13th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2009, Hammamet, Tunisia, 16-21 October 2009

YARD CRANE SCHEDULING IN CONTAINER TERMINALS-A LITERATURE REVIEW

Özge Nalan Alp
Hayri Baraçlı
Yildiz Technical University
Faculty of Mechanical Engineering
Industrial Engineering Department
Yıldız, İstanbul
Turkey

ABSTRACT
In this study, we have researched about yard crane scheduling in container terminals and prepared a literature review. In container terminals, time loses occure because of the inefficient use of equipments. Yard cranes are equipments those have been using to load container to vessels or to unload containers from vessels and container terminal operations are often bottlenecked by the slow yard crane movements. In order to reduce the completion time of handling containers and the congestion, yard cranes must be scheduled efficiently. We wish that this study will help to have some knowledge about this exponentially growing topic.
Keywords: Container Terminals, Scheduling, Yard Crane

1. INTRODUCTION
Breakdown of trade barriers among countries exploded the volume of international trade. Consequently, amount of bulk cargo carried in containers and transported over seas exploded due to flexibility, reliability and easy handling. Yard cranes transfer containers between truck and the stacks in the block, they straddle the entire width of the block beneath them and move along the length of the block. In container terminals bottlenecks occurs because of slow yard crane operations. Hence, we aim to focus on container terminals' and yard cranes' operations. In this study we present you the applications in the literature.

2. CONTAINER TERMINALS
A container terminal plays an important role in global manufacturing and international business by serving as a multi-modal interface, usually between the sea and land transports. Its three basic functions are as follows: (1) delivering containers to (carriers for) consignees and receiving containers from shippers, (2) loading containers onto and discharging containers from vessels, (3) storing containers temporarily to account for the differences in arrival times of the sea and land carriers. In the world, the %95 of mixed goods are transported by containers because of its trustworthy, low prices and the huge amount of transportability and the international trade volume by sea is increasing rapidly day by day (Ece, 2003).

3. THE EQUIPMENTS IN CONTAINER TERMINALS
- ***Containers:*** Containers are basically large boxes that are used for carrying goods and assess properties like; easy handling, hard structure for less damaging and most importantly globally standardized. As a result, containers become today's main unit in cargo transportation and usage is

spread all around the world. Containerization Institute defines, containerization as "the utilization, grouping or consolidating of multiple units into a larger container for more efficient movement".

- ***Yard Cranes:*** Yard cranes are the most popular container handling equipment for loading containers onto or unloading containers from trucks in container yards of land scarce port container terminals (Ng and Mak, 2005).
- ***Quay Cranes:*** A container crane (also container handling gantry crane, ship-to-shore crane) is a design of large dockside gantry cranes found at container terminals for loading and unloading shipping containers from container ships.
- ***Internal Trucks (IT)***
- ***External Trucks (XT)***
- ***Forklifts***

4. YARD CRANE SCHEDULING IN CONTAINER TERMINALS

Bish (2003) studies for determining a storage location for each unloaded container, dispatching vehicles to containers, and scheduling the loading and unloading operations on the cranes, so as minimizing the maximum time it takes to serve a given set of ships. A heuristic algorithm based on formulating the problem as a transshipment problem is developed. The effectiveness of the heuristic is analyzed from both worst-case and computational points of view. *Dohn (2003)* presents the Steel Plate Storage Yard Crane Scheduling Problem in this paper. The task is to generate a schedule for two gantry cranes sharing tracks. Goodchild and Daganzo (2007) find about the longer term impact of double cycling on port operations including crane, vessel, and berth productivity. Double cycling is a technique by which empty crane moves are converted into productive ones. A framework is developed for analysis, and a simple formula is developed to predict the impact on turn-around time. The formula is an accurate predictor of performance. It is shown that double cycling can reduce operating time by 10%, improving vessel, crane and berth productivity and identify additional benefits on the landside, but these are typically much less significant. *Guo et. al. (2008)* studies the problem of real time yard crane dispatching in container terminals. A judicious integration of real-time data into the yard crane management system will allow better utilization of terminal resources to improve overall terminal productivity. To minimize avarage vehicle waiting time, a yard crane dispatching algorithm based on real time data driven simulation is developed. Three scenerios are generated and in this scenerios simulation results show that dispatching yard crane based on real time data driven simulation is of great value in improving yard crane performance. *Han et. al. (2008)* study a storage yard management problem in a transshipment hub. In order to reduce the number of reshuffles. To reduce the potential traffic congestion of prime movers, a high–low workload balancing protocol is used. A mixed integer programming model is formulated to determine the storage locations of incoming containers, the number of incoming containers and the smallest number of yard cranes to deploy in each shift. An iterative improvement method is developed to solve the problem, in which a tabu search based heuristic algorithm is used to generate an initial yard template, and then the generated yard template is improved by an improvement algorithm iteratively until an optimal or a satisfactory solution is obtained. Experiment results show that the proposed method can generate excellent results within a reasonable time, even for the extreme cases. *Jung and Kim (2006)* proposes a method to schedule loading operations when multiple yard cranes are operating in the same block. The loading scheduling methods are based on a genetic algorithm and a simulated annealing method, which consider interferences between adjacent yard cranes. It attempts to minimize the make-span of the yard crane operation. They are considered that the container handling time, the yard crane travel time, and the waiting time of each yard crane, when evaluating the make span of the loading operation by yard cranes. *Han et. al. (2008)* aims at postulating a novel strategy in terms of yard crane scheduling. In this manner, a dynamic scheduling model using objective programming for yard cranes is initially developed based on rolling-horizon approach. To resolve the NP-hard problem regarding the yard crane scheduling, a hybrid algorithm which employs heuristic rule and parallel genetic algorithm, is then employed. *Imai vd.(2007)* addresses efficient berth and crane allocation scheduling at a multi-user container terminal. Firstly, they introduce a formulation for the simultaneous berth and crane allocation problem. Next, by employing genetic algorithm, they develop a heuristic to find an approximate solution for the problem. The results of numerical experiments show that the proposed heuristic is applicable to solve this difficult but essential terminal operation problem. *Kim vd. (2003)*

suggest a dynamic programming model for a static sequencing problem in which all the arrivals of trucks are known in advance. In port container terminals, the amount of delay time of outside trucks in the receiving and delivery operations is one of the important measures for the evaluation of the level of customer service. For dynamic situations where new trucks arrive continuously, a learning-based method for deriving decision rules is suggested. Also, several heuristic rules are suggested. A simulation study is performed to compare the performances of the suggested approaches. *Kim vd. (2004)* apply a beam search algorithm to solve the load-sequencing problem in port container terminals. The algorithm is used to maximize the operational efficiency of transfer cranes and quay cranes (QCs) while satisfying various constraints on stacking containers onto vessels. The load-sequencing problem consists of two decision-making subproblems. In the first subproblem, a pickup Schedule is constructed in which the travel route of a transfer crane as well as the number of containers it must pick up at each yard-bay are determined. In the second subproblem, the load sequence for individual containers is determined. Numerical experiments using practical data are performed to test the performance of the developed algorithm. *Kim and Kim (2007)* discuss a method of determining the optimal price schedule for storing inbound containers in a container yard. The price schedule in this study is characterized by the free-time-limit during which a container can be stored without any charge, and by the storage price per unit time for the storage beyond the free-time-limit. The profit or cost models for optimal price schedule are developed from the viewpoint of a public terminal operator as well as a private terminal operator. The probability distribution of delivery times is expressed by a continuous probability function. Various characteristics of the optimal solution are analyzed by numerical experiments. *Lee et. al. (2007)* investigate how type of transport vehicles and layout of the storage yard affect port operations. Two different types of transport vehicles and two different types of layouts are modeled in this study. A total of four simulation models are created to conduct this study. To evaluate the performance, the gross crane rate is used as the main performance measure, which is defined as the number of containers moved per quay crane per working hour. It has been shown that the incorporation of the chassis lane improves the gross crane rate for both prime movers and shuttle carriers. The improvement is more substantial when the port utilizes shuttle carriers. *Lee et. al. (2006)* study a yard storage allocation problem in a transshipment hub. The primary challenge is to efficiently shift containers between the vessels and the storage area. In particular, to reduce reshuffling unloaded containers are grouped according to their destination vessel. To reduce traffic congestion, a new workload balancing protocol is proposed. A mixed integer-programming model is then formulated to determine the minimum number of yard cranes to deploy and the location where unloaded containers should be stored. The model is solved using CPLEX. Due to the size and complexity of this model two heuristics are also developed. *Li et. al. (2008)* work on container terminal operations which are often bottlenecked by slow yard crane movements. Prime mover queues in front of the yard cranes are common. Hence, efficient YC scheduling to reduce the PM waiting time is critical in increasing container trucks' throughput. They develop an efficient model for yard crane scheduling by taking into account realistic operational constraints such as inter-crane interference, fixed yard crane separation distances and simultaneous container storage/retrievals. *Ng (2005)* studies the problem of scheduling multiple yard cranes to perform a given set of jobs with different ready times in a yard zone with only one bi-directional travelling lane. The scheduling problem is formulated as an integer program. A dynamic programming-based heuristic to solve the scheduling problem and an algorithm to find lower bounds for benchmarking the schedules found by the heuristic is developed. Computational experiments are carried out to evaluate the performance of the heuristic and the results show that the heuristic can indeed find effective solutions for the scheduling problem. *Ng and Mak (2004)* work on the yard cranes and yard cranes very often generates bottlenecks in the container flow in a terminal because of their slow operations. Hence, it is essential to develop good yard crane work schedules to ensure a high terminal throughput. The problem of scheduling a yard crane to perform a given set of loading/unloading jobs with different ready times is studied and the objective is to minimize the sum of job waiting times. A branch and bound algorithm is proposed and the performance of the proposed branch and bound algorithm is evaluated by a set of test problems generated based on real life data. The results show that the algorithm can find the optimal sequence for most problems of realistic sizes. *Petering vd. (2008)* has developed a real-time yard crane control system and showed that a terminal's long-run average quay crane rate depends on the portion of this system that dispatches yard cranes in the storage area in real time. Discrete event

simulation model of a pure transshipment terminal is used to reproduce the multi-objective, stochastic, real-time environment at an RTGC-based, multiple-berth facilityby evakuating several real time yard crane dispatching systems. *Zeng and Yang (2008)* has developed a simulation optimization method for scheduling loading operations in container terminals. The method integrates the intelligent decision mechanism of optimization algorithm and evaluation function of simulation model. A surrogate model based on neural network is designed to predict objective function and filter out potentially bad solutions, thus to decrease the times of running simulation model. Numerical tests show that simulation optimization method can solve the scheduling problem of container terminals efficiently.

5. CONCLUSION

In this sıudy we have researched about yard cranes and yard crane scheduling problem. The aim of this study is to determine the studied in the literature, then we are planning to work on yard crane scheduling problem.

6. REFERENCES

[1] Anders Dohn (2003), "Optimizing the Steel Plate Storage Yard Crane Scheduling Problem Using a Two Stage Planning/Scheduling Approach".

[2] Aydın, C. (2006), "Improved Rehandling Strategies For Container Retrieval Process", Sabancı Üniversitesi.

[3] Ebru K. Bish (2003), "A multiple-crane-constrained scheduling problem in a container terminal", European Journal of Operational Research 144 (2003) 83–107.

[4] Ece J. N. (2003), "Denizcilik Piyasalarındaki Gelişmeler.

[5] Goodchild A.V. ve Daganzo C.F. (2007), "Crane double cycling in container ports: Planning methods and evaluation", Transportation Research Part B 41: 875–891.

[6] Jung S. H. ve Kim K. H. (2006), "Load scheduling for multiple quay cranes in port container terminals", J Intell Manuf (2006) 17:479–492.

[7] Han Y., Lee L. H., Chew E. P. ve Tan K. C. (2008), "A yard storage strategy for minimizing traffic congestion in a marine container transshipment hub", OR Spectrum 30:697–720.

[8] He J., Chang D., Mi W. and Yan W. (2008), "A strategy for yard crane scheduling based on hybrid parallel genetic algorithm", 2008 International Symposium on Knowledge Acquisition and Modeling.

[9] Kim K. H. ve Kim K. Y. (2007), "Optimal price schedules for storage of inbound containers", Transportation Research Part B 41 (2007) 892–905.

[10] Kim K. H., Kang J. S. ve Ryu K. R. (2004), "A beam search algorithm for the load sequencing of outbound containers in port container terminals", OR Spectrum (2004) 26: 93–116.

[11] Kim K. H., Lee K. M. and Hwang H. (2003), "Sequencing delivery and receiving operations for yard cranes in port container terminals", Int. J. Production Economics 84: 283–292.

[12] Lee L. H., Chew E. P., Tan K. C. ve Han Y. (2006), "An optimization model for storage yard management in transshipment hubs", OR Spectrum 28:539–561.

[13] Ng W.C. (2005), "Crane scheduling in container yards with inter-crane interference", European Journal of Operational Research 164: 64–78.

[14] Ng W.C. ve Mak K.L. (2004), "Yard crane scheduling in port container terminals", Applied Mathematical Modelling 29: 263–276.

[15] Petering M. E. H., Wu Y., Li W., Goh M. ve Souza R. (2008), "Development and simulation analysis of real-time yard crane control systems for seaport container transshipment terminals", OR Spectrum DOI 10.1007/s00291-008-0142-7.

[16] Qingcheng Zeng and Zhongzhen Yang (2008), "Integrating simulation and optimization to schedule loading operations in container terminals", Computers & Operations Research.

[17] Wenkai Li**,** Yong Wu, M. E. H. Petering, Mark Goh and Robert de Souza (2008), "Discrete time model and algorithms for container yard crane scheduling", European Journal of Operational Research.

[18] Murty K. G. (2007), "Yard Crane Pools and Optimum Layouts for Storage Yards of Container Terminals", Journal of Industrial and Systems Engineering Vol. 1, No. 3, pp 190-199.

[19] Yongbin Han, Loo Hay Lee, Ek Peng Chew, Kok Choon Tan (2008), "A yard storage strategy for minimizing traffic congestion in a marine container transshipment hub", OR Spectrum (2008) 30:697–720.

[20] Guo X., Huang S. Y., Hsu W. J. and Low M. Y. H. (2008), "Yard Crane Dispatching Based On Real Time Data Driven Simulation for Container Terminals", Proceedings of the 2008 Winter Simulation Conference.

[21] Lee L. H., Chan T. H., Chew E. P., Tan K. C., Huang H. C., Lin W. and Han Y. (2008), "A Simulation Study On The Uses Of Shuttle Carriers In The Container Yard", Proceedings of the 2007 Winter Simulation Conference