Available online at www.sciencedirect.com

ScienceDirect

IFAC-PapersOnLine 48-3 (2015) 875–880

Decision Support System for Discrete Robust Berth Allocation

Saurabh Pratap*, Ashutosh Nayak, Naoufel Cheikhrouhou***, Manoj Kumar Tiwari******

**Department of Industrial and Systems Engineering, Indian Institute of Technology, Kharagpur, 721302, West Bengal, India; email: s.pratapiitkgp@gmail.com*

***Department of Industrial and Systems Engineering, Indian Institute of Technology, Kharagpur, 721302, West Bengal, India; email: ashutoshnayakkgp@gmail.com*

****Haute école de gestion de Genève, University of Applied Sciences Western Switzerland, 1227 Geneva, Switzerland; email: naoufel.cheikhrouhou@hesge.ch*

*****Department of Industrial and Systems Engineering, Indian Institute of Technology, Kharagpur, 721302, West Bengal, India; email: mkt09@hotmail.com*

Abstract

This paper aims to develop a decision support system for bulk material handling ports in relation to ship scheduling and discrete berth allocation. Ship scheduling according to available discrete berths and to customer priority is a complex problem. A multiobjective formulation is then proposed to model the problem in minimizing ship waiting times and deviation of customer priority. An modified Non-sorting Genetic Algorithm (Mod-NSGA II) is proposed to solve the problem in large-scale realistic environments. Utility of the developed decision support system in achieving good utilization of the available berths and resources is demonstrated using illustrative scenarios inspired from a real port management case.

Keywords: Berth allocation; Meta–heuristics; Marine Systems; Optimization; Scheduling Algorithm.

1. Introduction

Economic growth of a nation depends majorly on import and export of materials. There are three modes of transportation via seaside, airside and landside transportation, among them seaside are the cheapest and most robust one. Nowadays, most of the bulk transportation activities are carried out via sea. Some of the countries have mega bulk material handling terminals, which are known as transshipment hubs. Most of the researchers focus only on the container terminal and address the berth allocation and ship scheduling rather than focusing on bulk material handling port. The highest decision complexity is involved in assigning a berth to a particular ship. In this paper, the prime focus is to schedule the ships from anchorage to available berths by considering the operating time of the ships unloading and priority of ships customer at a bulk handling port.

The decisions of the berthing of ships to different berths are usually based on first in first out (FIFO) or priority rules set by port owner, which do not satisfy the customer demand. Some customers are more important to the ports based due to contracts. A priority is maintained for each of the customer expected to come at the port. As a port manager, it is required to allocate the berth to the customer based on this set priority. The priority can be set based on different criteria like the business contract, quantity of product or frequency of visit.. Due to this nature of setting priorities for the customers, a new objective of minimizing deviation from customer priority to actual berthing order is developed. The complexity of the berth allocation problem increases when integrated with the objective of minimizing priority. A decision support system is proposed to model the complex problem.

Ships arrive to anchorage and wait to get berthed. The port has a channel and due to infrastructure, the channel can pass only one ship from the anchorage to the berths at a time. Once the port operator calls a ship for berth, they assign the tug boats to tow the cargo ship through channel from anchorage to available berth. Thus, the problem can be modelled as a sequencing problem. The sequence is the order in which the ships are called from the anchorage to the available berth. The methodology proposed in this paper aims to solve the decisions pertaining to ship order based on the waiting time of ships and the customer priority deviation. It is one of the first attempts to integrate the objective of minimizing the total waiting time of ships at anchorage with the objective of minimizing the deviation of the berthing order from customer priority. A multi-objective methodology is proposed to formulate the berth allocation problem.

2. Literature Review

Most of the researchers focus their interest in strategic and tactical issues facing the container handling terminal port. A very few studies have been carried out for berth allocation as a ship scheduling problem for bulk material handling port.

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2015.06.193

Imai *et. al.* (2001) proposed a model for dynamic berth allocation and solved by heuristic based on Lagrangian relaxation. Imai *et. al.* (2010) introduced a model for berth allocation at Asian port and minimizes the ships staying time and minimizes dissatisfaction of the ships in terms of the berthing order. Brown *et. al.* (1994) introduced a berth allocation problem and to determine and optimize the berthing time to particular berth such that at a time only one vessel can occupy for a time horizon. Ting *et. al.* (2014) developed a model for discrete and dynamic berth allocation and minimizes the waiting and handling time of ships.

Wang et al. (2007) introduced a model for berth allocation in multi stage decision making procedure and implements the stochastic search method to solve this problem. Golias *et. al.* (2014) presented a model for discrete berth scheduling and provides a berth schedule by minimizing the average service time of vessel on container terminal. Murty *et. al.* (2005) developed a model for container handling port and minimize the berthing time of the vessel. Lin *et. al.* (2014) proposed an integrated greedy heuristic method to solve the discrete dynamic berth allocation and minimize the total service time of ship at the berth.

Xu *et.al.* (2012) presented a model based on robust berth scheduling to encounter the uncertainties due to arrival time, handling time of ship and yard space allocation. Ursavas (2014) developed a decision support system to determine berthing and quay crane allocation decisions. Babu *et. al.* (2014) suggested a model to schedule ships and rake scheduling to minimize the ship delay at the port terminal. In this paper, we foreground the port management issue that researchers usually consider, but in a holistic view; specifically, the scenario focus on ship sequencing and customer priority simultaneously.

After a literature review in section 2, discuss the details of problem description and model in section 3. Section 4 reports a case study. Finally, Section 5 concludes our work and future research direction.

3. Problem Description

In this problem, we considered a realistic scenario of a port located in the eastern coast of India as shown in figure 1 (schematic view of the port). At this port, there are an anchorage (where Ship S_1, S_2... S_6 wait for berthing), 3 berths (Berth 1, Berth 2 and Berth 3), ship unloaders (Su) and a channel to pass one ship from anchorage to berth. The ships arrive to anchorage and on the basis of berth availability, port management allows the ship for berthing and if there is no free berth at that time, then ships (S_1, S_2... S_6) wait to get berthed up-to available berth.

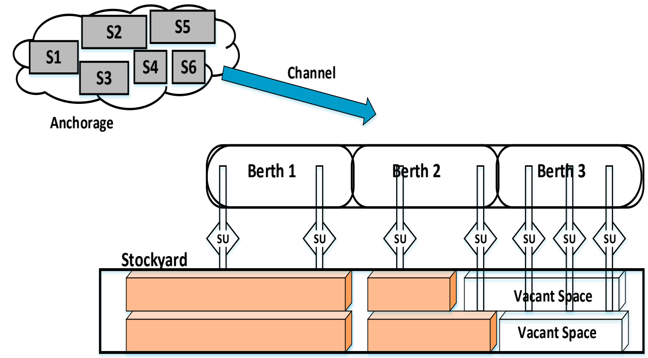

Figure 1. Schematic view of Port

In this model, we introduced a berth allocation model as multi-objective problem, aimed at minimizing the total ship waiting time and customer priority. A berth allocation is viewed as a sequential order of ship as the channel allows only one ship at a time. Fleet of ship is waiting on the anchorage, when berth is free, then port management allow the ship through the channel to get berthed according to specific order. As customer priority is port dependent, ship priority in this paper is given to ships according to the load being carried the biggest quantity of product.

The port has fixed number of ship-unloaders. The un-loading rate is considered constant as all the un-loaders are assumed to have equal capacity. The model assumptions are as follows:

(1) All berths are discrete and any cargo ship can be berthed in any free berth.
(2) In a given berth, only one ship can be served at a time.
(3) The maximum number of un-loaders that can be assigned to a ship is limited. This assumption is aligned with berth length constraint.
(4) The time to move a un-loader from one berth to another is negligible.
(5) The estimated arrival time of a ship at the anchorage and the quantity of cargo are known in advance.

Notation:

Indices

s is the index of the ship, s = 1,.., S

b is the index of the berth, b = 1,…, B

o is the index of the ship order, o = 1,…, S

Input Parameters

a_s Arrival time of ship s

b_s Berthing time of ship s

B	Number of berths
S	Number of ships
d_s	Departure time of ship s
p_s	Priority of ship s
o_s	Order of ship s
U_r	Unloading rate (Unloader)
Q_s	Quantity of cargo in ship s

Decision Variable

$y_{s,b,o}$	= 1 if s ship is berthed in berth b in order o

Model: Berth allocation

The objective of this problem is to find the optimal order in which the ships should be allowed to pass through the channel towards the berths.

The model:

The model

$$\min \sum_{s \in S} (d_s - a_s) \tag{1}$$

$$\min \sum_{s \in S} | o_s - p_s | \tag{2}$$

Constraint

$$\sum_{s \in S} \sum_{b \in B} y_{s,b,o} = 1 \tag{3}$$

$$b_s \geq a_s \qquad \forall s \in S \tag{4}$$

$$d_s \geq b_s \qquad \forall s \in S \tag{5}$$

$$\sum_{s \in S} y_{s,b,o} \leq 1 \qquad \forall b \in B, \forall o \in O \tag{6}$$

$$d_s = b_s + \frac{Q_s}{2r} \qquad \forall s \in S \tag{7}$$

$$\sum_{s \in S} a_s x_{s,b,o} < \sum_{l \in S} (a_l + \frac{Q_l}{2r}) x_{s,b,(o-1)} \qquad \forall s \in S \tag{8}$$

$$\sum_{v \in V} n_s \leq n\_\max \tag{9}$$

$$y_{s,b,o} \in \{0,1\} \qquad \forall s \in S, \forall b \in B, \forall o \in O \tag{10}$$

The objective stated in equation (1) and (2) aims to minimize the waiting time and minimizing the deviation from customer priority. The second objective aims at giving berthing orders to customers in such way that they are close to the priority assigned to them. Constraint (3) states that all the ships have to be berthed. Constraints (4-5) show that the ship is berthed after its arrival and departs after complete un-loading. Constraint (6) shows that a ship is berthed at most once. Constraint (7) shows that departure time is equal to the sum of the arrival time and the unloading time and highlights the assumption that two ship un-loaders are always available at a berth. Constraint (8) states that for a given berth, two ships cannot be berthed simultaneously. Constraint (9) shows that the maximum number of ship-unloaders is greater than, equal to the number of ship unloaders at any time. Constraint (10) states that $y_{s,b,o}$ is a binary decision variable.

4. Methodology

In case of multi objective problem, there is set of a solution which has to satisfy all the objectives and all constraints. Non-sorting genetic algorithm (NSGA II) is a meta-heuristic method to solve multi objective problem and generates a set of Pareto-optimal solution.

4.1 Implementation of Modified Non-sorting Genetic Algorithm II

The implementation of the algorithm on berth allocation is discussed below:

Initialization

The ship sequence is generated through random number generation. For each gene of ship sequence, a random number is generated and based on a random number, a berth number is assigned.

Mutation operation

The chromosome experiences mutation in the form of exchange of the berthing orders of ships after the mutation operation is performed on the chromosome.

Crossover Operation

The crossover operation between two chromosomes is performed through real number crossover; Random numbers are generated on the interval [0-1] as a binary and sorted such that their orders are the same as the order sequence in the chromosome.

Selection in Modified NSGA-II

In Modified NSGA-II, the number of individuals to be selected as new parents from the current best non-dominated Pareto front is restricted to maintain lateral diversity in the population of the next generation. The restriction is based on a pre-defined distribution of the number of individuals in each Pareto front using Geometric distribution. The number of individuals in each front is restricted to n_i where the geometric distribution is obtained from Equation (11):

$$n_i = r\, n_{i-1} \tag{11}$$

Where n_i *is* the maximum number of allowed individuals in front i and r *(r <*1*)* is the reduced rate the new population size N. Let k be the number of non-dominated fronts in population. Then, n_i can be defined as (12):

$$n_i = N \frac{1-r}{1-r^K} r^{i-1} \tag{12}$$

Let denotes the maximum number of individuals from front i. Then, check now n_i should be written (13), inconsistent

$$n_i \leq n^{(i)} \tag{13}$$

The selection of n_i individuals from the front i is done by the crowded distance operator. The geometric distribution ensures an exponential decrease of the number of solutions.

5. Result and Discussion

In this paper, a case study of a port situated on the eastern coast of India is explored. The data collected consist of 22 ships within the month of October. At this port, there are discrete 3 berths. We solved a case study by using the software MATLAB 2008 on i7 processors (8.0 GHz) in Windows 8 platform.

5.1. Determination of the optimal order of ships

Modified NSGA II and NSGA II generate the optimal order ship sequence for berthing mention the difference as in the selection process. The parameters adopted are: Population size is 100, crossover probability is equal to 0.65 and Mutation probability is equal to 0.1. To show the solution quality with respect to the generations, the Pareto front for Modified NSGA-II and NSGA II is shown in Figure 2(a) to Figure 2 (f). In each figure, ten different runs are used to generate the results. Diversity is an important criteria in Pareto front along with the quality of the solutions. More number of solutions in the Pareto front give more options to the managers to select from a wider range of available options based on his/her preference. It is generally considered better if a continuous Pareto is obtained with a high number of comparable solutions. From the results, it is observed that the Pareto becomes continuous with the increase of the number of generations (number of solutions in Pareto increases) and modified NSGA II gives better result in comparison to NSGA II as the objective function values are closer to the origin for the minimization problem.

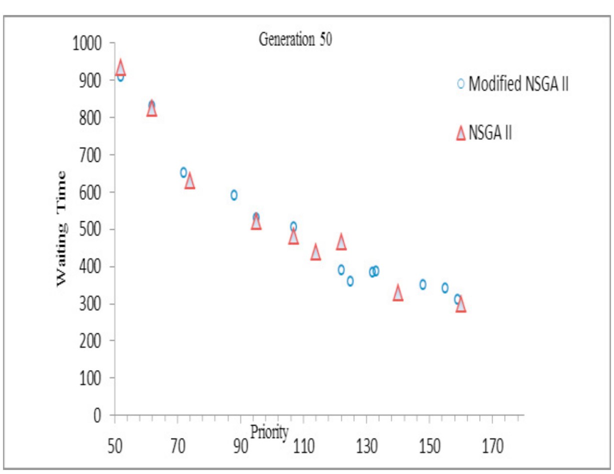

Figure 2(a)

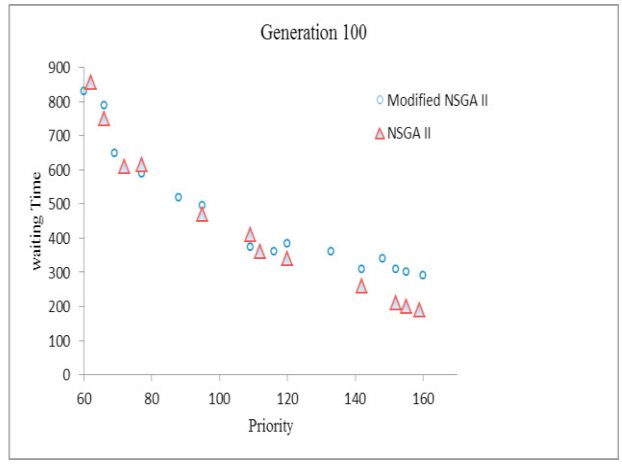

Figure 2(b)

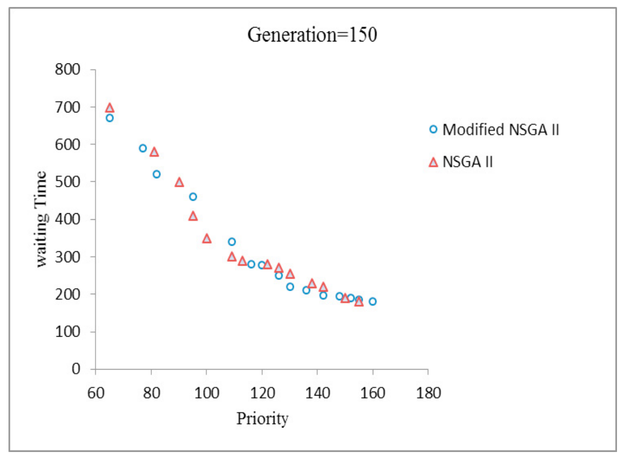

Figure 2(c)

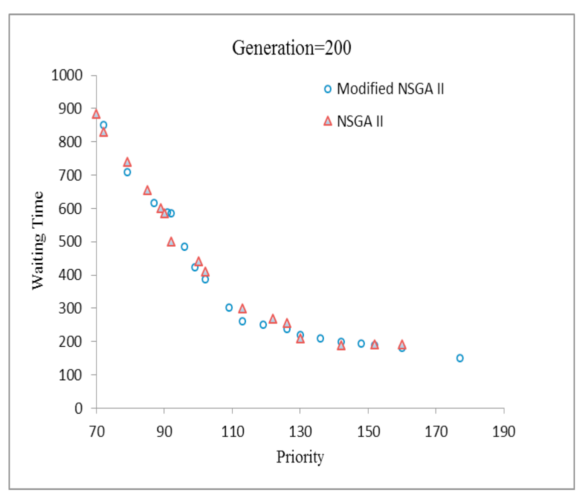

Figure 2(d)

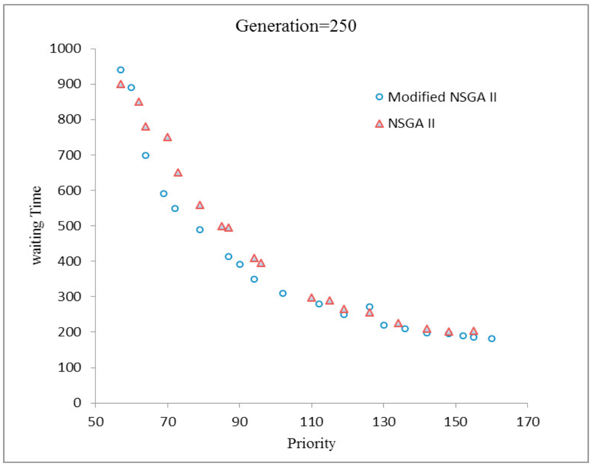

Figure 2(e)

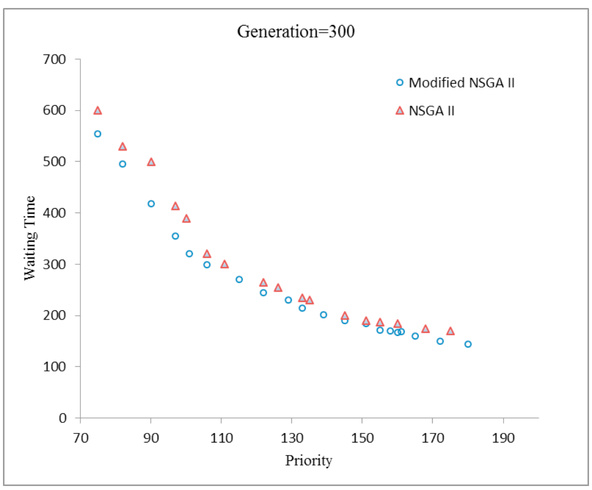

Figure 2(f)

The number of iterations is kept at 250 as the quality of Pareto deteriorates after 200 iterations due to the convergence to the same solutions.

The heuristics for allocation of berth based on order of ships is explained as:

Heuristics for Berth Allocation

Initialize $t\,(b) = 0$ for all berths
For $i = 1$ *to* V:
v = ship with order v
b = berth with min {t}
Assign berth b to ship v
If $t\,(b) < a_v$ then
$t(b) = a_v + a_v/2r$
else if $t\,(b) > a_v$ then
$t(b) = t\,(b) + a_v/2r$
end
end

The Ship order sequence obtained from the Pareto front of NSGA II and proposed Modified NSGA II are shown in Table 1(a) and (b) respectively.

3	5	1	8	2	4	10	7	19	9	12	11	6	13	16	14	15	17	18	21	20	22

Table 1(a)

5	3	2	1	8	4	10	9	7	6	12	18	13	16	17	15	14	19	22	20	11	21

Table 1(b)

The total operational time including minimized delay for NSGA II and Modified NSGA II is 729.210 Hrs. and 717.489 Hrs. respectively and modified NSGA II performs better result. The berth allocation results by proposed Modified NSGA II are shown in Figure 3. The figure is a schedule of the ships berthing over the period of time considered. The rectangle number is the ship number and the rectangle width shows the operating time of the ship. The schedule is obtained from the heuristics whose input is the optimal berth sequence obtained from Modified NSGA II.

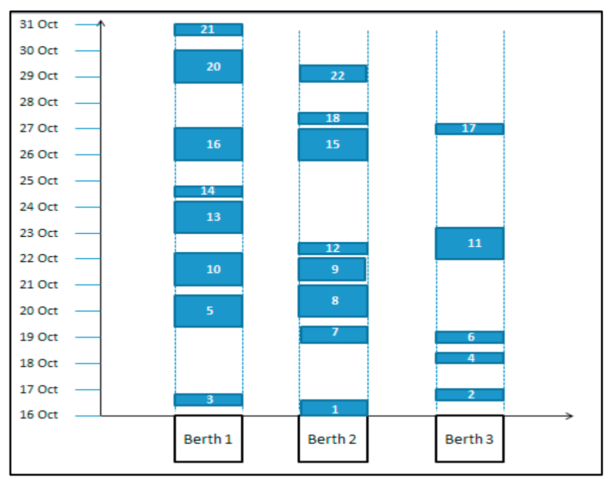

Figure 3

6. Conclusion

This paper presents a model that captures real industry scenario of port operations by taking into account ship arrival, berthing, departure, customer priority and operational time.

The problem is formulated as bi-objective berth allocation problem to minimize the operational delay and customer priority deviation. To solve the problem, two meta-heuristics are proposed: NSGA II and modified NSGA II. A comparative study is done between NSGA II and modified NSGA II for diversity in Pareto front and quality of solution, where it is observed that modified NSGA II performs better than NSGA II in both the fields.

REFRENCE

Brown, G. G., Lawphongpanich, S and Thurman, K. P. (1994).Optimizing ship berthing, *Naval Research Logistics*, 41(1) pp. 1-15.

Babu, S.A.K.I., Pratap, S., Lahoti, G., Fernandes, K. J., Tiwari, M. K., Mount, Mand Xiong, Y. (2014). Minimizing delay of ships in bulk terminals by simultaneous ship scheduling, stockyard planning and train scheduling, *Maritimes Economics and Logistic* .doi:10.1057/mel.2014.20.

E. Ursavas. (2014). A decision support system for quayside operations in a container terminal. *Decision Support System*, 59, 312–324.

Golias, M., Portal. I., Konur. D., Kaisar. E and Kolomvos, G. (2014). Robust berth scheduling at marine container terminals via hierarchical optimization. *Computers & Operations Research*, 41, 412–422.

Imai, A., Nishimura, E. and Papadimitriou, S. (2001). The dynamic berth allocation for a container port *Transportation Research Part B*, 35, pp. 401–417.

Imai, A., Nagaiwa, K. and Tat, C. W. (1997). Efficient planning of berth allocation for container terminals in Asia. *Journal of Advanced Transportation*. 31 (1), 75-94.

Lin, S.W., Ying, K.C., Wan, S.Y., (2014). Minimizing the Total Service Time of Discrete Dynamic Berth Allocation Problem by an Iterated Greedy Heuristic. *The Scientific World Journal,* 2014, 12. doi:10.1155/2014/218925

Murty, K. G., J. Liu, Y. W. Wan and R. Linn. (2005). A decision support system for operations in a container terminal, *Decision Support Systems*, 39, 309–332.

Ting, C. J., Wu, K. C. and Chou, H. (2014). Particle swarm optimization algorithm for the berth allocation problem. *Expert Systems with Applications*. 41, 1543–1550.

Wang, F and Lim, A. (2007). A stochastic beams search for the berth allocation problem. *Decision Support Systems*, 42 (4) 2186–2196.

Xu, Y., Chen, Q., Quan, X. (2012). Robust berth scheduling with uncertain vessel delay and handling time. *Annals of Operation Research*, 192, 123-140.