Advanced Engineering Informatics 27 (2013) 598–614

Contents lists available at ScienceDirect

Advanced Engineering Informatics

journal homepage: www.elsevier.com/locate/aei

A simulation optimization method for internal trucks sharing assignment among multiple container terminals

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ARTICLE INFO

Article history:
Received 9 January 2013
Received in revised form 28 May 2013
Accepted 7 August 2013
Available online 3 September 2013

Keywords:
Multiple container terminals
Internal trucks scheduling
Sharing strategy
Integer programming
Simulation optimization

ABSTRACT

Owing that the internal trucks (ITs) are frequently used as transportation equipments between yards and quaysides, the transportation efficiency of ITs secures a crucial position in container terminal productivity. Hence, a container terminal cannot contain a big number of ITs. As such, it is an imperative to explore an appropriate IT assignment strategy. Specifically for those container terminals with adjacent locations, an approach to sharing internal trucks among multiple container terminals (SIMT) is investigated. In this study, a novel strategy to resolve the SIMT problem was proposed for a specific large port with multiple adjacent container terminals. Firstly, an illustration of the SIMT strategy was presented. Then, an integer programming model for this problem is developed, where the objective functions are subject to the minimization of the total overflowed workloads and total transferring costs in every time-period among these container terminals. In particular, the rolling-horizon approach is employed for considering the immediate scheduling. Furthermore, a simulation optimization method, which integrates the genetic algorithm (GA) searching and simulation, is proposed for the near optimal solutions. Finally, the computational experiments are used to verify the effectiveness of the proposed SIMT strategy and simulation optimization method.

1. Introduction

With trends on international container transportation and great-size and large-tonnage containerized vessels, e.g. the mega-vessels capable of carrying 10,000–12,000 TEUs and beyond have been increasingly deployed by shipping companies [1], container terminals are encountering new challenges. On one hand, a container terminal should improve its productivity adapting to these new trends. On the other hand, due to high cost of the handling equipments, such as quay cranes (QCs), yard cranes (YCs) and ITs, and scarcity of land resources, container terminals can hardly purchase additional handling equipments and expand their storage areas. Moreover, the competitions amongst container terminals, especially between geographically-adjacent terminals, are significantly rising [2]. To improve the service level of container terminals has become a big challenge towards port operators.

Pertaining to the evaluation indices of service level, the service time for a vessel, which contains the handling time of QCs, the transportation time of ITs and the handling time of YCs, is rather critical [3,4]. More specifically, the QCs are engaged for discharging and loading containers from and to vessels, the ITs are used to transport containers between quayside and yard, and the YCs are employed to pick and stack containers from and to yard blocks. Thus, the unreasonable schedules even interruptions of these handling equipments could cause longer turnaround time. In terms of operations, a series of planning or scheduling problems, such as berth allocation problem, QC scheduling problem, YC scheduling problem, IT scheduling problem and yard allocation problem, are critical to the turnaround time. The relationships among these operation problems are described in Fig. 1. In this regard, it is necessary to develop proper planning and scheduling methods for improving service level so as to fully utilizing limited handling equipments and scarce land resources in container terminals.

The ITs, which are frequently used as transportation equipments in a container terminal, should first satisfy the schedules of QCs and YCs, viz., a group of ITs is usually assigned to a group of QCs until the workload is completed. In order not to keep the QCs idle, a group of ITs should be continuously deliver containers to and from the assigned QCs without any interruption. For effective transportation, additional ITs are needed whilst the vessel is berthed far from its container storage area. Although the terminals possess enough ITs when vessels are berthed close to their container storage areas, it is problematic when vessels are berthed far from their container storage areas. As well, this results in a critical costing.

For many ports, container terminals might be adjacent to each other. There are scenarios that many ITs of a terminal are idle, while at the same period the ITs of some adjacent terminals are not enough. Assumed that idle ITs can be shared among multiple

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http://dx.doi.org/10.1016/j.aei.2013.08.001

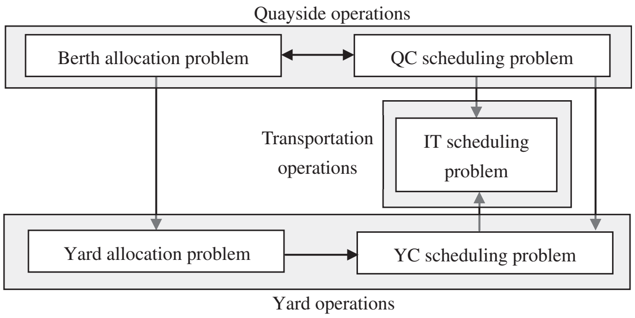

Fig. 1. The relationship among container terminal operation problems.

container terminals, the aforementioned scenarios would be resolved accordingly. A port with three adjacent container terminals is illustrated in Fig. 2, particularly when Terminal 2 is at its peak operation, the idle ITs from Terminal 1 and Terminal 3 are assigned to Terminal 2. Due that three terminals are quite close, the transferring costs should be relatively low. Therein, the proposed approach to sharing internal trucks among multiple container terminals (SIMT) is investigated and employed in this study.

In the next section, the literatures are reviewed. In Section 3, the proposed SIMT strategy is illustrated. Afterwards, an integer programming model is developed in Section 4. The decision variable is the number of ITs moved from one terminal to the others in each period, while the objective functions are subject to the minimization of the total overflowed workloads and the total transferring cost among container terminals within all time-periods among all terminals within all periods. In this model, considering the effect for the future periods, the rolling-horizon approach is employed, which is referred to ITs assignment of the future consecutive periods. A simulation optimization method for solving the SIMT problem is developed in Section 5, and numerical experiments are presented in Section 6. Conclusions and future directions were provided in the last section.

2. Literature review

Various operational problems of container terminals, e.g. planning and scheduling of handling equipments and spatial resources, attracted research attentions [5,6]. Intensive researches were focused on improving the operational efficiency of container terminals, such as berth allocation, storage space allocation, QCs scheduling, YCs scheduling and ITs scheduling [7], using such methods as operations research, heuristics and simulation [8].

Specifically for ITs scheduling, Bish [9] considered multiple QCs and a pool of ITs. Further elaborated, Bish et al. [10] developed a model to dispatch vehicles to the containers so as to minimize

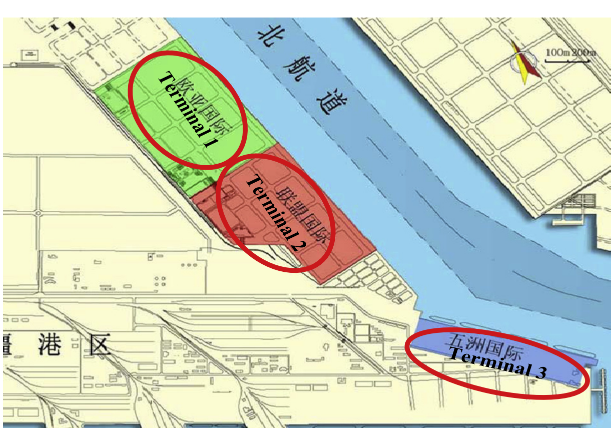

Fig. 2. A port with many adjacent container terminals in Tianjin, China.

the total time of vessel service. And they developed easily implementable heuristic algorithms, and identified both the absolute and asymptotic worst-case performance ratios of these heuristics. Kim and Bae [11] discussed the automated guided vehicles (AGVs) dispatch using a mixed-integer programming model for assigning optimal delivery tasks to AGVs. A heuristic algorithm was applied for overcoming the excessive computational time to solve the mathematical model. Chao [12] proposed a solution construction method and a tabu search improvement heuristic accompanied with the deviation concept for deterministic annealing to solve the truck and trailer routing problem. Similarly, Scheuerer [13] postulated two construction heuristics and a tabu search heuristic for the truck and trailer routing problem. It was indicated from computational results that the heuristic methods were rather competitive to the existing approaches. Ng and Mak [14] explored an algorithm with easy implementation to determine the sequence of trucks entering the working lane, which minimized the total time of idle trucks allocated to a loading yard block. Tan et al. [15] investigated a hybrid multi-objective evolutionary algorithm with specialized genetic operators, variable-length representation and local search heuristic to tackle the Pareto optimal routing solutions. Zhang et al. [16] constructed three mixed 0–1 integer programming models for vehicle dispatching to complete a sequence of container jobs, where the starting time and the vehicle order were determined via the greedy algorithm. For the same problem, Nishimura et al. [17] speculated an efficient ITs assignment method called 'dynamic routing'. Cao et al. [1] deployed an integrated model for ITs and YCs scheduling problem for loading operations formulated as a mixed-integer programming model, and two efficient solutions were obtained based on Benders' decomposition. Lee et al. [18] synthesized ITs scheduling with yard allocation, the objective of which was to minimize the weighted sum of total delay and total travel time of ITs. A hybrid insertion algorithm was used for effective solutions. Ng et al. [19] addressed the problem of yard trucks scheduling in order for the make-span minimization. An NP-hard MIP problem was solved by a genetic algorithm (GA), whereas the trucks undertook a set of transportation jobs with sequence-dependent processing time and different ready time.

For simulation optimization, Arango et al. [20] constructed a mathematical model for the berth allocation planning problems, and developed a GA-based heuristic procedure to solve the nonlinear problems. Simulation was used for simulating the handling operations as the ships arrived, passing through the lock, unloading/loading containers with Arena. Legato et al. [21] proposed a simulation optimization approach to solve the assignment and deployment of rubber tired gantry cranes among yard blocks, where simulation was applied for YCs assignment policy evaluation. He et al. [22] developed an objective programming model for YCs scheduling based on a static rolling-horizon approach, and a hybrid algorithm was designed for resolving. In this paper, simulation model also was developed for evaluation of YC schedules. Petering and Murty [23] employed a simulation model to evaluate the block's length of container storage yard and YCs deployment among blocks. In the same manner, Petering [24] used the same approach for the block's width evaluation. Chang et al. [25] combined berth allocation with QCs assignment based on the rolling-horizon model and simulation optimization approach. Cortés et al. [26] studied the simulation of the freight transport process in the Seville Port. And they found that the facilities of the Port of Seville allow to deal with the incoming logistic flows, except for momentary difficulties in the container traffic.

As aforementioned, the ITs dispatches in a specific container terminal were focused on amongst most previous researches. However, few literatures were dedicated to the SIMT strategy. Owing that the peak operations in any container terminals in a specific port are scarcely at the same time-period and the adjacent