Investigation of a Competitive Transport Market Considering Demand Uncertainty and Risk Attitude of Shipping Companies

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Abstract. The proportion of containerized shipping in freight transportation has been growing over the last few years (Zhang & Zhang, 2020; Nagurney, 2021). For instance, containerized shipping has grown by 33% since 2012 and reached 160 million TEUs (Twenty-Foot Equivalent Units) in 2021 (Manaadiar, 2021). This growth is forecasted to continue for the next decades. For instance, the total Canadian and US container port volumes were 54.6 million TEU in 2010 and are predicted to reach 89.8 million TEU by the end of 2050 and 99 million TEU by 2060 (VEPA, 2020). Considering the growth of containerized shipping, Empty Container Repositioning (ECR) has become a significant concern for many transportation systems. Several factors, such as different economic requirements and tariffs between distinct countries or locations, usually lead to imbalances in freight volumes between areas and result in different patterns of demand and supply for empty containers (Zheng et al., 2017; Lee & Moon, 2020; Jeong & Kim, 2023). Hence, these companies must relocate empty containers from demand points to supply nodes for the shipping service continuity, imposing an extra cost (Yu&Chen, 2016; Chen et al., 2022).

Competition and demand uncertainty are other concerns for shipping companies (Chen et al., 2022; Zhang et al., 2022). On one side, these companies need to control their operational costs, including ECR costs, to improve their competitive edge (Kuo et al., 2017). On the other side, they must be responsive to consumer demands and increase their satisfaction by offering high-quality services (Thai, 2008; Kuo et al., 2017). Although these decisions are manageable in the case of deterministic demand, it is a significant challenge when the market demand is uncertain. To this end, shipping companies need to have an estimation of the realized demand, which is based on three significant factors: the market potential demand, the price of the service, and the quality of the service (Zhou & Lee, 2009; Sen, 2013). Then, the competitors should have an estimation of the potential demand in dealing with market uncertainty. However, these estimations are not necessarily the same because the shipping companies may have different optimism and risk attitude in their estimates. Owing to these significant parameters, the research focuses on the following three questions: i) what is the optimal pricing policy considering the market parameters and the shipping companies' optimism and risk attitude? ii) how do the competition and competitors' risk attitudes affect the shipping prices? and iii) how does demand uncertainty influence the companies' profits?

Although the ECR has been investigated in the area of freight transportation (e.g., Zheng et al., 2017; Yu et al., 2019; Zhang & Zhang, 2020; Yang et al., 2021; Najafi & Zolfagharinia, 2021), this study contributes to the literature by capturing main characteristics of the imbalanced freight transportation, including competition, ECR, and demand uncertainty. It also captures competing companies' optimism and risk attitudes and considers them in pricing. Furthermore, this study utilizes a robust optimization technique in the developed algorithm to handle potential demand uncertainty. Finally, it conducts a simulation analysis to investigate the developed algorithm's performance and provides practical managerial insights and recommendations for different possible states of demand materialization in the market.

The problem under investigation includes two transportation companies offering shipping services between two ports. These companies use containerized shipping and move freight between these ports in two directions. Each direction has its own uncertain potential demand. However, the realized demand is distinct and revealed after the demand materialization. Due to limited containers, these companies should reposition empty containers from one port to another if the realized demands in two lanes are imbalanced (Zhou & Lee, 2009; Zheng et al., 2017; Zhang & Zhang, 2020). Hence, these shipping companies incur two types of costs during the service: (1) The Laden Container Movement (LCM) cost, and (2) the ECR cost, which is less than the LCM cost. Furthermore, each company has two options for the shipping service: regular shipping (RS) service or high-quality shipping (QS). In the QS service, the company adds some selectable value-added services to the RS service (Thai, 2008).

Consequently, we investigate the service quality variation as a binary variable to specify whether providing additional value-added service benefits the shipping company. Finally, it is worth noting that although the companies have two options for service quality, they do not offer both levels of service quality. Additionally, it is intuitive that providing the QS service enhances the potential demand on one side and increases the LCM cost but not the ECR cost on the other side. Therefore, they aim to choose the best level of quality for shipping service based on its impacts on demand and price. Given the above challenges, this study aims to help shipping companies

determine each lane's price and service level simultaneously.

To analyze the problem, we first ignore the potential demand uncertainty and analyze the deterministic competitive market to determine the service quality and prices using three propositions. Afterward, we prove four propositions to include the demand uncertainty impacts and develop an algorithm to determine the optimal decisions in an uncertain market. We also examine the optimism parameter's impact on each company's profit and discuss how the developed algorithm can improve the profit. In this regard, we design 405 test cases and generate 1000 instances for each test case to investigate how considering demand uncertainty affects the companies' profits. We also identify key decision parameters, including market price sensitivity and potential demand imbalance, and analyze their impacts on the decisions. In addition, we examine the effects of companies' optimism in demand forecasting and their risk attitudes in the decision-making process. The companies' optimism is investigated at three levels representing pessimistic, realistic, and optimistic. The risk attitude is also considered at three levels, denoting three types of decision-makers: (1) risk-seeking, (2) risk-neutral, and (3) risk-averse decision-makers. The results of these analyses are then used to generate practical recommendations under different market conditions.

Applying the developed algorithm in designed experiments revealed that the less demanded direction incurs more changes in the charged price when the firms are pessimistic. However, this impact is smaller in the direction with lower potential demand when the companies are optimistic. Furthermore, considering demand uncertainty in the pricing process improves companies' performance by 15%, 12%, and 14% for risk-averse, risk-neutral, and risk-taking companies, respectively. Finally, these analyses demonstrated that considering the competition in the market leads to, on average, a 9.93% price reduction for the service.

Keywords: Containerized shipping, Demand Uncertainty, Risk Attitude.

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