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Decomposition approach for integrated intermodal logistics network design

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ABSTRACT

The integrated intermodal logistics network design problem consists of determining terminal locations and selecting regular routes and transportation modes for loads. This problem was formulated using a path-based formulation and a decomposition-based search algorithm has been proposed for its solution. Computational results show that this approach is able to obtain optimal solutions for non-trivial problem instances of up to 150 nodes in reasonable computational times. Previous studies have only been able to obtain approximate solutions for network problems of this size. A few general insights about the effects of design parameters on solution characteristics were also obtained.

1. Introduction

In the current environment of marketplace globalization, there is a greater chance that suppliers would need to reach customers that are physically very distant apart. In this context, suppliers would require using long-haul transportation services more often to send their products to those distant customers. Most of the long-haul transportation demand in the United States and other parts of the world is handled using road transportation (i.e., trucking). However, despite the economical aspect of using this transportation mode and the resulting service level provided to customers, road transportation also produces significant environmental and road congestion problems (Crainic and Kim, 2007). To overcome these challenges, policy makers have started to promote the use of intermodal freight transportation as an alternative to road transportation. For example, the European Commission has started the Marco Polo program in Europe to incentivize the shift of a significant portion of freight demand from road to other transportation modes (European Commission, 2014).

Intermodal freight transportation consists on the use of at least two different transportation modes to move freight loads that are in the same transportation unit (e.g., a shipping container) from origin to destination without handling the goods themselves (Macharis and Bontekoning, 2004). In recent years, the demand for intermodal freight transportation has continuously increased and this trend is expected to remain the same in the future. In this context, the installation of additional intermodal infrastructure will be necessary to fulfill potential future demand. The way in which the intermodal transportation infrastructure is used to handle freight significantly affects transportation costs and service times. As a result, one of the most important decisions in intermodal freight transportation planning is the design of its logistics network. An intermodal logistics network is formed by the collection of hubs (i.e., physical locations) which are used for the transfer of freight loads

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from one transportation mode to another; and, the connections between hubs based on the transportation modes that are available at each node.

The intermodal logistics network design problem is a strategic planning problem that determines the number of hubs needed, their locations, and the allocation of non-hub nodes to hubs. However, this problem is not independent of other decisions that are made at different levels of decision making which affect hub locations and are also affected by them at the same time. For example, resource levels at hubs, terminal layout, and type and number of material handling and storage equipment are determined at the tactical level, while the selection of routes and mode of transportation for shipments are determined at the operational level. However, all of these tactical and operational decisions greatly depend on the configuration of the hub network. These decisions should be handled together as much as possible to minimize the total cost of the intermodal logistics network or to maximize the level of customer satisfaction. To the best of our knowledge, Ghane-Ezabadi and Vergara (2015) has been the first attempt at integrating in a single mathematical programming formulation the hub location problem with the route and mode selection problems within the context of intermodal freight transportation. In the current research, the same decisions have been integrated to find an optimal intermodal logistics network design by developing a path-based formulation which is then solved using a decomposition-based approach.

Network operators at large logistics companies such as Class I railroads and large full truckload carriers providing intermodal service are the potential decision makers who would be affected by the current research. Network operators make the strategic decisions of determining the network topology and designing the logistics network for intermodal transportation (Macharis and Bontekoning, 2004).

Various network topologies have been implemented for intermodal transportation including point to point, corridor, hub and spoke, connected hubs, static routes, and dynamic routes (Woxenius, 2007). This research considers a hybrid network topology that combines the point to point, connected hubs and static routes topologies as alternatives for intermodal freight transportation service (Fig. 1). Therefore, the problem studied in this research is not a traditional hub-and-spoke network design problem, but one in which any pair of nodes can be connected with a direct link and there is no restriction that loads must visit one or at most two hubs in a route. In this way, all hubs are directly connected with each other and freight might visit multiple hubs in its route from origin to destination. Nodes in a network may represent physical locations where single mode terminals exist or where intermodal hubs can be potentially installed, as well as customer locations. In this way, network planners can address problems at different levels of aggregation from regional networks, to national and even international networks.

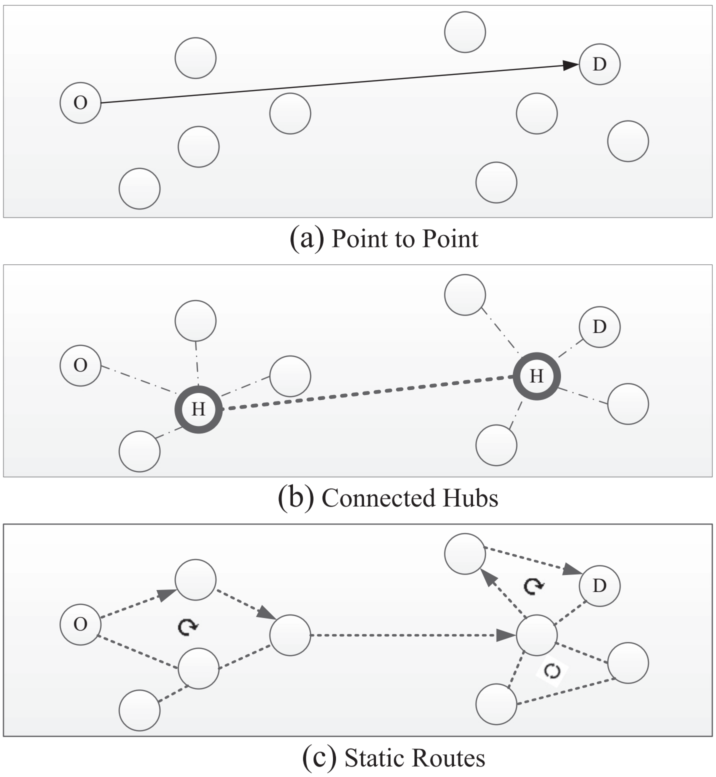

Fig. 1. This research considers a hybrid network topology that combines point to point, connected hubs and static routes topologies (adapted from Woxenius (2007)).