Scheduling Quay Crane and Yard Equipment

A case study of terminal in Central region

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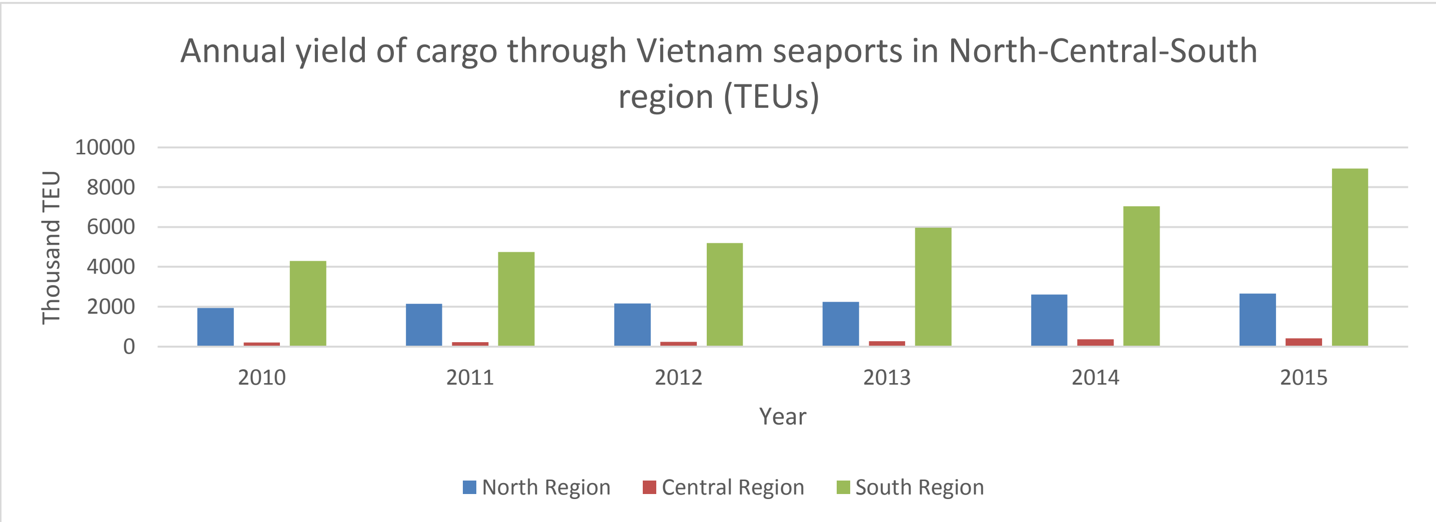
Abstract. Terminal is a complex system and important part in logistics. Our paper aims to show the relationship between Quay Cranes, Internal Trucks, Stackers, berths and apply Chen [8]'s mathematical model for increasing efficiency of terminals operation. We focus on reducing operation cost, time for serving ships and optimizing the usage of resources and we use CPLEX to solve this problem. Finally, several scenarios have been tested and compared with current situation.

Keywords: Scheduling quay crane, optimize operation terminal, CPLEX

1. INTRODUCTION

Port operation plays important role in Vietnam Logistics with more than 80% of goods import and export by sea. Annual yields of container cargo through this past 5 (2010 ~ 2015) years have gradually grown with average about 14.38% per year (Fig.1), which consists 69.52% of Southern region, 27.23% of Northern area and 3.25% of Central area.(Fig.2) In 2016, according to Vietnam Financial Times, the container cargo yield is expected to be 13,300 thousands TEU. With the rapid increase of quantity of containers through port, the port scheduling becomes a difficult issue for managers. The main purpose is to reduce service time port vessel as well as increase the quantity of containers through the port each year. In addition, port scheduling increases the performance of other equipment in the port.

Fig.1: Annual yield of cargo through Vietnam seaports in North-Central-South Region



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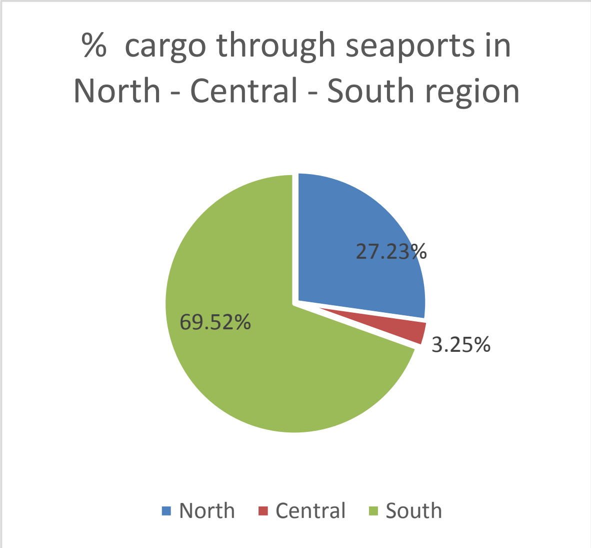

Fig.2: % cargo through seaports in North - Central – South region
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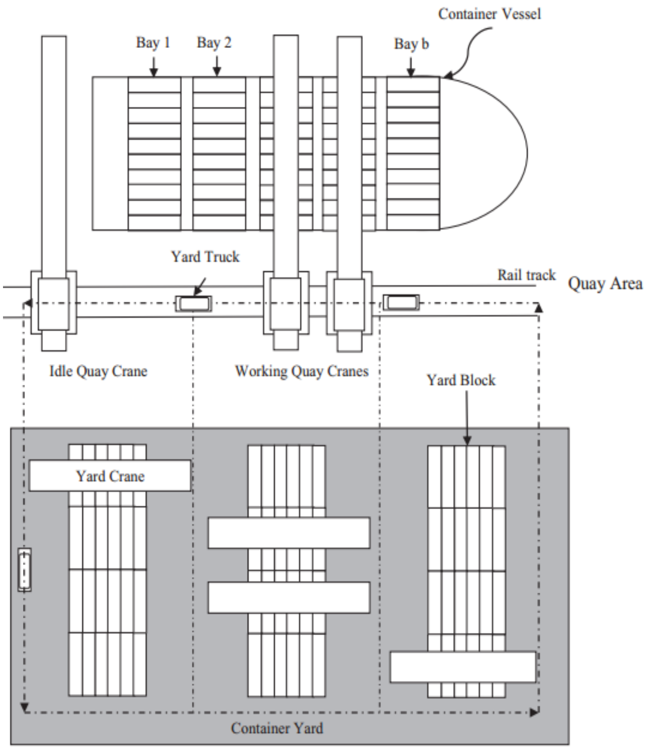

Fig.3 Typical layout of marine container terminal (N. Kaveshgar, N. Huynh [5] / Int. J. Production Economics 159 (2015) 168–177)

In the real life, the terminal of seaport consists of multi quay cranes, a fleet of yard vehicle, multi yard crane and container storage yard (Fig.3)

- Quay crane: the crane at the berth is used to load/unload containers to/from large ship. The ship can be served by one or several quay cranes which scheduled by manager.

- Yard vehicle: internal trucks only run in the terminal yard, they move outbound containers from storage yard to the quay crane in order to load on the ship and move inbound container from the ship to storage yard.

- Yard crane: cranes are used to arrange containers in container yard.

- Container yard: place where inbound and outbound container are stored.

2. LITERATURE REVIEW

Wong and Kozan [6] investigate the relationship between Quay Crane (QC), Yard Crane (YC) and Yard Vehicle (YV) in multi – berth and vessels situation. Their work was to design a mathematical model to increase the performance of inbound and outbound operations. The goal of their model was to minimize serving time for ships when they were at berth. They also proposed List Scheduling and Tabu Search to solve this problem. Finally, they introduced a case study to illustrate their work.

In the seaport, each ship is served by many cranes which load and unload containers on the ship. Then containers is move in/out storage yard by yard vehicles, each yard vehicle has finite capacity. The problem is to schedule quay cranes and yard vehicles effectively in order to minimize serving time for ship. This problem also called Quay Crane Scheduling Problem.

Bish [3] designed mathematical model to determine a position of storing the containers; scheduling yard vehicle to containers and scheduling the loading and unloading operation on the cranes. The purpose of model was to minimize the largest serving time for ships. They also developed algorithm to solve the problem. Finally, their work used computational calculation to demonstrate the effectiveness of algorithm.

Chen [8] presented a new model to schedule quay cranes, yard cranes and fleet of yard vehicles. This paper used Hybrid Flow Shop Scheduling with blocking constraint (HFSS-b) to formulate problem. The objective of this problem was to minimize the make span serving time for ship. Their work also provided and developed Tabu Search algorithm to solve the problem. Finally, computational point of view was used to demonstrate the performance of Tabu Search Algorithm.

Junliang He, Youfang Huang, Wei Yan, Shuaian Wang [4] mentioned about the quay crane, yard crane and yard vehicle scheduling problem, the authors used Mixed – Integer Programming (MIP) to formulate the model for this problem which was able to minimize total delay departure of all ships and total transportation energy in all tasks. The model was solved by using simulation-based optimization, when simulation was used for evaluation and optimization was designed for finding best solution. The optimization algorithm in this problem was GA and PSO for searching optimum solution. Finally, The Authors used numerical to test the performance of the proposed method.

Kaveshgar [5] introduced the integrate Quay Crane and Yard Vehicle Jointly scheduling problem which Quay Crane and Yard Vehicle scheduled at the same time. The Objective was to minimize the make span of the unloading inbound containers. This problem was formulated by using MIP and solved by GA in accordance with greedy algorithm proposed by authors. Finally, authors used numerical experiment to test the proposed method.

Ng et al [7] focus on scheduling yard vehicle to minimize the make span serving time for all unloading and loading containers. Specifically, the authors scheduling fleets of yard trucks to perform a set of transportation with predetermine – order with different processing time. Mixed integer programming was used to formulate this problem. GA with new developed crossover scheme was also proposed to solve this problem. Finally, computational experiment was used to demonstrate the solution.

The next part we will focus on the problem statement and the model formulation.

3. PROBLEM STATEMENT

In order to reduce the pressure on seaports in North and South region, the government now focuses on increasing the development of seaport in Central region. A huge investment is invested to build facilities which have capability to serve large vessels. However, there are some problems of terminal operation which make terminal in Central region is not a suitable destination of large vessels:

The first problem is the long serving time for vessels. Each vessel has own schedule to stop at specific terminal for loading and unloading containers and it usually has only 48h for all tasks. Thus, this is the most difficult scheduling task for managers because Central Region Terminal has only 2 quay cranes with moving rate about 15 moves/hours for each ~ 4 mins/ containers. . If we do not scheduling for quay cranes, while a crane is fully handle at one bay and the next crane haven't finished yet, it must wait for them to finish and move to next bay. Therefore, we need to research how to schedule the quay crane in order to get the shortest make span with limit resources.

The second problem is to schedule and determine yard vehicle to quay crane for delivering containers. Assume that 2 quay cranes operate 100% of their capacity, the scheduling yard vehicles become the bottle neck because the quay crane becomes idle to wait for yard vehicle for container delivery. Thus, this problem makes serving time longer. In conclusion, we not only schedule the quay cranes but also schedule the yard trucks.

4. OBJECTIVE

Firstly, I will find an optimal quay crane scheduling by CLPEX software. A vessel has several bays, a bay has several containers for loading/unloading. In this model, I check individual vessel, then we can see the position of each quay crane at each bay for period of time. Secondly, I will find optimal yard truck scheduling integrate with optimal quay crane scheduling mentioned above. The solution will be the sequence container delivery for fleet of yard trucks and the minimum yard trucks required for this task. Thirdly, I will test several scenarios in order to propose a more suitable solution for terminal in Central region.

5. MODEL FOMULATION

a/Problem description

In this section, we base on the idea of Chen [8] to formulate the model. Each container is considered one job. Quay cranes, yard trucks, yard cranes are considered machines. There are 3 main stages. The 1st stage includes set of quay cranes. The 2nd stage includes set of yard trucks. The 3rd stage includes set of yard cranes:

-For the case of unloading container from ship: containers will be processed by some equipment as follows: >> Quay Crane > > Yard Truck > > Yard Crane

-For the case of loading container on ship: container will be processed by some equipment as follows: >> Yard Crane >> Yard Truck >> Quay Crane

We realize that all the containers are common process so we will formulate the problem using Hybrid Flow Shop Scheduling with 3 stage: Quay Crane – Yard Truck – Yard Crane (for unloading) (Fig.4), Yard Crane – Yard Truck – Quay Crane (for loading) (Fig.5)

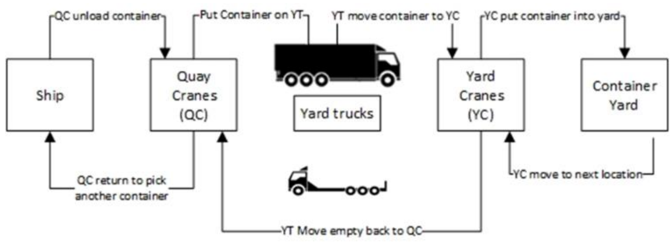

Fig.4: Unloading process

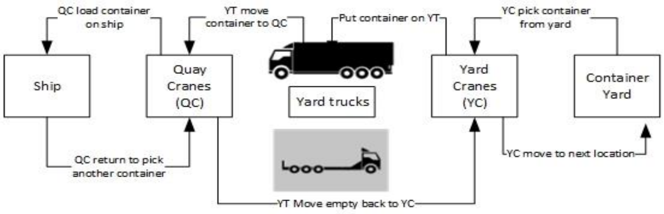

Fig.5: Loading process

Every empty move is considered a setup process of each machine in stages, so our model becomes Hybrid Flow Shop Scheduling with setup time.

b/ Model Formulation

We use the model formulated by Chen [8] to solve our problem:

$Parameter$

i, k: $job\ index$

j: $stage\ index$

m: $machine\ index$

N: $the\ set\ of\ all\ the\ job$

P: $The\ set\ of\ ordered\ pair\ of\ job\ between\ which\ there\ is\ a\ precedence\ relationship, when\ job\ i\ must\ precedence\ job\ k, (i,k) \in P$

O_{ij}: $operation\ of\ job\ i\ at\ stage\ j$

M_{ij}: $the\ set\ of\ machines\ out\ of\ which\ O_{ij}\ can\ be\ processed\ on$

E_m: $the\ set\ of\ job\ that\ might\ be\ perform\ on\ machine\ m$

p_{ij}: $processing\ time\ of\ O_{ij}$

s_{ikj}: $setup\ time\ between\ job\ i\ and\ job\ k\ at\ stage\ j$

H: $a\ sufficiently\ large\ number$

$Decision\ variable$

x_{ijm}: $1, if\ O_{ij}\ is\ assigned\ to\ machine\ m; 0, otherwise$

y_{ikjm}: $1, if\ O_{ij}\ and\ O_{kj}\ are\ assign\ to\ the\ same\ machine\ m; 0, otherwise$

u_{ikjm}: $1, if\ O_{ij}\ precedes\ O_{kj}\ (not\ neccessarily\ immediately)\ on\ machine\ m; 0, otherwise$

z_{ikjm}: $1, if\ O_{ij}\ immediately\ precedes\ O_{kj}\ on\ the\ machine\ m; 0, otherwise$

t_{ij}: $starting\ time\ of\ O_{ij}$

C_{max}: $makespan$

$Min\ C_{max} = \max(t_{ij} + p_{ij})$ (1)

$subject\ to$:

$t_{ij} \geq 0, \forall i \in N, \forall j \in \{1,2,3\}$ (2)

$t_{ij} + p_{ij} \leq t_{i(j+1)}, \forall i \in N, \forall j \in \{1,2,3\}$ (3)

$\sum_{m \in M_{ij}} x_{ijm} = 1, \quad \forall i \in N, \forall j \in \{1,2,3\}$ (4)

$y_{ikjm} \leq 0.5(x_{ijm} + x_{kjm})$, $0.5(x_{ijm} + x_{kjm}) \leq y_{ikjm} + 0.5, \forall i,k \in E_m, \forall j \in \{1,2,3\}, \forall m \in M_{ij}$ (5)

$y_{ikjm} = y_{kijm}, \forall i,k \in E_m, \forall j \in \{1,2,3\}, \forall m \in M_{ij}$ (6)

$u_{ikjm} + u_{kijm} = y_{ikjm}, \forall i,k \in E_m, \forall j \in \{1,2,3\}, \forall m \in M_{ij}$ (7)

$u_{ikjm} - z_{ikjm} \geq 0, \forall i,k \in E_m, \forall j \in \{1,2,3\}, \forall m \in M_{ij}$ (8)

$\sum_{k \in E_m} z_{ikjm} \leq 1, \quad \forall i \in E_m, \forall j \in \{1,2,3\}, \forall m \in M_{ij}$ (9)

$\sum_{k \in E_m} z_{kijm} \leq 1, \quad \forall i \in E_m, \forall j \in \{1,2,3\}, \forall m \in M_{ij}$ (10)

$x_{ijm} \geq (\sum_{k \in E_m} z_{ikjm} + \sum_{k \in E_m} z_{kijm})0.5$, $(\sum_{k \in E_m} z_{ikjm} + \sum_{k \in E_m} z_{kijm})0.5 \geq x_{ijm} - 0.5, \forall i,k \in E_m, \forall j \in \{1,2,3\}, \forall m \in M_{ij}$ (11)

$t_{i(j+1)} + s_{ikj} \leq t_{kj} + H(1 - z_{ikjm})$, $t_{k(j+1)} + s_{kij} \leq t_{ij} + H(1 - z_{kijm}), \forall i,k \in N, \forall j \in \{1,2,3\}, \forall m \in M_{ij}$ (12)

$t_{ij} \leq t_{kj}, \forall i,k \in P, \forall j \in \{1,2,3\}$ (13)

$x_{ijm}, u_{ikjm}, y_{ikjm}, z_{ikjm} = 0\ or\ 1, \forall i,k \in E_m, \forall j \in \{1,2,3\}, \forall m \in M_{ij}$ (14)Type equation here.

(1) Is the objective function which minimize the make span, (2) ensure that the starting time of all jobs is greater than zero, (3) make sure that all job have to complete each stage in order. (4) every job processed by exactly one quay crane, one yard truck, one yard crane at each stage. (5) and (6) make sure both job i and k are assigned on machine m. (7) and (8) when both job i and job k are assigned on machine m, they must have to be in order, (9) and (10) make sure that every job has one predecessor and successor on machine m, (11) use to balance the flow, (12) is about setup time constraint, (13) is the order constraint for containers, (14) is a binary constraint for decision variable.

6. RESULT AND EXPERIMENT

I will test several scenarios in order to propose a more suitable solution for terminal in Central region.

Here is the bay layout

Bay 1 & Bay 2: Assigned to Quaycrane 2

Bay 3 & Bay 4: Assigned to Quaycrane 1

Quaycrane 2		Quaycrane 1	
Bay 1	Bay 2	Bay 3	Bay 4
Container 1	Container 2	Container 3	Container 4
Container 5	Container 6	Container 7	Container 8
Container 9	Container 10	Container 11	Container 12
Container 13	Container 14	Container 15	Container 16

	TEST 1	TEST 2
Number of container	16	16
Number of quaycrane QC	2	2
Number of yard truck YT	3	4
Number of yard crane YC	1	1
Processing time QC	4 min	4 min
Processing time YT	3 min	3 min
Processing time YC	1 min	1 min
Setup time of YT	2 min	2 min

Result: TEST 1: makespan 38min (Fig.6)

Result: TEST 2: makespan 38min (Fig.7)

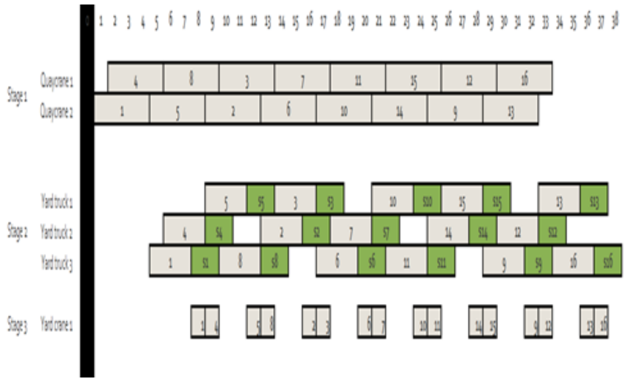

Fig.6: Result TEST 1

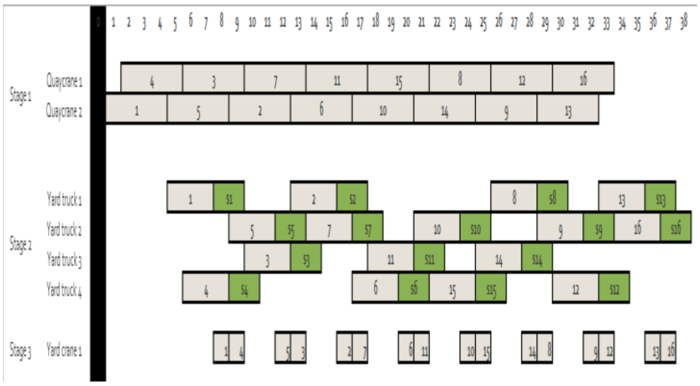

Fig.7: Result TEST 2

Here is the order constraint of these TESTS

P	*Container i before*	*Container k after*
1	*1*	*5*
2	*5*	*9*
3	*9*	*13*
4	*2*	*6*
5	*6*	*10*
6	*10*	*14*
7	*3*	*7*
8	*7*	*11*
9	*11*	*15*
10	*4*	*8*
11	*8*	*12*
12	*12*	*16*
13	*2*	*7*
14	*7*	*9*
15	*4*	*7*
16	*7*	*10*
17	*15*	*9*
18	*5*	*3*

With the same makespane, the manager should choose

TEST 1 due to using less resources than TEST 2

7. CONCLUSION

In this paper, a mathematical model of Chen is used to solve the case study of scheduling of various kinds of container handling equipment in the Central region terminal. Result obtained from mathematical model is suitable to solve the practical problems with large scale. It could support for managers to manage all equipment operation with optimal time. Furthermore, managers can choose an exact quantity of necessary equipments used for serving vessels. Hence, it has capability to increase the efficiency of the seaport performance.

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