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On service network improvement for shipping lines under the one belt one road initiative of China

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ABSTRACT

This paper aims to reconstruct the shipping service network between Asia and Europe by considering the improvement of New Eurasian Land Bridge rail services and Budapest-Piraeus railway. In particular, to reflect the decision making process in reality, a bi-level programming model is established to maximize the total profit of the liner shipping company in the upper level and meanwhile to minimize the total cost of the shippers in the lower level. Computational experiments considering different scenarios are conducted to obtain the new optimal networks under different cases. Several insightful findings are observed, further leading to useful managerial insights.

1. Introduction

China has grown to the largest manufacturing and trading country in the world in the past two decades. However, it is recognized that China is now facing a big challenge, i.e., slowdown of domestic economy and trade (Timmer et al., 2016). To cope with this challenge, in March 2016, Chinese Government issued the "Action plan on the China-proposed Belt and Road Initiative", which aims to improve and reconfigure logistics and transportation networks along the One Belt One Road (OBOR) trade corridors and connectivity among the countries along the route (Sheu and Kundu, 2017). Under this initiative, two main routes, the land-based "Silk Road Economic Belt" and ocean-going "Maritime Silk Road," are proposed to connect China and other Eurasia countries, as shown in Fig. 1.

Following this initiative, there are two important railway systems significantly impacting the current shipping service network from China to Europe. First, as an important part of the OBOR initiative, the railway along New Eurasia Land Bridge has achieved a quick development in recent years. The New Eurasia Land Bridge, also known as the Second Eurasia Land Bridge, is an international railway line connecting China and other Eurasia countries such as Kazakhstan, Russia, Belarus, and Poland. Through capitalizing on the New Eurasia Land Bridge, eleven Chinese cities have successively opened direct railway container services to European cities, for example, Chongqing to Duisburg (Germany), Wuhan to Melnlk and Pardubice (Czech), Chengdu to Lodz (Poland), and Zhengzhou to Hamburg (Germany). By October 2015, 1070 trains in total have left China for Europe with cargoes, as the number of trains increased from 17 in 2011 to 623 in 2015. Thus, the cargo delivery service provided by this railway system is continuously increasing, leading to possibly extensive changes on the other cargo delivery services such as liner shipping.

Second, following the OBOR initiative, the railway system built to connect Southern European hub ports to their hinterland is also changing the current shipping network. In particular, in Fig. 1, Venice and Piraeus (Athens) are highlighted as two

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Fig. 1. Map of the one belt one road initiative. *Source:* Eurasia Review

gateway ports in Europe. In order to help build these two gateway ports and better utilize them to construct the liner shipping service network, a Chinese liner shipping company, i.e., COSCO, signed a concession agreement to operate Piraeus port with the Piraeus Port Authority in 2016, which provides COSCO with 67% shares of the port. Furthermore, COSCO is expected to invest more than half a billion euros (€552 million) in the Piraeus Port within the next five years and the investment aims "to make Piraeus the biggest transit port in the South Europe".[1]

With respect to the importance of these gateway ports in Central and Eastern Europe (CEE), besides COSCO's investment on the port construction, China also cooperated with CEE to construct a high-speed rail line (as shown in Fig. 2) linking the Piraeus Port of Greece in the south to Budapest of Hungary in the north via Skopje of Macedonia and Belgrade of Serbia.[2] Upon its completion by 2018, the travel time by train between Southern and Central Europe will be significantly reduced. More importantly, the investment on these hub ports and the railway system linking the hub ports with other inland cities will tremendously reduce the cargo delivery time from China to other inland European cities through these ports and thereafter the railway.

Due to the improvement of these aforementioned two railway systems (i.e., the New Eurasia Land Bridge and the railway connecting Southern European hub ports to its hinterland), the corresponding transportation activities will change accordingly (Rodrigue et al., 2013). Therefore, it is of significance for the Chinese liner shipping companies such as COSCO, who merged China Shipping in 2016 and became a giant shipping line in China, to re-optimize their liner services from Asia to Europe by incorporating the increasing land-bridge rail services, the expansion of the Piraeus Port, and the construction of Piraeus-Budapest railway. To deal with this problem, in this paper, we propose an optimization model for Chinese liner shipping companies such as COSCO to re-construct their liner shipping service networks by considering the impacts from the aforementioned two railway systems. In particular, a bi-level optimization model is proposed to reflect the decision making of a static network design problem in practice, in which the liner shipping company decides which shipping routes to be operated and then the shippers decide the corresponding cargo amounts delivered by the chosen routes. Accordingly, in the upper level of our proposed bi-level programming model, the liner carrier's profit is maximized by deciding which routes are chosen and meanwhile the lower level problem minimizes the total cost of the shippers by deciding the cargo amounts corresponding to each available path. We reformulate the proposed bi-level mixed-integer programming model into a single level one by replacing the lower level problem with its Karush-Kuhn-Tucker (KKT) conditions since it is a convex problem when the upper level decision is fixed. To further improve the computational performance, we linearize the bilinear terms of the complementary slackness constraints in the KKT conditions and finally obtain a mixed-integer linear programming (MILP) model, which can be easily solved by a commercial optimization solver (e.g., CPLEX).

[1] http://www.wsj.com/articles/china-cosco-to-invest-over-552-million-in-port-of-piraeus-1467789308.
[2] http://thediplomat.com/2015/11/chinas-belt-and-road-reaches-europe/.

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