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# A PRIORITY DECISION MODEL FOR BERTH ALLOCATION AND SCHEDULING IN A PORT CONTAINER TERMINAL

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**ABSTRACT**

A container port terminal is an important link in the overall logistic chain and plays a vital role in the intermodal transport chain. The aim of this paper is study the problem of berth allocation with a priority service by presenting a model of priority, the simulation of the problem show some improvement especially the minimization of the total waiting time of the vessels, and the improvement of the availability of the berths.
**Key words:** *Container Terminal, Vessel, Queues, Crane Allocation, Decision Making,*

## 1. INTRODUCTION

Today in the era of globalization and competition, industrial companies focus more and more on their heart activity and outsource other tasks out of their areas of expertise. Hence flows of goods have increasingly growing and development of international intermodal transport networks. With the arrival of container, handling is standardized and transit time from one mode of transport to another has significantly decreased. However, the passage through the port container terminal remains the weakest link in the intermodal transport chain, hence the need to optimize port management in order to accelerate and reduce the cost of moving the goods through the port. Optimization of operations within the port container terminal is very important, because the charging time has a great impact on the economic viability, hence the importance for the efficiency and effectiveness of the identification and location of containers inside the port area.

Given the complexity of operations in a port container terminal, it is difficult to optimize the entire system with a single analytical model. The problem is generally divided into several problems. Each problem is optimized separately. Among the problem known in the literature, there are quay crane allocation problem (QCAP), and berth allocation problem (BAP), optimizing inventory management and storage space containers, and the assignment internal trucks during workflow ... etc.

## 2. LITERATURE REVIEW:

### BAP:

There are numerous studies on BAP: The work of Lu Zhen et al. (2011) addressed the issue BAP, this article discussed the berth allocation problem in an uncertain environment, authors didn’t take in consideration cranes allocation problem, for that they suggested a Meta heuristic. The goal is to answer the question where and when a ship has to berth while minimizing latency and reducing the overall distance traveled by the vehicles at the loading and unloading operations of a ship. Hence the proposal of a model as a basis planning with a Meta heuristic approach and numerical results validated the model. But this model does not take into account the problems and constraints of availability of handling equipment such as cranes.

However, Dongsheng Xu et al. (2002) studied the same problem berth allocation BAP taking

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into account the constraints of draft and tidal, the authors neglected the problem of cranes allocation. The goal of this work is to test if it is necessary to consider the tidal conditions when berth decision assignment. This paper proposes a heuristic approach to the treatment of static and dynamic case, the model developed to show that the port terminal operators can make better decision, taking into account the depth variation in berth allocation. However, the model assumes that a berth supports only one ship, but in fact a berth can accommodate two small ships, and they divided the time horizon of only two periods: high tidal period and low tidal period when in fact it is cyclical.

In addition, and always with the BAP Victor Hugo Barros et al. (2010) proposed a model that give berthing priority to the ship with the most critical level of stock in order to regulate the flow in the terminal, and also decide what sequence of vessels in planning at given time horizon. This problem is modeled as a heuristic algorithm to solve it.

**BAP QCSP:**
Moreover, Liyin Song et al. (2011) developed a genetic algorithm "branch and bound method" to solve the problems of berth allocation and quay crane scuduling BAP & QCSP, in minimizing the total waiting time and the total time required for ship loading and unloading operation, and at the same time guarantee the cranes use efficiency. The model assumes that upon schedule realization, the vessels involved in this planning are already in terminal (static case), but in reality the order and the time of ships arrival is random (dynamic case).

Similarly, Xia Han et al. (2010) also studied both problems, BAP & QCSP, the authors assumed that vessels arrival time is unknown and the time required for loading and unloading is also not given in advance, thereby the proposed model is complex but it is near to reality. The authors have developed a model that can generate a schedule that will affect every ship to a quay and it allocated a number of cranes to ensure loading and unloading containers from the ship. That is why they have opted for a mixed integer linear programming and simulation with genetic algorithm and process simulation Monte Carlo. This paper proposes a heuristic approach that search an efficient schedule affection cranes and quay, and discusses the interaction between the latter two problems by heuristics to achieve maximum productivity in an uncertain environment, and finally they proposed a management tool for the daily operations of the terminal managers and also a tool to assess the return on investment in the automated handling system adoption at terminal. The model assumes a discrete quay distribution, and also assumes that a ship can change its position before finishing the loading and unloading operation which is logically true but is not economically viable due to the high cost and time required to change position.

In addition, G. Giallombardo et al. (2009) also addressed both problems BAP & QCSP, the validation of the mathematical model was developed on the basis of actual data, the dimensions of the problem are as follows: (ship number, quay number, weeks number, cranes number) [(10, 3, 1.8), (20, 5, 1, 13), (30, 5.1, 13), (40, 5 , 2, 13), (50, 8, 2, 13), (60, 13, 2, 2, 13)]. The authors used a mixed integer quadratic programming and linearization which reduces the model mixed integer linear programming to solve the problem. They proposed a solution to the decision problem at the port container terminal, assume that a ship needs six cranes / shift, there are several possibilities: allocate three cranes for 2 shift or two cranes for 3 shift etc ... knowing that the increase in the number of crane lowers their availability for a possible use for arriving ships through, however maximize cranes number minimizes the time required to complete the loading and unloading operation which increases in this case the rate of quay availability, so which scenario to choose is the objective of the paper. The paper proposes a heuristic approach that combines between mathematical programming technique and what we call "tabu search methods" in order to reduce the cost of ships staying in port generated by transshipment between ships and to maximize the total value of cranes profile selected. The model assumes a discrete crane distribution (13 cranes distribution), and does not take into account the constraint of non-overlapping of cranes, which reduces the efficiency model proposed, because in reality the gates are positioned on the same rails

**QCSP:**
JIN Zhihong et al. (2011) focused on the problem QCSP, the authors assumed that arrival time and berthing ships are known, and they took

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into account the constraints non-overlapping of cranes and the schedule of all tasks carried out by ship (the movement of each container to be loaded or unloaded), which makes a heavy model viewpoint resolution. The authors proposed a model able to produce a schedule that manages the dynamic crane allocation and scheduling based on the berthing schedule. That is why they have developed a non-linear programming model and genetic algorithm to find a solution for this problem. The model has been tested on three statistics sets (uniform distribution, normal distribution, standard dual distribution) based on the Handling rate (20%, 50%, 80%), the average results obtained each time are successively (-15.5%, 1.2%, 2.9%). However, the model does not take into account the berth allocation problem.

## 3. BERTH ALLOCATION AND SCHEDULING PROBLEM

The berth allocation and scheduling problem is one of the critical issues for port management and has been widely discussed in the literature through several research and has mainly been approached from two slightly different names: Berth allocation problem (BAP) and Berth scheduling problem (BSP), but the principal goal is the same, as in the goal in the two problem is to exploit in an efficient manner the berth length available for berthing the maximum possible ships for a given time interval.

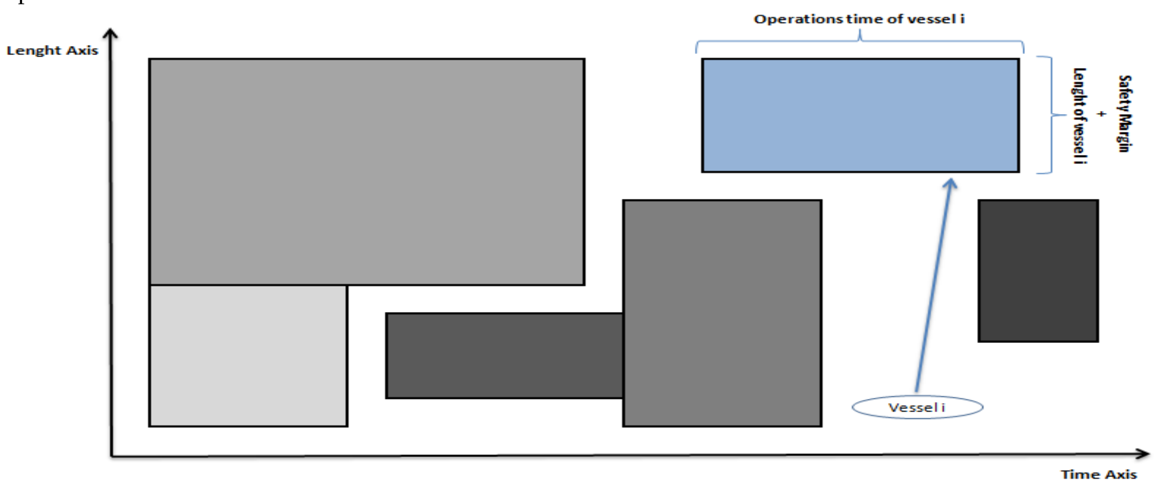


*Figure 1: Representation Of The Berth Allocation Process*

The process of berth allocation is to allocate a berth to a ship in order to ensure her berthing operation while respecting a number of technical standards, including draft (depth), berthing priority, operation time involved, specific needs of the vessel (bunker, etc ...) ... etc., there are two scenarios: berth discrete distribution ( berth positions are known in advance) or berth continuous distribution (the distribution of the quay is as required in need of the terminal, and this scenario is the most used), this process is extremely important, especially at multi-users ports, because the position assigned to a ship can significantly impact the productivity of the terminal and the productivity of the ship as well, as poor planning can cause an unnecessary delay for some ship and thus caused dissatisfaction of the ship-owners.

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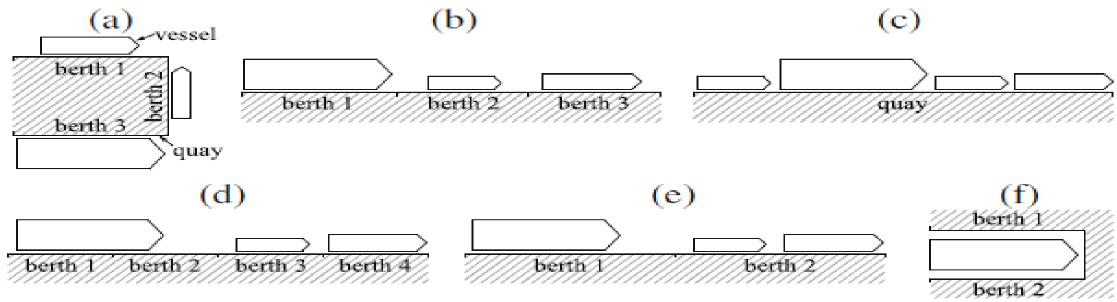


*Figure 2: Presentation Of Possible Berth Configurations (Bierwirth Et Al. 2009)*

(a) Berths are known in advance;

(b): Berths are defined depending on the position occupied by vessels;

(c) Berths are defined by the number of cranes for ships;

(d) Berths are defined according to the schedule of operations and cranes assigned to ships;

(e): This model is a combination of b, c and d.

Berth scheduling aims is to provide a fast and reliable service to vessels wishing do commercial operation, the problem is generally treated by different objective functions according to the approach adopted, for example minimizing the waiting time or minimizing the time handling vessels (Bierwirth et al. 2010).

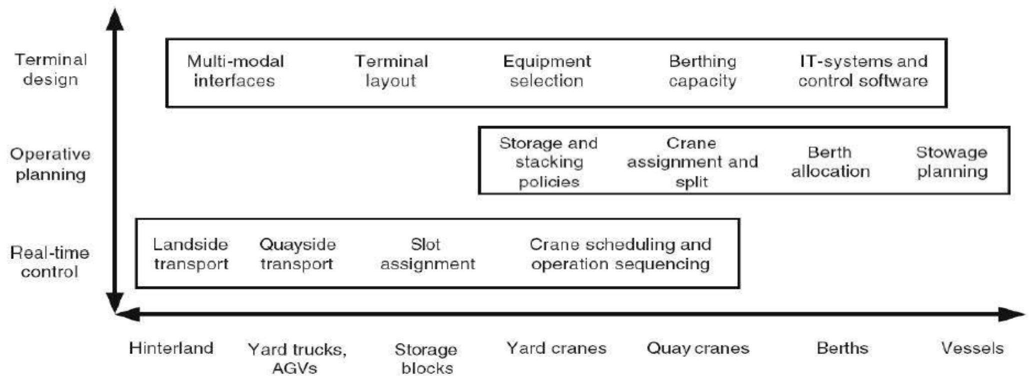


*Figure 3: Planning Levels In A Port Container Terminal (Günther Et Al. 2006)*

The port container terminal handles a huge number of operations, and is essentially a work planning and scheduling, which is characterized by the decision level, ranging from the strategic to the operational level via the tactical level, Figure 3 shows and gives a decision level for each activity of the port environment, e.g. determining berthing capacity decided before the terminal layout, which stems from a strategic decision, the choice of an information system for the management of the terminal is a strategic choice, but it can also be done after the construction of the terminal. But before start to use the port infrastructure, and also takes an example, the assignment of a handling device has a rolling operation that is derived from the daily management of a terminal.

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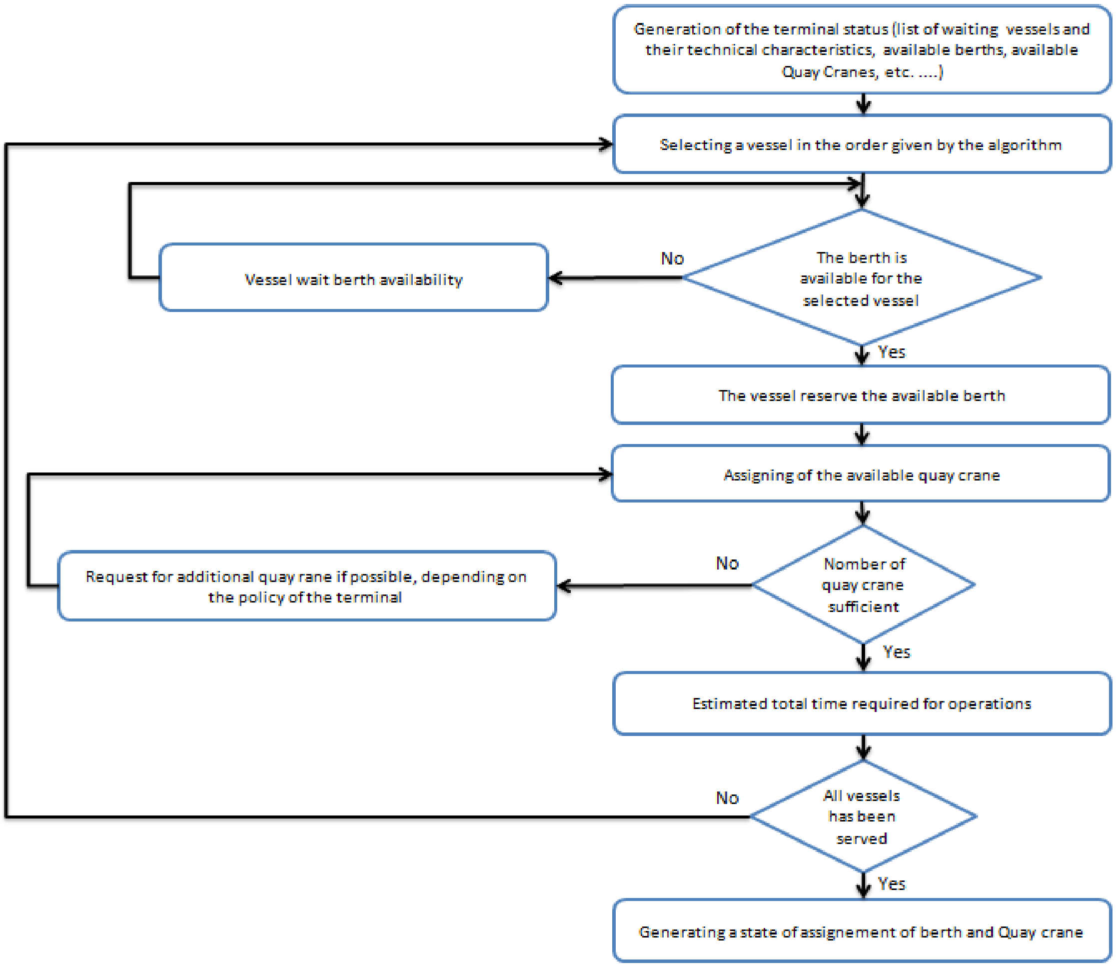


*Figure 4: Algorithm Quay Allocation Process*

## 4. QUAY CRANE SCHEDULING AND ALLOCATION PROBLEM:

Quay Crane allocation and scheduling problem widely discussed in the literature across multiple research, this problem has been addressed in two different sub-problem, Quay Crane Allocation problem" (QCAP), which is allocated a number of quay crane to incoming ships, so the goal is to determine the number of quay crane to allocate for each vessel. Otherwise Quay Crane scheduling Problem" (QCSP) is to determine the work schedule for each quay crane, by elaborating and editing a schedule work.

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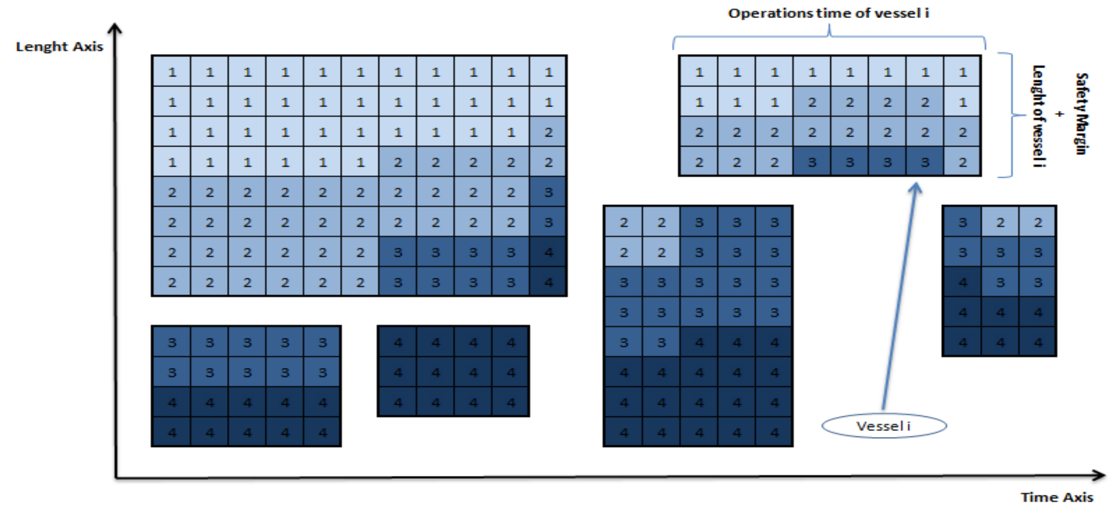


*Figure 5: Representation Of The Process Of Cranes Scheduling.*

The objective was addressed by the literature in most cases is maximizing use time of quay crane, in order to obtain the maximum profitability and productivity of handling facilities, because they are the most expensive handling equipment at the port container terminal, and are usually the neck position at the import and export process in the port area (liying Song et al. 2011).

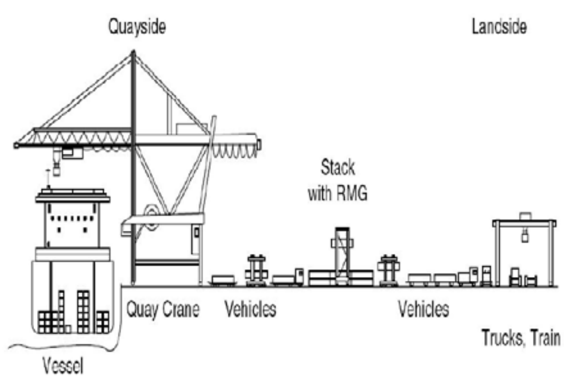


*Figure 6: Schematic Representation Of The Port Container Terminal (Steenken Et Al. 2004).*

The figure above represents a summary of the container port terminal activity, which consists primarily vessels berthing arriving from any destination to another, and requires a number of services, namely, the unloading and loading containers, this operation of loading and unloading are carried out by specialized handling equipment we called Quay Crane, which moves on rail throughout the quay and it characterized by a definite productivity depends on several parameters, such as the crane driver, the availability of containers handled, availability of containers transport vehicle to and from storage areas, etc. ..., that is on the one hand ... On the other hand and inside the port area we find also yard crane, internal tractor, the storage areas, etc. ...

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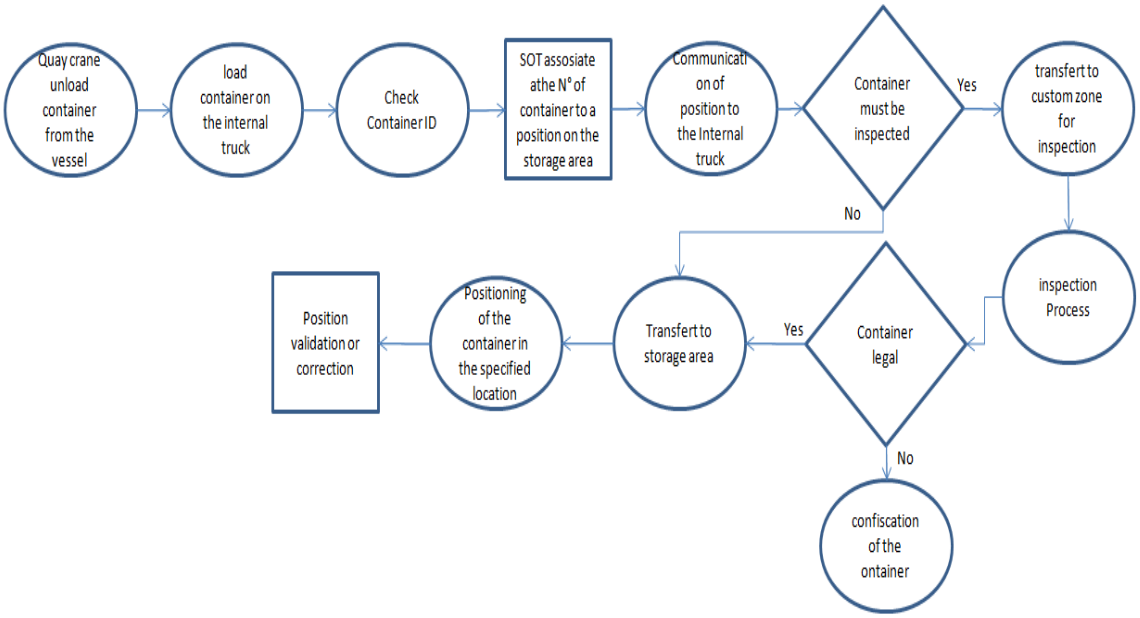


*Figure 7: Unloading Process (J. Dubreuil Et Al. 2008)*

The process involves unloading containers (empty or full) from a vessel that was already berthed and that he was allocated a number of human and material resources.

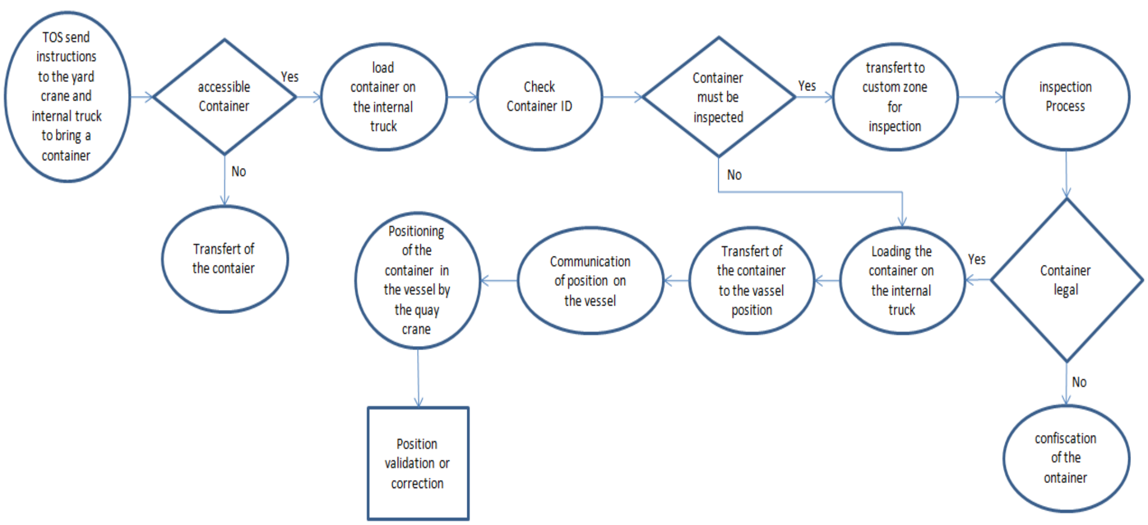


*Figure 8: Loading Process (J.Dubreuil Et Al. 2008)*

## 5. MATHEMATICAL FORMULATION:

Max $\sum (\mathbf{X_{i*}}\ \mathbf{V_i})$ ;

subject to:

$\sum (\varepsilon_i + L_i)_* X_i \leq L_{max}$

With:

$\mathbf{X_i}$: binary variable = 1 if the vessel i might berth, =0 else

$\mathbf{V_i}$: assigned value to the vessel i, according to the developed model (multicriteria model) and the terminal policy

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**$\varepsilon_i$**: Security margin (distance between two vessels)

**$L_i$**: vessel i length

**$L_{max}$**: total length of the quay

**Algorithm:**

Begin
| Arrivé en rade
| Priority measurement (algorithm for priority mesurment)
| Display the new classification
| *If* (Berth empty) *than* Replacement vessel used by the first of the list *else* Awaiting release another location
| Allocation of the berth
| Gain calculation (calculation algorithm)
| *If [* (a vessel leave) *Or* (a vessel arrive)] *than* Update of priority list *else* ( )
| Display of the new priority list
|
End

## Data:

We considered a dataset consisting of ten vessels arriving in random order, each ship is characterized by ETA “Estimated Time of Arrival”, length, draft, number of containers unloaded, number of containers loaded, special needs, etc. ..., we consider a total berth length of 400 meters.

| Vessel | Priority | Arrival time | Total operations time | Vessel lenght |
|---|---|---|---|---|
| 1 | 8 | 1:00:00 | 6:00:00 | 179 |
| 7 | 3 | 4:00:00 | 9:00:00 | 101 |
| 5 | 6 | 5:00:00 | 4:00:00 | 143 |
| 2 | 4 | 6:00:00 | 16:00:00 | 149 |
| 8 | 2 | 7:00:00 | 8:00:00 | 240 |
| 3 | 9 | 9:00:00 | 8:00:00 | 235 |
| 6 | 7 | 10:00:00 | 4:00:00 | 95 |
| 4 | 1 | 12:00:00 | 6:00:00 | 190 |
| 9 | 10 | 13:00:00 | 6:00:00 | 189 |
| 10 | 5 | 14:00:00 | 9:00:00 | 94 |

*Fig. 9: Table Of Arrival Vessel Data*

## 6. Results:

The data in Table Fig. 9. were simulated in three scenarios, each scenario follow an algorithm, the goal is to make a comparison between different algorithm and to show the difference between the outcome of each case, the first algorithm Represent the rule generally applied by port terminals, first come first served that is to serve the first ship arriving independently of any other criterion or consideration, the second algorithm (our proposition) represents the rule of the shorter first, which is to serve vessel requesting the minimum total time of work (time loading and unloading), regardless of the arrival order, his inconvenient is that it is not real and a ship too loaded may be in delay, but it presents the many advantage for small vessels and terminal managers in terms of the increase in availability of the quay, the third algorithm (our proposition) represents the priority rule first, independently of the order of arrival, his inconvenient is a non-priority ship or with a low priority can be in delay, but it present many significant advantages such as the reduction of waiting costs for ships extremely priority, among the advantages of this model is that priority is adjustable according to the standards and policies outlined by the terminal, non-priority vessels can received financial reward or reduction of cost of services offered by the terminal, which will be paid by clients (ship-owners) who receive a high priority.

## Scenario 1:

The table below represents the result of the simulation, the algorithm first come first served:

| Vessel | Arrival time | Berthing time | Operations starting time | Operations finishing time | Sailling time | Total operations time | Service mean time | Waiting mean time |
|---|---|---|---|---|---|---|---|---|
| 1 | 1:00:00 | 1:00:00 | 1:00:00 | 7:00:00 | 7:00:00 | 6:00:00 | 6:00:00 | 0:00:00 |
| 2 | 6:00:00 | 7:00:00 | 7:00:00 | 23:00:00 | 23:00:00 | 16:00:00 | 17:00:00 | 1:00:00 |
| 3 | 9:00:00 | 21:00:00 | 21:00:00 | 29:00:00 | 29:00:00 | 8:00:00 | 20:00:00 | 12:00:00 |
| 4 | 12:00:00 | 29:00:00 | 29:00:00 | 35:00:00 | 35:00:00 | 6:00:00 | 23:00:00 | 17:00:00 |
| 5 | 5:00:00 | 7:00:00 | 7:00:00 | 11:00:00 | 11:00:00 | 4:00:00 | 6:00:00 | 2:00:00 |
| 6 | 10:00:00 | 23:00:00 | 23:00:00 | 27:00:00 | 27:00:00 | 4:00:00 | 17:00:00 | 13:00:00 |
| 7 | 4:00:00 | 4:00:00 | 4:00:00 | 13:00:00 | 13:00:00 | 9:00:00 | 9:00:00 | 0:00:00 |
| 8 | 7:00:00 | 13:00:00 | 13:00:00 | 21:00:00 | 21:00:00 | 8:00:00 | 14:00:00 | 6:00:00 |
| 9 | 13:00:00 | 29:00:00 | 29:00:00 | 35:00:00 | 35:00:00 | 6:00:00 | 22:00:00 | 16:00:00 |
| 10 | 14:00:00 | 35:00:00 | 35:00:00 | 44:00:00 | 44:00:00 | 9:00:00 | 30:00:00 | 21:00:00 |

*Fig. 10: Simulation Result According To The First Algorithm*

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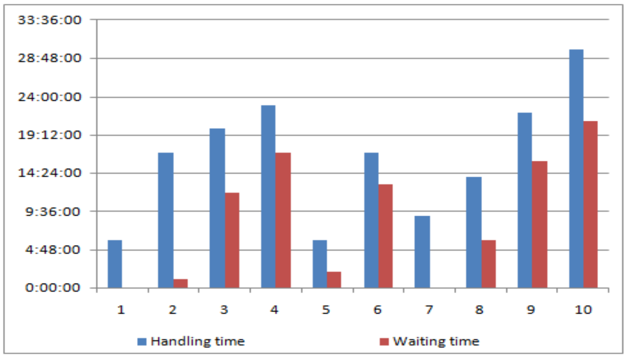


*Fig. 11: Handling And Waiting Time According To The First Algorithm*

## Scenario2:

| Vessel | Arrival time | Berthing time | Operations starting time | Operations finishing time | Sailling time | Total operations time | Service mean time | Waiting mean time |
|---|---|---|---|---|---|---|---|---|
| 1 | 1:00:00 | 1:00:00 | 1:00:00 | 7:00:00 | 7:00:00 | 6:00:00 | 6:00:00 | 0:00:00 |
| 2 | 6:00:00 | 7:00:00 | 7:00:00 | 23:00:00 | 23:00:00 | 16:00:00 | 17:00:00 | 1:00:00 |
| 3 | 9:00:00 | 38:00:00 | 38:00:00 | 46:00:00 | 46:00:00 | 8:00:00 | 37:00:00 | 29:00:00 |
| 4 | 12:00:00 | 23:00:00 | 23:00:00 | 29:00:00 | 29:00:00 | 6:00:00 | 17:00:00 | 11:00:00 |
| 5 | 5:00:00 | 7:00:00 | 7:00:00 | 11:00:00 | 11:00:00 | 4:00:00 | 6:00:00 | 2:00:00 |
| 6 | 10:00:00 | 11:00:00 | 11:00:00 | 15:00:00 | 15:00:00 | 4:00:00 | 5:00:00 | 1:00:00 |
| 7 | 4:00:00 | 4:00:00 | 4:00:00 | 13:00:00 | 13:00:00 | 9:00:00 | 9:00:00 | 0:00:00 |
| 8 | 7:00:00 | 30:00:00 | 30:00:00 | 38:00:00 | 38:00:00 | 8:00:00 | 31:00:00 | 23:00:00 |
| 9 | 13:00:00 | 24:00:00 | 24:00:00 | 30:00:00 | 30:00:00 | 6:00:00 | 17:00:00 | 11:00:00 |
| 10 | 14:00:00 | 14:00:00 | 14:00:00 | 23:00:00 | 23:00:00 | 9:00:00 | 9:00:00 | 0:00:00 |

*Fig. 12: Simulation Result According To The Second Algorithm*

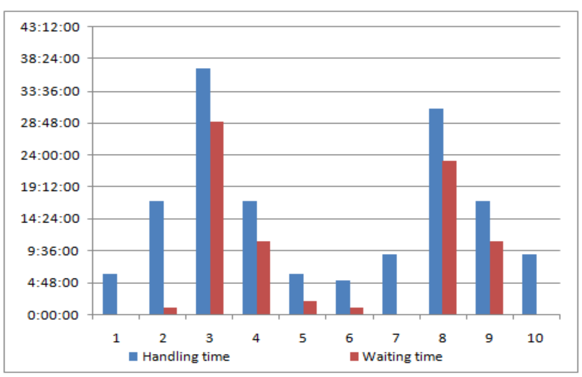


*Figure 13: Handling And Waiting Time According To The Second Algorithm*

## Scenario 3:

| Vessel | Priority level | Arrival time | Berthing time | Operations starting time | Operations finishing time | Sailling time | Total operations time | Service mean time | Waiting mean time |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 8 | 1:00:00 | 1:00:00 | 1:00:00 | 7:00:00 | 7:00:00 | 6:00:00 | 6:00:00 | 0:00:00 |
| 2 | 4 | 6:00:00 | 9:00:00 | 9:00:00 | 25:00:00 | 25:00:00 | 16:00:00 | 19:00:00 | 3:00:00 |
| 3 | 9 | 9:00:00 | 31:00:00 | 31:00:00 | 39:00:00 | 39:00:00 | 8:00:00 | 30:00:00 | 22:00:00 |
| 4 | 1 | 12:00:00 | 14:00:00 | 14:00:00 | 20:00:00 | 20:00:00 | 6:00:00 | 8:00:00 | 2:00:00 |
| 5 | 6 | 5:00:00 | 20:00:00 | 20:00:00 | 24:00:00 | 24:00:00 | 4:00:00 | 19:00:00 | 15:00:00 |
| 6 | 7 | 10:00:00 | 24:00:00 | 24:00:00 | 28:00:00 | 28:00:00 | 4:00:00 | 18:00:00 | 14:00:00 |
| 7 | 3 | 4:00:00 | 4:00:00 | 4:00:00 | 13:00:00 | 13:00:00 | 9:00:00 | 9:00:00 | 0:00:00 |
| 8 | 2 | 7:00:00 | 7:00:00 | 7:00:00 | 15:00:00 | 15:00:00 | 8:00:00 | 8:00:00 | 0:00:00 |
| 9 | 10 | 13:00:00 | 25:00:00 | 25:00:00 | 31:00:00 | 31:00:00 | 6:00:00 | 18:00:00 | 12:00:00 |
| 10 | 5 | 14:00:00 | 20:00:00 | 20:00:00 | 29:00:00 | 29:00:00 | 9:00:00 | 15:00:00 | 6:00:00 |

*Figure 14: Simulation Result According To The Third Algorithm*

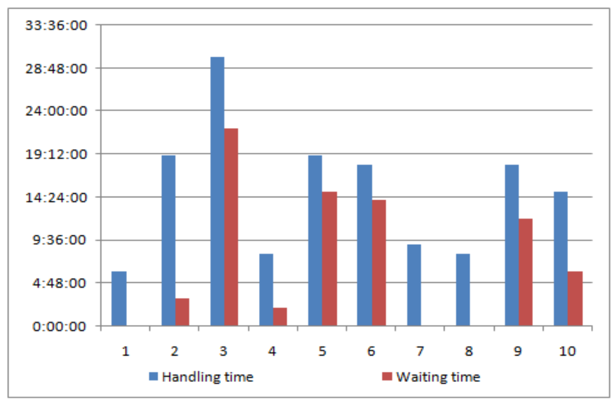


*Figure 15: Handling And Waiting Time According To The Third Algorithm*

## 7. CONCLUSIONS

The results of the three scenarios have shown the interest of the need for serious reflection at the priority berthing management, especially with regard to the ships of the last generation that does not admit of considerable delay.

## REFERENCES

[1]. Akio Imai a,, Etsuko Nishimura a, Stratos Papadimitriou Marine container terminal configurations for efficient handling of mega-containerships Transportation Research Part E 49 (2013) 141–158.

[2]. Akio Imai a,b,*, Etsuko Nishimura a, Masahiro Hattori c, Stratos Papadimitriou Berth allocation at indented berths for mega-containerships European Journal of Operational Research 179 (2007) 579–593.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[3]. Akio Imai a,b,*, Etsuko Nishimura a, Stratos Papadimitriou c Berth allocation with service priority Transportation Research Part B 37 (2003) 437–457.
[4]. Akio Imai a,b,*, Hsieh Chia Chen a, Etsuko Nishimura a, Stratos Papadimitriou The simultaneous berth and quay crane allocation problem Transportation Research Part E 44 (2008) 900–920.
[5]. Akio Imai a,b,*, Xin Sun a, Etsuko Nishimura a, Stratos Papadimitriou Berth allocation in a container port: using a continuous location space approach Transportation Research Part B 39 (2005) 199–221.
[6]. Bin Yua,∗, Zhongzhen Yanga, Xueshan Suna, Baozhen Yaob, Qingcheng Zenga, Erik Jeppesen Parallel genetic algorithm in bus route headway optimization Applied Soft Computing 11 (2011) 5081–5091.
[7]. Birger Raa a,, Wout Dullaert b,c, Rowan Van Schaeren An enriched model for the integrated berth allocation and quay crane assignment problem Expert Systems with Applications 38 (2011) 14136–14147.
[8]. Bradley Skinner a, Shuai Yuan a,, Shoudong Huang a, Dikai Liu a, Binghuang Cai a, Gamini Dissanayake a, Haye Lau b, Andrew Bott b, Daniel Pagac Optimisation for job scheduling at automated container terminals using genetic algorithm Computers & Industrial Engineering (2012) –.
[9]. Canrong Zhang a,b, Li Zheng a,*, Zhihai Zhang a, Leyuan Shi b, Aaron J. Armstrong The allocation of berths and quay cranes by using a sub-gradient optimization technique Computers & Industrial Engineering 58 (2010) 40–50.
[10]. CAO Jinxin 1,2, SHI Qixin 1,**, Der-Horng Lee3 Integrated Quay Crane and Yard Truck Schedule Problem in Container Terminals TSINGHUA SCIENCE AND TECHNOLOGY ISSNll1007-0214ll15/16llpp467-474 Volume 15, Number 4, August 2010.
[11]. CAO Jinxin **, SHI Qixin , Der-Horng Lee A Decision Support Method for Truck Scheduling and Storage Allocation Problem at Container TSINGHUA SCIENCE AND TECHNOLOGY ISSN 1007-0214 34/67 pp211-216 Volume 13, Number S1, October 2008.
[12]. Carlos Arango, Pablo Cortés , Jesos Muouzuri, Luis Onieva Berth allocation planning in Seville inland port by simulation and optimisation Advanced Engineering Informatics 25 (2011) 452–461.
[13]. CharlieWen, SandraDuniEks-ioˇglu, AllenGreenwood, ShuZhang Crane scheduling in a shipbuilding environment Int. J. Production Economics 124 (2010) 40–50.
[14]. Chengji Liang a,*, Youfang Huang a, Yang Yang A quay crane dynamic scheduling problem by hybrid evolutionary algorithm for berth allocation planning Computers & Industrial Engineering 56 (2009) 1021–1028.
[15]. Christian Bierwirth *, Frank Meisel A survey of berth allocation and quay crane scheduling problems in container terminals European Journal of Operational Research 202 (2010) 615–627.
[16]. Chunxia Yang , Xiaojun Wang, Zhenfeng Li An optimization approach for coupling problem of berth allocation and quay crane assignment in container terminal Computers & Industrial Engineering 63 (2012) 243–253.
[17]. Daofang Chang a,b, Zuhua Jiang a, Wei Yan b, Junliang He Developing a dynamic rolling-horizon decision strategy for yard crane scheduling Advanced Engineering Informatics 25 (2011) 485–494.
[18]. Daofang Chang a,b, Zuhua Jiang a, Wei Yan b, Junliang He Integrating berth allocation and quay crane assignments Transportation Research Part E 46 (2010) 975–990.
[19]. Der-Horng Lee *, Jiang Hang Chen, Jin Xin Cao The continuous Berth Allocation Problem: A Greedy Randomized Adaptive Search Solution Transportation Research Part E 46 (2010) 1017–1029.
[20]. Der-Horng Lee , Jian Gang Jin Feeder vessel management at container transshipment terminals Transportation Research Part E 49 (2013) 201–216.
[21]. Der-Horng Lee , Jian Gang Jin, Jiang Hang Chen Terminal and yard allocation problem for a container transshipment hub with multiple terminals Transportation Research Part E 48 (2012) 516–528.
[22]. Der-Horng Lee a,*, Hui Qiu Wang a, Lixin Miao Quay crane scheduling with non-interference constraints in port container terminals Transportation Research Part E 44 (2008) 124–135.
[23]. Dirk C. Mattfeld a, Christian Bierwirth b An efficient genetic algorithm for job shop

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scheduling with tardiness objectives European Journal of Operational Research 155 (2004) 616–630

[24]. Dongsheng Xu a,1, Chung-Lun Li b,2, Joseph Y.-T. Leung Berth allocation with time-dependent physical limitations on vessels European Journal of Operational Research 216 (2012) 47–56

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

[26]. Eduardo Lalla-Ruiz,Bele´n Melia´ n-Batista, J.MarcosMoreno-Vega Artificial intelligence hybrid heuristic based on tabu search for the dynamic berth allocation problem Engineering Applications of Artificial Intelligence 25 (2012) 1132–1141.

[27]. Fan Wang a, Andrew Lim A stochastic beam search for the berth allocation problem Decision Support Systems 42 (2007) 2186–2196

[28]. Francesco Longo Design and integration of the containers inspection activities in the container terminal operations Int. J. Production Economics 125 (2010) 272–283.

[29]. Frank Meisel *, Christian Bierwirth Heuristics for the integration of crane productivity in the berth allocation problem Transportation Research Part E 45 (2009) 196–209.