Integrated scheduling of berth and quay crane considering maintenance activities

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Introduction

In the last few decades, there was a fast growth in container transportation in the world, one of the evidence is that the throughput in the largest international container port has increased from 9.62 million TEU in 1993 to 40.2 million TEU in 2017. Various scarce and critical service resources in the container terminal are with heavy workloads in their daily operations. One effective way to further improve the operational capabilities of these resources, such as berth, quay crane (QC), vehicle and yard crane, etc., is to produce efficient processing schedules for them and improve their utilization.

About the integrated scheduling of berth and QC, there has been a bulk of literature ([1],[2]). However, they all assumed that all the equipment are always available in the planning horizon. In fact, maintenance activities occur frequently, especially the preventive maintenance (component renewal, equipment check, clean, lubrication and etc) on QC, which can be implemented flexibly during a pre-planned hard time window, and have a huge influence on the scheduling of berth and QC. During the maintenance of a QC, it is fixed on a corresponding berth segment, called home berth segment, and both the QC and the home berth segment are unavailable for handling any vessel. Moreover, any other QC on its left (or right) cannot process the vessels berthing on its right (or left) during the maintenance period due to the non-crossover constraint. Therefore, we investigate the integrated berth allocation, QC assignment and specific QC assignment (BACASP), and consider the preventive QC maintenance activities with hard time windows.

Problem Description

In a container terminal, there are a length of continuous berth line on the sea-side quay and a set Q of identical QCs to process a set V of vessels with different release times. Once a vessel arrives at the port, decision maker needs to assign berth and QCs to it. The processing time of a vessel depends on its workload and the number of QCs assigned to it. In addition, there also have a subset QM (⊂ Q) of QCs each of which requires $O_k$ consecutive time for its maintenance in the planning horizon, and the maintenance must be fulfilled within the given time window $[M_k^L, M_k^U]$. We give an example of three vessels to show the influence of QC maintenance activity. As shown in FIG. 1, QC 3 is under maintenance, thus both the QC and its home berth segment are unavailable for any vessel during the maintenance time window. The processing time periods of the three vessels 1, 2 and 3 overlap the
execution time of quay crane 3’s maintenance activity. Due to the non-crossover constraint of QCs, vessel 1 which is berthed to the left of the QC 3’s home berth segment can only be handled by QCs 1 and 2. Similarly, vessels 2 and 3 can only be processed by QCs 4, 5 and 6.

FIG. 1—Illustration of vessel processing with one QC under maintenance

Main Contributions

In this work, we investigate the integrated berth allocation, QC assignment and specific QC assignment (BACASP), and consider the preventive QC maintenance activities with hard time windows. The main contributions of this work are as follows: (1) the QC maintenance activities with hard time window constraints are introduced in the BACASP problem; (2) an integer linear programming model is established where the QC maintenance activities are technically transformed into special vessels whose start and completion times, berthing segments and assigned quay cranes are accordingly constrained; (3) because of the NP-hardness of the problem, we propose a heuristic algorithm named LRVM (Left-and-Right Vessel Move) and an improved GA (Genetic Algorithm) based on the properties of the problem, and extensive computational analysis is provided; and (4) a sensitivity analysis is carried out to illustrate the impact of preferred berth factor to the considered problem.

Conclusions et perspectives

In this work, we investigate a BACASP model where a small number of QCs require maintenance activities with respective hard time windows. We focus on the time-variant case such that during the processing of any vessel, the set of QCs assigned to it may change in different time periods. Two algorithms LRVM and GA are proposed to solve the problem. Experiments are conducted on 100 randomly generated instances with up to 50 vessels, then demonstrate that the performance of GA is slightly better than that of LRVM for most instances with respect to solution quality, while LRVM runs much faster than GA and the CPLEX solver. One of the future studies is to consider the cost or penalty for frequent movement of QCs during their dynamic assignments, and another interesting one is for the scenario with unexpected QC breakdown and emergency maintenance.

Reference
