principles are to be found, of course, but the trend of successfully mixing the two is also strongly noticeable.

The first group of three papers addresses various issues related to the planning of operations and the management of the fleet of intercity freight carriers. The first paper in the group by Bouzaïene-Ayari, Cheng, Das, Fiorillo, and Powell addresses the locomotive-optimization problem for railroads. The authors present, using a unified notation, a series of models capturing different levels of detail and complexity in operations and in the attributes and status of locomotives. The most realistic formulations involve multiple commodities and attributes and represent the impact of several main sources of uncertainty. This portfolio of integer-programming models, two of which are in production at a major U.S. railroad, aims to address the problem at strategic and tactical-operational levels. A well-known mixed-integer commercial solver and an adaptive dynamic programming algorithm are used, their comparison on real instances offering insightful conclusions on addressing large, multiattribute, time-dependent, stochastic fleet management problems. The paper has won the 2015 Best Paper Award of the Transportation Science & Logistics Society of INFORMS. The second paper, by Pantuso, Fagerholt, and Wallace, addresses the strategic fleet renewal problem within the context of maritime transportation. The objective is “simple,” satisfy demand at minimum cost, but the problem is complex as decisions involve not only the number and type of vessels to add to the fleet or dispose of over time but also how the additions and disposals should be performed, e.g., should the firm buy new vessels, or buy on the second-hand market, or should it lease? Decisions must be taken under uncertainty

due, in particular, to the evolution of the demand, compounded by the time required to build a vessel and the evolution of its value and operating costs over time. The authors present a comprehensive modeling framework, which can yield two or multiple-stage formulations, and where aggregated tactical service routes are used to evaluate the strategic design decisions. Using the case of a large liner shipping company, the authors investigate the relevance of explicitly addressing uncertainty in relation to a number of problem characteristics and show that the stochastic formulation yields significantly better results than the one obtained by using average values for the stochastic parameters. Borndörfer, Klug, Schlechte, Fügenschuh, Schang, and Schüllndorf study the problem of designing the route network for a set of origin-to-destination train movement requests in the presence of heavy passenger traffic, which cannot be modified. The authors present a system-wide multicommodity formulation over a time-space network, explicitly modeling several operational characteristics, in particular, the expected average delay on rail tracks due to the congestion generated by a high number of trains competing for the use of the same track. The resulting large non-linear mixed-integer formulation is solved by a combination of preprocessing and linearization techniques and a state-of-the-art mixed integer programming solver, for a set of German rail instances.

Bianco, Caramia, Giordani, and Piccialli address the problem of indirectly regulating the routing of vehicles carrying hazardous materials to both minimize the total risk over the network and spread that risk somewhat equitably among the links of the network. Tolls set by the regulator make up the regulatory mechanism. Carriers select routes to minimize their own costs, including tolls. The authors propose a formulation where the toll paid by a carrier on a link depends on the total risk induced by all the routes of all carriers using the link. This makes the route choices of each carrier dependent on the choices of the others and aims to deter carriers from using links with high total risk. The authors study the properties of the resulting bilevel formulation, providing toll-fixing optimality conditions, as well as a local search heuristic based on these conditions.

Harks, König, Matuschke, Richter, and Schulz address the tactical planning of transportation activities within a logistics network, that is, deciding how much flow to move among the nodes of the logistics network, thus selecting, e.g., what customers to serve from what suppliers or distribution centers, the transportation mode, tariff, and delivery frequency for each movement, and the level of inventory to keep at each location. The goal is to minimize the total cost of the system, addressing the tradeoffs between the tariffs proposed by carriers, which vary by mode, distance, and quantity, and the various operating costs, in particular the

costs related to consolidation in time, that is to managing inventories, and space, i.e., to grouping small loads into large shipments taking advantage of vehicle capacity. The authors propose a fixed-cost capacitated multicommodity network design formulation, together with a meta-heuristic based on a novel and fast procedure to select tariffs for given origin-to-destination movements and path-decomposition neighborhoods rerouting several commodities simultaneously. Experiments on real-world data indicates that the proposed methodology achieves solutions close to the optimal ones with significant implications for cost reductions in actual practice.

Vehicle routing is a core family of problems within operations research and transportation science, its importance in terms of science and practice not requiring any further explanation. It is thus not surprising to find vehicle routing-related issues within the six remaining articles making up this special issue. The first paper, by Archetti, Campbell, and Speranza, addresses the general issue of the value of using “flexible” vehicles able to carry combinations of different commodities (the multicommodity case) with respect to the more classical single-commodity case where routing is performed by commodity-dedicated vehicles. Several problem settings are defined according to the type of vehicle and to whether demands may be split in the multicommodity case. Worst-case analysis and a computational study are used to compare the cases and identify the most appropriate situations for each.

Routing is also central to the next two contributions, where it appears as a component of demand management and estimation. The first paper, by Yang, Strauss, Currie, and Eglese, study the problem of delivery to customers, within agreed-upon time windows, of goods purchased online, an application field which is growing steadily. The difficulty of the problem increases with the narrowness of the time windows, the number of customers requesting delivery at roughly the same time, and the geographical distribution of customers. The authors thus study the problem from the point of view of demand management, aiming to identify incentives to steer customers towards delivery time windows that contribute to maximize the revenues of the carrier. They propose a multinomial logit customer choice model-based on historic booking data, show that it can be calibrated well on real-world e-grocery data, and use it to propose dynamic pricing policies to determine the incentive, discount, or surcharge, to offer customers for delivery time slots when they intend to make a choice. The delivery cost is also estimated dynamically. Results of simulations show that anticipating the likely future delivery cost of an additional order in a given location can lead to significantly increased profits. The second paper is authored by Holguín-Veras, Xu, Jaller, and Mitchell and addressed the difficult problem of modeling freight transportation demand. The authors

emphasize that a significant part of freight deliveries, particularly within urban areas, are performed by means of vehicle tours, and that this fact is generally not accounted for in the literature. They thus propose a new spatial price equilibrium model that considers delivery tours rather than the traditional point-to-point deliveries, while also accounting for the dynamics between production levels, routing and pricing. Heuristics are proposed to address the model and shown to perform well on small to medium-size instances. The experimental results also show the interest of the new formulation and offer precious insights into the behavior of the model and its components.

This first part of the special issue concludes with a group of three papers addressing planning issues for multi-tier city logistics systems. Winkenbach, Kleindorfer, and Spinler study the problem of (re-)designing the urban network for a major postal operator. The proposed two-echelon location-routing model selects the number and location of facilities at each tier, together with the size of the service area and the dimension and composition of the vehicle fleets. The goal is to minimize the overall cost of the system within global customer service requirements. To address large-scale instances, the authors also propose a closed-form expression for approximating the optimal pickup and delivery routing cost under constraints on the global maximum service time, vehicle capacity, and vehicle access and positioning. An extensive experimentation with data from the postal operator offers insights into both the behavior of the methodology and its main components and parameters and the structure of multi-tier postal networks with mixed vehicle fleets. The paper by Gianessi, Alfandari, Létocart, and Wolfler Calvo is also studying a two-echelon location-routing problem, but within the context of a novel organization for two-tier city logistics. The system is composed of a set of first-tier facilities, the “gates,” and a set of “urban distribution centers” on the second tier. The latter are connected through a ring, operated by motor vehicles or light rail, for example, in which massive flows will operate. Thus, delivery paths start at a first-tier facility, go through one or two second-tier ones, using the ring connection in the latter case, to be finally distributed through vehicle tours (tours may also be initiated from

first-tier facilities). Reverse pickup activities are also possible. Consolidation operations take place at facilities. The authors propose a location-routing model aimed to select the second-tier facilities and the ring connecting them, to satisfy demand while minimizing the total system cost of setting up the ring and moving the goods. The model takes the form of a set partitioning-like formulation for the pickup and delivery tours, with arcs representing inter-facility movements. The authors describe how to strengthen the formulation and propose and analyze three solution methods, a branch-and-bound algorithm for small instances, a matheuristic based on solving sequentially the main components of the problem, and a hybrid method solving the initial formulation on the limited-sized set of columns generated by the metaheuristic. Finally, Crainic, Errico, Rei, and Ricciardi address the issue of building the tactical plan of a two-tiered city logistics system while explicitly accounting for the uncertainty in the forecast demand. The authors define the problem and propose a general two-stage stochastic programming modeling framework, the first stage selecting the first-tier service network design and the workloads of the intertier transfer facilities, while the second stage determines the vehicle routing on the second tier as well as some limited adjustments of the first-stage service design decisions. Four recourse strategies are defined and compared through a Monte Carlo simulation of the tactical planning process. Comparisons are based on system performance measures in terms of costs, resource utilization, and impact on the city in terms of intensity of vehicular presence, as well as from the point of view of the impact of the recourse strategies on the management of physical and human resources. The analysis emphasizes the interest of flexibility in adjusting the plan to the observed demand and underlines the benefits of consolidation in terms of system efficiency and impact on the city.

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