AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Design and Production Engineering

Logistics Operations Scheduling in Port Terminals

A Thesis submitted in partial fulfilment of the requirements of the degree of

Doctor of Philosophy in Mechanical Engineering

(Design and Production Engineering)

by

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Master of Science in Mechanical Engineering

(Design and Production Engineering)

Faculty of Engineering, Ain Shams University, 2011

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Cairo - (2017)

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Date:24 January 2017

Statement

This thesis is submitted as a partial fulfilment of Doctor of Philosophy in Mechanical Engineering Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Thesis Summary

As international trade has grown tremendously during the last couple of decades, ports have played the major role in this area as they represent the focal point in goods exchange between countries and continents. Sea ports are one of the most important types of ports as they represent the interface between different transportation modes. Nowadays, 60% of the world trade in transported by sea. Therefore, ports compete with each other in terms of the quality of service provided to shipping lines. Thus, ports exert a huge effort to reduce vessels turn-around time to improve their customer satisfaction together with minimizing ports overall costs and efficiently utilizing available resources. Since scheduling problems in ports have very complex nature, research tackling such problems has started many years ago to aid decision makers to achieve improved port performance and minimizing costs to enhance competitiveness. Researchers have classified decision making problems in ports according the area in the port and the resources used.

Port areas can be classified into a quay area and a land or yard area, each area contains different types of material handling equipment. Research tackling the quay area included berth allocation problem, quay crane assignment problem and quay crane scheduling problem. Berth allocation problem is considered one of the most important problems in ports scheduling due to the huge investment needed to construct a berth. Thus, berthing space is considered as a scarce resource in port terminals. Berth allocation decision is concerned with assigning berthing time and location to incoming vessels. Also, problems related to quay cranes scheduling attracted the attention of researchers. Quay crane assigning problem is concerned with assigning available quay cranes to berthed vessels, while quay crane scheduling problems is concerned with determining a detailed schedule for each quay crane according to vessels stowage plans. Since both berth allocation decisions and quay crane assignment decisions are dependent, integrated models for berth allocation quay crane assignment decisions were introduced by researchers. Most of the existing literature

is concerned with developing solution techniques using metaheuristics to obtain optimal or near optimal scheduling decisions.

The objective of this thesis is to study different parameters affecting port scheduling performance. Different performance measures such as mean flow time; make span and berth utilization are considered to study port scheduling performance. In order to perform this study, a model for berth allocation problem is developed. The model aimed to obtain a berthing schedule for incoming vessels with static or dynamic vessel arrival in a continuous berth port. An analogy between berth allocation problem and parallel machines scheduling problems is introduced where it was shown that berth allocation problem is a special case of parallel machines scheduling problem. The developed model is the extended to perform the quay crane assignment, thus; the model is capable to solve the integrated berth allocation quay crane assignment problem. An analogy is performed to compare berth allocation quay crane assignment problem with parallel machines scheduling problems. The analogy shows that berth allocation quay crane assignment problem is a special case of parallel machines scheduling problem with additional resources.

Since the problem under study is known to be NP hard in a very strong sense, a genetic algorithm model is proposed to solve berth allocation problem. Also, a heuristic is proposed to perform quay crane assignment for berthed vessels based on the berthing sequence and positions obtained by the genetic algorithm. The developed genetic algorithm is applied to berth allocation problems where the results are compared with that obtained using exact solution methods. The proposed genetic algorithm is found to be capable to obtain the same objective value for small size problems in much less computational time. Also, the developed heuristic is applied to solve integrated berth allocation quay crane assignment problems. The obtained results are compared with that obtained using exact solvers where a gap ranging between 1.5% to 4% exists in the objective value.

The proposed genetic algorithm and crane assignment heuristic is applied to analyse different parameter and their effect on port scheduling performance. The effect of incoming vessels configurations is studied where problems with different vessels configurations are solved for minimum mean flow time and maximum berth utilization. The difference between berthing schedules which satisfy different objectives is studied. It is concluded that minimum make span and maximum berth utilization are achieved through the same berthing schedule. While minimum mean flow time together with minimum vessels waiting time are achieved through a different schedule.

The effect of berth length on ports scheduling performance is studied, different vessels configurations is considered in the study. Performance measures such as mean flow time make span and effective berth utilization are studied versus the berth length. It is concluded that mean flow time and make span values are highly affected by vessels configuration at lower values of berth length.

A unified index is developed to be used to estimate the values of mean flow time and make span for a static berth allocation problem. A linear relationship is found between both mean flow time and make span versus the proposed index. A number of medium and large sized problems are solved using genetic algorithm where the obtained objective value are compared with that obtained using the linear index relationship. The proposed index is proved to be efficient to be used to estimate mean flow time and make span values for static problems of any size.

Dynamic berth allocation problem is studied to analyse the effect of arrival period and berth length on port scheduling performance. Two vessels configurations are considered in the study where the arrival times of vessels are chosen randomly from a uniform distribution. The ratio between the make span and vessels arrival period as well as the ratio between mean flow times in the dynamic problem and the static problem are studied versus berth length. It is found that at small values of berth length, a large gap occurs between make span and vessels arrival period which affect further cycles. At large values of berth length, the make span ratio is approaches one but a reduced berth utilization is obtained.

Also, a study to investigate the effect of number of available quay cranes is performed. It is found that the ratio between number of available cranes and the maximum allowable cranes per vessel have significant effect on different port performance measure such as mean flow time and make span. It is concluded that minimum mean flow time is achieved by dedicating available quay cranes to least number of vessels, which in turns decreases berth utilization in case of unavailability of sufficient number of quay cranes to serve all berthed vessels. The effect of workload distribution among the vessel on the crane assignment decisions is studied. The distribution of workload among the vessel is described by the maximum allowable cranes to serve a vessel. It is shown that reduced crane utilization is obtained as the number of allowable cranes per vessel decreases.

Abstract

In this thesis, a model for berth allocation problem in port terminals is introduced. The developed model considered a continuous berthing space where vessels can berth at any position within the quay length. The model is then extended to include the crane assignment problem. An integrated decision covering berth allocation quay crane assignment problem can be obtained through the developed model. The considered problem is known to be NP Hard; thus, a genetic algorithm is proposed to solve the berth allocation problem. The developed genetic algorithm is applied to small size problems to compare its results with that obtained using exact solvers. The developed algorithm obtained the same results in competitive computational time. A heuristic is proposed to perform the crane assignment for berthed vessels according to the berthing plan obtained from genetic algorithm. The developed heuristic is applied to a number of problems to validate the algorithm and evaluate its accuracy. Results of the genetic algorithm together with the assignment heuristic is compared to that obtained from solving the integrated berth allocation quay crane assignment model using exact solvers. An acceptable error ranging from 1.5 – 4 % is obtained due to the heuristic used in crane assignment stage. The proposed genetic algorithm and assignment heuristic are able to obtain results with much less computational effort for the examined problem. Also, they are capable of obtaining solutions for medium size and large size problems that are not solvable with exact methods.

An analysis for different parameters affecting ports scheduling performance is performed. Different performance measures are considered to analyse the scheduling performance and utilization of different resource such as total make span, mean flow time, total vessels waiting time and berth and crane utilization. Different parameters are considered to study their effect on the previously mentioned performance measures. Vessels mean flow time and total make span is studied versus incoming vessels lengths and workloads at different values of berth length. Also, the effect of berth length is studied where make span, mean flow time and berth utilization is considered at different values of berth length. An index to estimate the values of mean flow time and make span for a number of incoming vessels in a static berth allocation problem is proposed. A linear relationship is obtained for the mean flow time and make span is obtained versus the proposed index.

A study considering quay cranes is also conducted throughout this research. Mean flow time, make span and berth utilization is studied versus the number of available quay cranes. Also, the effect of the maximum allowed number of quay cranes per vessel is studied.

Results showed that increasing berth length has significant effect on improving port performance especially at large vessel sizes and workloads. Also, increasing number of cranes has significant effect on port scheduling performance at lower ratios between total number of cranes to the number of cranes per vessel.

Keywords: Port scheduling, berth scheduling, quay crane scheduling, port performance

Acknowledgment

Not only do I feel thankful for the power I have been provided with by God, but I am also grateful for the people around me whom I was blessed with. Without these two main factors, I would have never been able to accomplish a mission I was dreaming of for years.

To my family, no words I would say would do you justice. Your endless love and trust is what got me here today. I owe you big time for supporting me and appreciating what I believe in.

On the other hand, I would like to take a moment to thank my supervisors for their extreme gentleness. At first, the man who found no hesitation to offer me his wide range of knowledge, and sincerely supported me throughout the whole journey, **Prof Amin Elkharbotly**, thank you so much. Secondly, I am much obliged to **Prof Nahid Afia**, who offered the greatest spiritual contribution with her unlimited kindness and insightful encouragement. To add, **Dr. Mohamed ElBeheiry** who guided and supported me with no doubts, thank you very much. Moreover, **Dr khaled seif**, thank you for your attention and cooperation in this matter, it means a lot to me.

Furthermore, hats off to my friends. They offered full support, motivation, love, and they never complained about how disconnected I was obliged to sometimes be. However, they were understandable enough.

Last but not least, many thanks for my colleagues. Dr. Nessren Zamzam and Dr. Ghada Essam, I do appreciate your effort and I am thankful for all your genuine assistance and companionship. In addition to Eng. Ahmed Saif and Dr. Raghda Bahaa, thank you very much for your generous collaboration, it was priceless.

January 2017

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