Universe
Scientific Publishing

Review on integrated scheduling of quay crane and yard truck

Sun Qifeng

School of Management, Shanghai University, Shanghai China 201800

Abstract:With the development of port shipping trade, the increasing container throughput has brought pressure to port operation. Research literatures on quay crane scheduling, yard truck scheduling and integrated scheduling of quay crane and yard truck are reviewed in turn. Combined with the current research, the future research direction of integrated scheduling of quay crane and yard truck is proposed.

Key words: quay crane scheduling; yard truck scheduling; integrated scheduling

1 .Current situation of container ports

With the development of economic globalization and trade, the volume of global shipping trade and the container throughput of ports is increasing, and container ports are becoming more and more important hub centers in international logistics and multimodal transport, which brings great pressure to container port operations. The handling capacity of China's container ports has been overloaded. According to the statistics of the designed bearing capacity and actual throughput of container terminals in 2017, the overall utilization rate of China's container terminals has reached 106.7%.

Taking Shanghai port as an example, from 2010 to 2019, the container throughput of Shanghai Port ranked first in the world. In the meantime, the container throughput of Shanghai port has maintained a steady growth rate of 4.56% on average over the past 10 years. The container throughput in 2010 was 29.07 million TEU, which has exceeded 40.00 million and reached 40.23 million TEU in 2017, reached 42.01 million TEU in 2018, and increased to 43.30 million TEU in 2019.

Tang et al. [1] established a model combining grey prediction method and Markov chain prediction method, and predicted that the throughput of Shanghai port in 2021 and 2022 will reach about 55.28 million TEU and 58.53 million TEU respectively. Gui et al. [2] predicted that the container throughput of Shanghai port will increase by 4.23% in 2021-2025, and will reach 54.67 million TEU by 2025. Feng et al. [3] predicted that the container throughput of Shanghai port will continue to maintain a steady growth trend for the foreseeable future, and the problem of container terminal capacity will become increasingly serious.

For relieving the pressure, a few ports with economic strength chose to expand or purchase new equipment, but this required huge cost investment. Most ports chose to optimize the scheduling scheme of equipment of existing terminal to improve the utilization rate of equipment, so as to increase the throughput capacity of container terminals. At present, scholars believe that under the existing equipment resources, the scheduling optimization of equipment is not only the core of port enterprise operation, but also the key to improve the container throughput bottleneck.

2. Research on quay crane scheduling and yard truck scheduling

The scheduling of container port is mainly to allocate and use the facilities and equipment of the terminal reasonably to load, unload, transport and store the import and export containers. From the shore to the land, the order is berth allocation, quay crane scheduling and allocation, yard truck scheduling, yard allocation and yard bridge scheduling. Among them, quay crane scheduling and yard truck scheduling are the key points of port optimal scheduling.

2.1 Research on quay crane scheduling

Quay crane is the equipment for loading or unloading containers on the shore. Quay crane scheduling refers to assigning containers to a given number of quay cranes, and determining the operation sequence of containers handled by each quay crane.

At the beginning, scholars considered using accurate algorithm to solve the model. Kim et al. [4] used branch and bound method to solve the model, and used a greedy randomized adaptive search procedure to overcome the difficulty of branch and bound algorithm in solving model. Moccia et al. [5] considered the safe distance between landing bridges to improve Kim's model, and solved it by branch and bound algorithm.

With the deepening of the research, scholars continued to consider the actual constraints in the operational process of quay crane to perfect the model, such as the non-crossing between quay cranes, the safety distance, the initial congestion and the priority constraints of tasks, which made the model more difficult to solve. Quay crane scheduling has been fully proved to be NP hard problem [6,7], and it is not feasible to solve the exact solution. Most scholars used heuristic algorithms to solve model. Fu et al. [8] established a quay crane allocation and scheduling model considering the interaction between quay cranes, and used a lagrangian relaxation approach to deal with the large-scale problem of 100 ships. Fan et al. [9] established a mixed integer programming model considering the constraints of non-crossing between quay cranes, safety distance and tasks priority, and solved it by a genetic algorithm. Qin et al. [10] further considered the initial congestion of the quay crane, and established a one-way scheduling model to release the quay crane resources.

2.2 Research on yard truck scheduling

yard truck is the vehicle that transports containers between the shore and the yard. Yard truck scheduling is to transport containers by a certain number of yard trucks and determine the operation sequence of containers handled by each yard truck.

Yard truck scheduling mainly includes operation line mode and operation surface mode. Operation line mode means that a truck is fixed to serve a certain quay crane. Operation surface dynamically allocates trucks so that the truck fleet can be shared by all quayside bridges, so the utilization rate of trucks in operation surface mode is higher. Nishimura et al. [11] studied the dynamic allocation rules and route optimization of yard trucks to shorten the empty driving distance. Ma et al. [12] studied the yard truck scheduling mode of multi vessels in loading and unloading containers to minimize the total completion time, and improved the genetic algorithm to solve the model. Zhao et al. [13] considered the number of trucks and empty driving distance, constructed a two-stage model to optimize the operation efficiency of trucks, and solved it with particle swarm optimization algorithm. Zhang et al. [14] optimized the yard truck transportation route of multi yards, and designed a hybrid ant colony algorithm to solve the model.

2.3 Research on integrated scheduling of quay crane and yard truck

In the port operation system, the operation surface mode of yard truck is closely related to the quay crane scheduling. It is impossible to realize the overall optimization of container port operation by considering one operation link and ignoring the others. Therefore, in order to improve the production efficiency of the whole container terminal, it is necessary to consider the quay crane and yard truck as a whole, and carry out integrated scheduling.

The integrated scheduling of quay crane and yard truck refers to quay cranes load and unload containers, and yard trucks transport containers between quay crane and yard. They are interrelated, influenced and restricted each other, and cooperate with each other to complete the loading and unloading operation of container port.

The single quay crane scheduling problem or yard truck scheduling problem is a NP-Hard problem. The combination of the two problems is more complex, so it is difficult to guarantee that the two problems can be considered greatly. And because quay crane is the bottleneck of port operation, most of the integrated scheduling literatures assumed that yard truck chose the optimal route by default. Tang et al. [15] established a mathematical model to minimize the total completion time, and improved the particle swarm optimization algorithm to solve the problem. Zheng et al. [16] considered the quay crane interference and tasks priority, and schedule yard trucks in the operation surface mode, comprehensively optimized the completion time of quay crane and yard truck, and designed particle swarm optimization algorithm to solve the model. Liang et al. [17] considered the constraints of quay crane interference, tasks priority and truck operation face scheduling, aimed at reducing the completion time, and designed a genetic algorithm to solve the model.

At present, the integrated scheduling of quay crane and yard truck has been well studied. In the aspect of mathematical model, a quite unified and perfect mixed integer programming model has been formed. The objective function of most research is to minimize the completion time, and the constraints are to combine the actual constraints of quay crane with the operation surface mode of truck. In the aspect of solving algorithm, heuristic algorithms are usually designed to solve the model. Gradually, genetic algorithm and particle swarm optimization algorithm has become the mainstream algorithm.

3 .Extended research on integrated scheduling of quay crane and yard truck

Recently, the throughput of container ports has increased year by year. Under the huge amount of containers, the impact of uncertainty caused by weather, human error and equipment damage on port operation will be magnified. Therefore, the integrated scheduling of quay crane and yard truck needs to consider the uncertainty factors to make the scheduling plan more robust, or the application of automation equipment to ensure the stability of operation efficiency.

3.1 Extended research on considering uncertainty

In fact, the operation efficiency of equipment is not a fixed value, but has uncertainty, which will fluctuate under the influence of the outside world. When the amount of processing containers is large, ignoring uncertainty may lead to serious deviation from the actual scheduling situation. The scheduling plan based on uncertainty can keep robustness in case of port emergency and ensure the smooth operation of port.

For the integrated scheduling problem of quay crane and yard truck under uncertain environment, Fan et al. [18] established a two-stage model by the method of multidisciplinary variable coupling design optimization to achieve the optimal coordination of equipment operation. Lu et al. [19] considered the uncertain factors of the unit time of quay crane in processing containers and the traveling speed of yard truck, aiming at minimizing the shore completion time so that reduce the time of ships in port. Noura et al. [20] dealt with the uncertainty by following a certain distribution of the operation time of quay crane and truck, and studied simulation optimization based on genetic algorithm.

3.2 Extended research on automation equipment

In automated port, quay crane and yard truck are upgraded to dual-trolley quay crane and automated guided vehicle (AGV). In the unloading operation, the front trolley unloads the container from the ship to the transfer platform, and the back trolley unloads the container from the transfer platform to the AGV, and AGV transports the container automatically to the storage yard.

The equipment of dual-trolley quay crane and AGV is more complex, and the solution of integrated scheduling problem is more difficult. Scholars usually assume that the sequence and time of the containers of the front trolley are known, and set up time windows for integrated scheduling; or establish a two-stage model, and get the sequence and time of the tasks of the front trolley from the first stage scheduling model, so as to get the time windows.

Liang et al. [21] considered the transfer platform capacity of dual-trolley quay crane to minimize the delay time of quay crane operation and the waiting time between quay crane and AGV, so as to shorten the overall operation time. For Simultaneous loading and unloading problem, Tang et al. [22] set a time window based on the scheduling plan of the front trolley to achieve the integrated scheduling for the dual-trolley quay crane and AGV. Fan et al. [23] established a two-stage model to realize the coordinated optimization of the dual-trolley quay crane and AGV. In the first stage, dispatch quay cranes to minimize energy consumption of quay cranes. In the second stage, the AGV was scheduled according to the quay crane scheduling plan to minimize the energy consumption of the AGV.

4. Conclusion and Prospect

Scholars have done extensive and in-depth research on quay crane scheduling problem and yard truck scheduling problem, and combined them to conduct integrated scheduling research. The rapid growth of container throughput puts forward new requirements for the integrated scheduling of quay crane and container truck, so scholars have carried out Extended research on considering uncertainty and automation equipment.

At present, most literatures take minimizing the completion time as a single goal. In the future research, for creating green port logistics, cost saving and energy consumption can be included to establish a multi-objective function. In addition, most literatures make integrated scheduling based on the given number of quay cranes or yard trucks, so the future research can optimize the number of equipment to maximize the utilization of port resources.

References

1. Tang TC, Li L. Prediction of container throughput of Shanghai port based on grey markov model[J]. Logistics Sci-Tech, 2020, 43(03): 105-108.
2. Gui DH, Zhang XX. Prediction and analysis of container throughput of Shanghai port based on cubic exponential smoothing method[J]. Industrial & Science Tribune, 2020, 19(24): 59-60.
3. Feng HX, Grifoll M, Agusti M, et al. Container throughput forecasting model for Shanghai port based on data decomposition method[J]. Navigation of China, 2019, 42(02): 132-138.
4. Kim KH, Park YM. A crane scheduling method for port container terminals[J]. European Journal of Operational Research, 2004, 156(3): 752-768.
5. Moccia L, Gaudioco M, Laporte G. A branch-and-cut algorithm for the quay crane scheduling problem in a container terminal[J]. Naval Research Logistics, 2006, 53 :45-59.
6. Kayeshgar N, Huynh N, Rahimian SK. An efficient genetic algorithm for solving the quay crane scheduling problem[J]. Expert Systems with Applications, 2012, 39(18): 13108-13117.
7. Chung SH, Chan FTS. A workload balancing genetic algorithm for the quay crane scheduling problem[J]. International Journal of Production Research, 2013, 51(16): 4820-4834.
8. Fu YM, Diabat A. A Lagrangian relaxation approach for solving the integrated quay crane assignment and scheduling problem[J]. Applied Mathematical Modelling, 39(3-4): 1194-1201.
9. Fan ZQ. Modeling and solving uniform quay crane scheduling problem with task precedence constraints[J]. Operations Research and Management Science, 2013, 22(02): 235-242.
10. Qin TB, Ge H, Sha M. Unidirectional quay crane scheduling problems solving by combination of mixed integer programming and constraint programming[J]. Computer Integrated Manufacturing Systems, 2015, 21(02): 546-555.
11. Nishimura E, Imai A, Papadimitriou S. Yard trailer routing at a maritime container terminal[J]. Transportation Research Part E, 2005, 41(1): 0-76.
12. Ma C, Liang CJ. Integrated quay crane allocation and yard truck schedule problem in container terminals[J]. Journal of Guangxi University (Natural Science Edition), 2015, 40(03): 643-650.

[13] Zhao JL, Huang JH, Liu X. Two-stage optimization for yard trailers routing in container terminals[J]. Chinese Journal of Management Science, 2017, 25(04): 152-157.
14. Zhang JT, Song YJ, Ye CM. Hybrid ant colony algorithm for multi-depot container truck transportation problems[J]. Industrial Engineering and Management, 2017, 22(02): 89-96.
15. Tang LX, Zhao J, Liu JY. Modeling and solution of the joint quay crane and truck scheduling problem[J]. European Journal of Operational Research, 2014, 236(3), 978-990.
16. Zhen L, Yu SC, Wang SA, et al. Scheduling quay cranes and yard trucks for unloading operations in container ports[J]. Annals of Operations Research, 2019, 273(1-2): 455-478.
17. Liang CJ, Shen JJ. Study on problem of quay cranes and container trucks scheduling with consideration of handling order[J]. Application Research of Computers, 2016, 33(12): 3591-3595.
18. Fan LB, Liang CJ, She WJ. Coupling model and its algorithm for coordinated scheduling of quay crane and truck under uncertain environment[J]. Journal of Computer Applications, 2016, 36 (03): 843-848.
19. Lu YQ, Le ML. The integrated optimization of container terminal scheduling with uncertain factors[J]. Computers & Industrial Engineering, 2014, 75: 209-216.
20. Noura AD, Aida J, Ali D. A simulation-based genetic algorithm approach for the quay crane scheduling under uncertainty[J]. Simulation Modelling Practice and Theory, 2016, 66: 122-138.
21. Liang CJ, Li Y, Tang PF. Study on AGV scheduling with considering dual-trolley quay crane's transfer platform[J]. Application Research of Computers, 2018, 35(04): 1056-1061.
22. Tang SK, Yan NN. Research on coordinated scheduling of double-trolley quay crane and AGV based on time window[J]. Application Research of Computers, 2019, 36(05): 1343-1347.
23. Fan HM, Guo ZF, Yue LJ, et al. Joint Configuration and Scheduling Optimization of Dual-trolley Quay Crane and AGV for Container Terminal with Considering Energy Saving[J]. Acta Automatica Sinica, 2020, 45(1): 1-15.