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A multi-objective sustainable load planning model for intermodal transportation networks with a real-life application

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A R T I C L E I N F O

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A B S T R A C T

Growing importance of intermodal transportation necessitates modeling and solving load planning problems by taking into account various complex decisions simultaneously like transportation mode/service type selection, load allocation, and outsourcing. This paper presents a mixed-integer mathematical programming model for a multi-objective, multi-mode and multi-period sustainable load planning problem by considering import/export load flows to satisfy transport demands of customers and many other related issues. Several multiple objective optimization procedures are utilized in order to handle conflicting objectives simultaneously under crisp and fuzzy decision making environments. A real-life case study is also performed to present application and usefulness of the proposed model.

1. Introduction

Nowadays, there is a rapid increase in intermodal transportation research in the literature. The intermodal transportation was defined as "transportation of freights in one and same intermodal load unit (container, trailer, swap, box, body, etc.) by using successive modes of transport (railway, maritime, road, etc.) without handling the freights themselves when the transportation mode is altered" (UNECE, 2009). There are some different terminologies, i.e., multimodal, intermodal, co-modal and synchro-modal, for the multi-mode transportation systems in the current literature and global logistics industry. Actually, multimodal transportation is the broadest term and covers all of the others (SteadieSeifi et al., 2014). In detail, multimodal transportation is able to provide more efficient, reliable, flexible and sustainable way of freight transportation. Intermodal transportation and containerization can also support the transport flexibility and give advantage of economies of scale to the logistics companies. Because, more efficient usage of company sources can be yielded resulting from the integration of different transportation modes, improvements in handling speed and throughput (Rodrigue and Slack, 2013). In fact, popularity of the intermodal transportation which is the most widely utilized multimodal term, takes root from the problems of road congestion, environmental responsibilities and traffic safety. In other words, intermodal freight transportation planning problem has become a seriously studied research topic since its ability to increase traffic safety, customer satisfaction and decrease transportation costs, road congestion and environmental pollution. The intermodal freight transportation combines at least two different transportation modes in a single transport chain. In general, a transport chain mainly consists of three components namely pre-haulage, long-haulage and end-haulage which correspond to pick-up, door-to-door transfer and delivery services, respectively. The pre and end-haulages correspond to the trucking part of a transport

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chain and also named as drayage activities. These initial and final journey activities are mostly performed by road freight transportation due to the short travel distances. Drayage costs constitute the majority portion of the overall transportation costs even though the relatively short distance of truck movements. For this reason, drayage activities may have a significant impact on the profitability of intermodal transportation systems (Macharis and Bontekoning, 2004). In addition to these pre and end-haulage activities, transfer of the load units between any two terminals, i.e., seaports, railway stations and hubs, is called as long-haulage. In contrast to the large proportion of trucking for inland transportation, many logistics companies tend to prefer railway, airline, maritime transportation services and their combinations for long-haul freight transportation in Europe (UIC, 2014; SteadieSeifi et al., 2014). A typical intermodal transport chain including both short and long haulages can be portrayed as in Fig. 1. Although there are several studies on the logistics network design, transportation mode and service type selection, hub/terminal location and vehicle routing problems, there are still a lack of studies in the literature for freight planning problems of intermodal transportation networks. Actually, most of the previous studies have focused on single mode freight transportation planning problems from the perspective of logistics service providers or production companies which undertake the logistics activities by themselves. In other words, there are a few papers on intermodal freight transportation planning problems when compared to the unimodal transportation systems. On the other hand, planning problems in intermodal freight transportation may become much more complex than the traditional unimodal transportation systems. Therefore, they may require development of more comprehensive mathematical models, advanced Operational Research (OR) and Artificial Intelligence (AI) based solution methodologies. Fortunately, multi-mode load planning or intermodal freight transportation planning problems have become attractive research areas in recent years. Because, there has been an increasing interest to multimodal transportation systems by both researchers and practitioners in the global logistics sector all over the world. Besides, environmental aspect of the intermodal transportation systems was highlighted as current research trends by Caris et al. (2013) since it plays an important role in policy making. On top of all these, development of decision support systems based on advanced optimization models and innovative applications of AI techniques for intermodal freight transportation planning problems was given as a future research direction by Macharis and Bontekoning (2004).

Based on these motivations, this paper presents a new mixed-integer programming model for a multi-objective, multi-mode and multi-period sustainable load planning problem. In other words, a sustainable intermodal freight transportation planning model is developed based on network flow modeling for tactical planning activities. The main contributions of this research can be listed as follows: A novel mathematical programming model is proposed for a real-life intermodal freight transportation planning problem of a large-scaled international logistics company in Turkey. The proposed model is able to handle various critical decisions concurrently such as transportation mode/service type selection, outsourcing, periodic load allocation, consolidation at the transshipment seaports/rail stations, usage frequency of block train services and Ro-Ro vessels. Both of the import and export load flows are considered by the proposed model in order to satisfy the bi-directional transport demands of the customers. Consolidation operations or exchange of load units at the transshipment seaports/railway stations are also incorporated into the proposed model. For the maritime logistics operations, different transportation services by company-owned Ro-Ro vessels and other logistics service providers' Ro-Ro vessels are taken into account while generating the load plans. In addition to the railway transportation services by block trains with fixed time schedule, alternative public train services with flexible time schedule are also considered within the proposed model. As well as to minimize the overall transport costs, maximal customer satisfaction is targeted by minimizing the total road, marine and railway transit times. Furthermore, environmental conscious load plans are generated by minimizing the amounts of total CO_2 emitted by the different transportation modes. Therefore, sustainable load plans can be produced by making

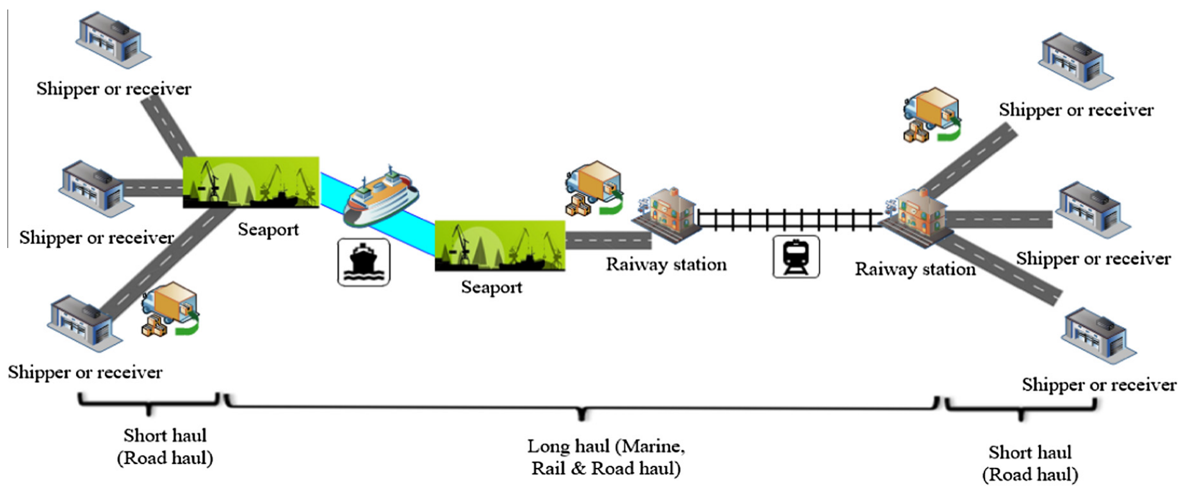

Fig. 1. A simple depiction of road-marine-rail intermodal freight transport.