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A simulation-based vessel-truck coordination strategy for lighterage terminals

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ABSTRACT

Lighterage contributes significantly to the maritime industry since thousand tons of necessary supplies have to be delivered to mother vessels anchored near sea every day. A single lighter waits to receive cargoes from multiple suppliers at the berth, while the trucks wait for their turns to enter the terminal. Due to the limited space, the terminal operation becomes vulnerable to the lack of coordination of their arrivals. In this study, despite a traditional industry, we are interested in applying the emerging technologies to improve the operation efficiency. We develop a simulation-based coordination strategy to construct coordinated schedules for both the lighters and suppliers to reduce congestions in the lighterage terminal The discrete event simulation model is developed based on understanding the real-world terminal in Singapore, and the controlled arrival method, determining coordinated arrival schedules of trucks, is introduced and embedded to the simulation model. The simulation model is tuned up with a benchmark setting of 6-month historical data. To find the optimal strategy, an advanced bi-objective simulation optimization algorithm is employed. According to our findings, the proposed strategy could significantly improve the efficiency of both lighters and trucks in various indicators. At the end, a mobile application prototype is proposed to deliver the coordinated schedules to different parties, and improve the communication between parties.

1. Introduction

As the foundation of the global economy, international shipping industry carries about 90% of the world's trade. According to United Nations Conference on Trade and Development (2017), the international seaborne trade has a significant growth in the past 40 years. With the increasing demand of the shipping market, the size and endurance of vessels, as well as the number of vessels, have had a tremendous development and increase. Ever since the global financial crisis in 2008, the global trade has slowed down and the shipping industry has been suffering, resulting in the situation of excessive vessels with inadequate goods to ship. Despite this slowdown, there are still nearly 300,000 cargo ships in operation every day. Amongst them, many vessels, especially the large long-haul vessels, arriving at a major port like Singapore, Shanghai, Qingdao require ship supplies (i.e.; water, food, spare parts, etc.) at anchorage points of near sea.

To serve these vessels, the lighterage service with a fleet of lighters, dozens of suppliers and trucks, and the lighterage terminal are needed. As illustrated in Fig. 1, the lighters serve to transport the requested supplies to the mother vessels from a ligherage terminal, and the supplies at the terminal are replenished by suppliers via trucks in advance. To be specific, there are four different types of

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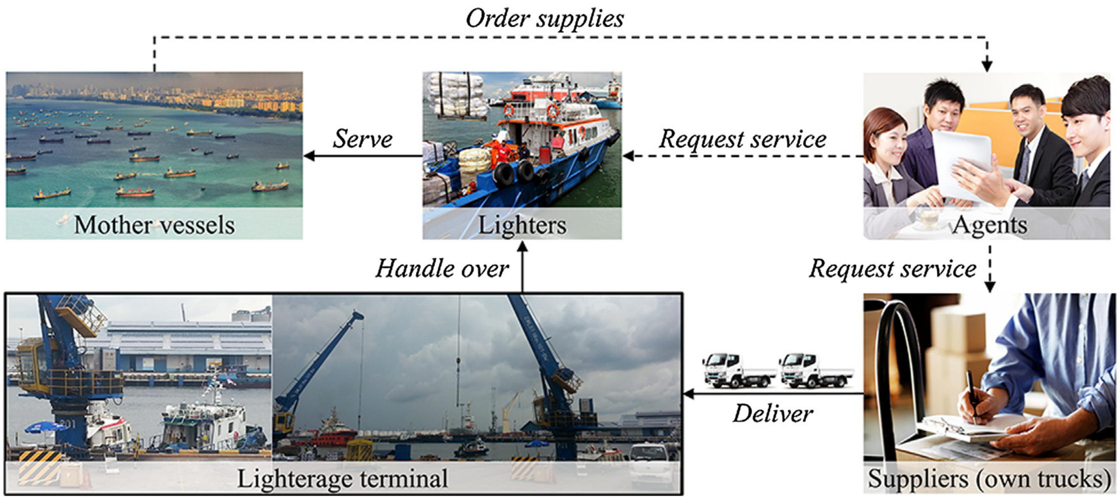

Fig. 1. The lighterage terminal operations in Singapore.

stakeholders (or parties, i.e. mother vessels, lighters, agents and suppliers/trucks) within the lighterage industry. The parties except the agent each have their own operations, while the agent serves to coordinate between the parties. When the mother vessel approaches or moors at the anchorage, it will order supplies with the agent. Once the agent receives the order, he/she will send instructions on when to arrive at the lighterage terminal to the lighters and suppliers separately. Upon receiving the instructions, lighters and trucks (owned by the suppliers) will schedule their dispatch to the terminal. Both parties will be updated of each other's statuses, such as early or late arrival, through the agent. When a lighter receives supplies from the trucks at the terminal, it will then deliver them to the mother vessel. It should be noted that although the cargoes continuously flow between different parties via the terminal, the terminal has no direct control or influence on the coordination. In addition, information on lighterage operation is dynamic in nature due to the stochastic behaviors of different parties. As a result, the quality of the coordination depends greatly on the time-lines, and the accuracy of the information passed among the parties via the agents, which generates inefficiency of operations at the current stage.

Despite having the agent to play the role as the coordinator, information handled by the coordinator is static and does not allow him to trace the latest changes. The lighter arrival is highly uncertain depending on the traffic in sea around the anchorage. Although the lighters will negotiate the estimated time to arrival (ETA) with the lighterage terminal to reserve a time slot for berthing, this information is neither reliable nor accurate, though the terminal encourages the lighters to report their pre-arrival notification. This inaccurate information leads to inefficiency in berth allocation. Therefore, there is always uncertainty between ETA and the actual time to berth (ATB). Note that if the lighter misses its assigned time slot, it may need to wait for another available time slot by communicating with the terminal via interphone. Cargoes on a lighter are delivered via a number of trucks owned by suppliers and each truck delivers a different amount of cargoes. Usually, the suppliers instruct their trucks to reach the terminal on time or in advance to avoid delaying the lighters. The information relayed to suppliers via the agents is summarized as a single page document, referred to as Delivery and Shipment Advice (DSA). The truck drivers hold the DSA and reach the terminal earlier than the ETA of the lighter. When the lighter is delayed, an unexpected queue is created, and may disrupt other trucks delivering cargoes for other lighters. As a result, the lighter departure time, practically categorized as the expected time to departure (ETD) and the actual time to unberth (ATU), become unreliable. In summary, when the demand is high and space is limited, the lack of coordination between lighters and trucks will lead to low efficiency of the terminal, as well as congestion on both sea and land sides.

The Strait of Malacca is one of the most important shipping lanes in the world and Singapore welcomed 186,000 vessel arrivals in 2011, and 214,000 vessel arrivals in 2017 (Maritime and Port Authority of Singapore, 2017). To serve the passing vessels, the lighter fleet and the lighterage terminal of Singapore receives approximately 48,000 calls and handles a cumulative amount of about 650,000 tons of cargo annually. The lighterage industry does not only generate operational revenue, but also supports Singapore's position as a leading international maritime center. To illustrate the problem, we use one of the Singapore lighterage terminals as a case study. As illustrated in Fig. 2, due to the limited space of the terminal, trucks usually queue on the road outside the terminal gate, and the lighters can wait up to 90 min before it can depart during the morning peak.

As a traditional industry, a lot of processes are still running in a manual way and a lot of real-time information is not captured. For example, DSAs are printed on papers, messages are communicated via interphones, time is manually recorded by operators, and real-time locations of vessels and trucks are unknown. The lack of digitalization also contributes to the lack of coordination. In this study, we expect to apply the emerging technologies to improve the performance of the lightering operation, such as advanced simulation and optimization technologies, mobile devices and Internet-of-Things, etc. This study proposes a simulation-based coordination strategy to construct coordinated schedules for both the lighters and suppliers, and then develops a prototype of the mobile application. As a core of the coordination strategy, a discrete-event simulation model is developed to learn the behaviors of lighters and trucks. Based on the real-world data, we find the benchmark setting for the model, propose a controlled arrival method to determine