SIMULATION MODEL FOR BERTH ALLOCATION PLANNING IN SEVILLE INLAND PORT

Carlos Arango[1], Pablo Cortés[1], Jesús Muñuzuri[1], Luis Onieva[1]

[1] Ingeniería de Organización. Engineering School of Seville. University of Seville. Camino de los Descubrimientos s/n 41092. Seville, Spain.
cap@esi.us.es, pca@esi.us.es, munuzuri@esi.us.es, onieva@esi.us.es

ABSTRACT

We study the current allocating berths for containerships in the port of Seville. It is the only inland port in Spain and it is located on the Guadalquivir River. This paper addresses the berth allocation planning problems using simulation with Arena software. We propose a simulation model by the identification of the main bottleneck. Allocation planning aims to minimise the total service time for each ship and considers a first-come-first-served allocation strategy. We conduct a large amount of computational experiments which validate the model.

Keywords: Berth allocation, Simulation, Port operations, Container transportation.

1. INTRODUCTION

Ports are very important to the transport logistic networks, therefore all of its operations must be optimised, according to Ambrosino *et al* (2004). Some of the main operations are: container pre-marshalling problem, landside transport, stowage planning problem, yard allocation problem, etc in Voß S and Stahlbock R (2004) and Steenken D and, Voß S. (2008) which has been one of the most complete reviews and one of the most important papers. In the Figure 1 show a classification of the port operations.

The Port of Seville is the only inland port in Spain. It is located on the Guadalquivir River, in the city of Seville and it can be accessed by rail, air, road and motorway. It has always been one of Spain's main ports due to the high frequency in small ship traffic, including RO-ROs, ferries, feeders, etc. between Seville and the Canary Islands, and other Spanish and European ports.

Seville's inland port currently has a bottleneck because there is only one lock which is for small ships. Therefore, a new lock is being built that will increase the amount of ships which can enter in the coming years. Fig. 1 shows the port's future appearance with the new lock. This lock is highly important for Seville inland port to continue being one of the main intermodal centres in the south of Spain. The new lock improves the port's performance and will double current freight traffic. However, other processes and resources must be managed to maintain its competitiveness.

The simulation presented in this paper considers the freight traffic data from the Port Authority of Seville (PAS). This data is mainly about cargo containers, because in the last 6 years this cargo type has increased greatly. It also represents additional ships arriving in the Seville port due to the new lock. The new potential bottlenecks may occur in the container terminals, because the PAS has only two quay cranes for containerships. We therefore simulated the handling operations as the ships arrived, passing through the lock, unloading/loading containers, and propose a simulation model for berth management.

As an outline for the rest of the paper, we will give the literature review in Section 2. Section 3 looks at the simulation scenario and in Section 4 we describe the freight traffic situation. Section 5 presents the simulation model constructed from such. The results appear in section 6. Lastly, main conclusions and future work are addressed.

2. LITERATURE REVIEW

Several authors have approached the BAP concept. For example, Imai A. *et al* (2001), and Nishimura E. *et al* (2001) determine the berth allocation problem (BAP) as a dynamic berth allocation problem (DBAP) which is a generalisation of the static berth allocation problem (SBAP). They propose a genetic algorithm in public berth systems which can be adapted to real world application: Park and Kim (2003), Liu *et al* (2005) and Lim A. (1997) consider BAP and quay crane scheduling problem (QCSP) as a single problem and that berth scheduling depends on the crane number that is assigned to the ship. Imai A. *et al* (2005; 2007) approaches BAP in a multi-user container terminal (MUT). In the first work they use a continuous location space approach and in the second work they solved the BAP by Genetic algorithms at a port with indented berths, where mega-containerships and feeder ships are to be served for higher berth productivity. Imai A. *et al* (2003) consider the relations between the ports and shipping lines, and when some vessel operators desire high priority services, the authors have indicated BAP as BAP with service priority.

Due to the cost and complexity involved in port and vessel operations, the simulation models have been used intensively to understand the containers terminals and test different strategies in the port operations. e.g. see (Bruzzone 1998; Chung et al. 1998; Hayuth et al. 1994). These simulators differ widely in objectives, complexy, and details. Cortés P. *et al* (2007) simulated the freight transport process in Seville's inland port, considering all existing types of cargo and testing several scenarios. They analyse the performance of the several Seville port terminals and processes. Ballis and Abacounkim (1996) developed a simulation model to evaluate different configurations, such as changes in the yard layout and equipment. (Ramani 1996; Yun and Choi 1999) developed a simulation model to analyze container port operations, evaluate the port performance and obtain estimates for terminal performance indicators. Laganá D. *et al* (2006) and Legato P. *et al* (2009) developed optimisation and simulation models by scheduling yard crane use in the Gioia Tauro port. The authors follow ranking and selection (R&S) techniques to approach the scheduling yard crane (Rubber tired gantry cranes - RTG). Others works as

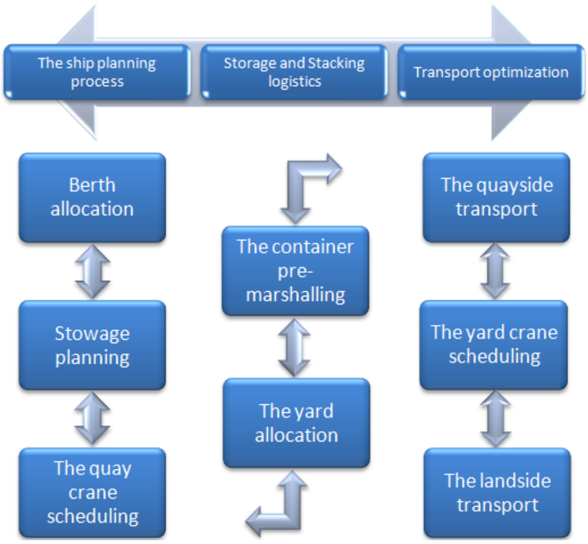

Figure 1: Operations of a container terminal

3. SIMULATION SCENARIO

PAS is a multi-purpose terminal: different types of cargo are moved through this port such as cereals, scrap metal and cement containers. The port has various specialised terminals for handling these types of cargo such as container terminals UTE Batan 1 and UTE Batan 2, TLP Esclusa cereals terminal, Holcim cement terminal, GPMA iron terminal, TLD Grupo Gallardo scrap and metal terminal and more. Our simulation scenario will only consider container terminals and the facilities needed for them to operate, the access channel and the lock. Fig 2 shows the simulation scenario model.

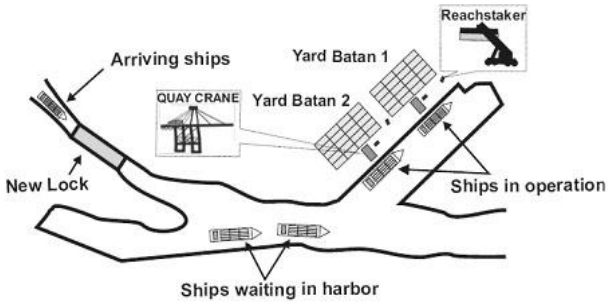

Figure 2: Simulation scenario

The container terminals Batan 1 and Batan 2 are for two different logistic operators although located in the same dock (*Centenario*). Therefore, all resources such as quay cranes, Reachsteakers and facilities are used in pairs for container handling. We therefore consider these two terminals to be one with two berths and two yards (yard Batan 1 and yard Batan 2). Table No. 1 shows the resources used in handling operations. All resources, such as the quay crane and reachsteaker must be scheduled by one terminal with two yards.

The model simulation considers information about the ship–containers' traffic through Seville port during February 2009. This simulation included data about arrival date, departure date; unload containers' number and the load containers' number by the study date.

Table 2 shows an abstract about this information, in which we can observe that 32 ships came to the port in February. The arrival frequency and the ship's country destination can also be seen. The 32 containerships transport 9954 TEUS (Twenty-foot Equivalent Unit) of which 57% is loaded in the port.

The data used in the simulation is based on the daily reports from the Port of Seville's web during February 2009. The data shows that in an ordinary month 32 containerships arrived at the Port. The Seville port is a small port, because of this it moves small amounts of containers compared with hub ports.

Table 1: Containers terminal resource

Towboat	Reachstackers	RoRo Ramp	Size Yard	Capacity yard/TEUS	Quay cranes
2	17	2	97,310m^2	150,000	2

Table 2: Ship lines

Country	Frequency	Ships month	Containers Min	Max	Average
Spain	2/Week	8	64	429	243
Morocco	1/Week	4	100	157	114
Spain	1/Week	4	54	86	75
Germany	1/Week	4	30	43	41
Spain	1/Week	4	64	86	75
UK	1/Week	4	43	430	214
Netherlands	1/Week	4	86	114	98

4. METHODOLOGY

A lot of ships arrives to the Seville inland port for load and unload containers each *t_arrive_S* hours, these ships within to the Port and wait by a free berth. When the berth is assigned to the first ship in the queue a towboat pick them up and carry them to the berth. The operations time in the berth by every ship depends of 1) Quantity of containers to load and unload; 2) the localization of these containers at the yard; 3) the reachstacker available for the operations in this moment.

The same way a lot of trucks arrives to the port each t_arrive_T minutes. The first process every truck is checking, theses trucks can load or unload container (only one operation), the operations time depend of the localization of the container at the yard.

5. SIMULATION MODEL

We are not optimising all operations in the Port of Seville, but the simulation model is formed by five module groups that represent some operations, such as 1.Truck arrivals. 2. Containership arrivals. 3. Berth assignment systems. 4. Towing vessels and 5. Berths.

5.1. Truck arrivals

We include these modules in the simulation model because truck handling operations use the reachstacker at the same time as ship handling operations. Fig 3 shows the truck modules. The truck handling operation time depends on where the containers are located in the yard: it is modelled with a module named *decide*.

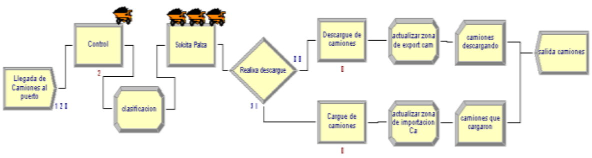

Figure 3: Truck arrival modules

5.2. Containership arrival

More than 45% of the time intervals between the arrival of one containership and another are from 0 to 15 hours. The shipping lines used for obtaining that data are shown in Fig 4 and it is modelled by the module *create*. Fig 5 shows the containers arrival modules.

The ship characteristics are assigned by a module *assign* when it arrives at the port, such as unload containers, load containers, containers located to load, etc. The ships wait in the channel access (module *Queue*) while they are waiting to be assigned a dock.

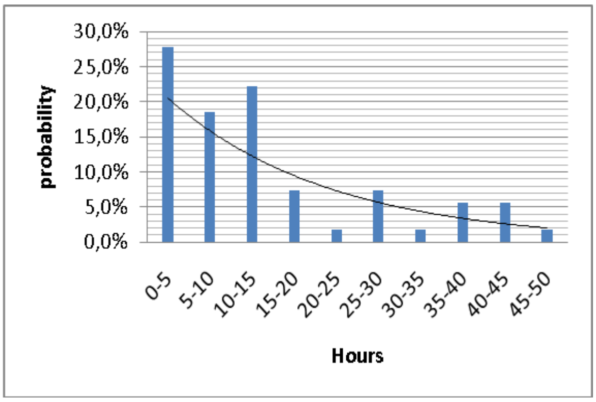

Figure 4: Intervals time between arrivals of ships

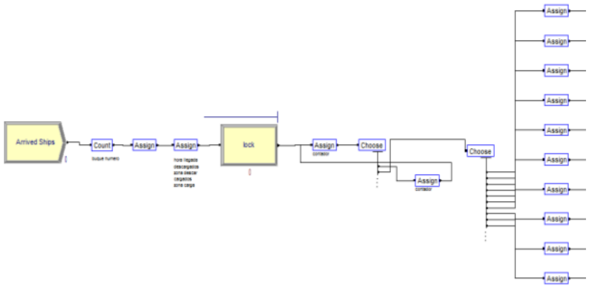

Figure 5: Containership arrival modules

5.3. Berth management system

A module *seize* and three modules *choose* were used in the study to simulate the current berth management system used in the port of Seville (Fig 6). The system used the First-come-first-served allocation strategy (FCFS) Lai K. y Shih K. (1992). Hence when a ship arrives at the port it has to wait in the queue until a berth becomes free. If there are not any other ships waiting to be serviced and the two berths are free then it is assigned the berth that is near to yard where less containers will be handled. Fig 6 shows the berths assignment modules.

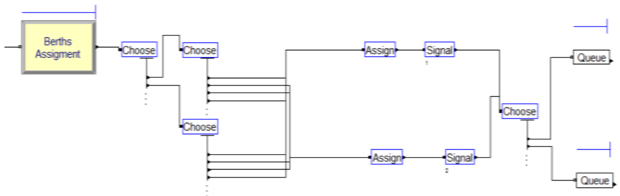

Figure 6: Berths assignment modules

5.4. Tow vessels

Two towboats are created when the simulation is started, one for each berth and it is sent to the first modules' group (Fig 8). In this group the tows are waiting for the ships, and then a signal is sent to the towboats for them to collect the ships that have been assigned to berth to pick them up and carry them to the berth. Fig 7 shows the creation the towboat.

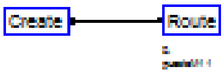

Figure 7: Creating towboat

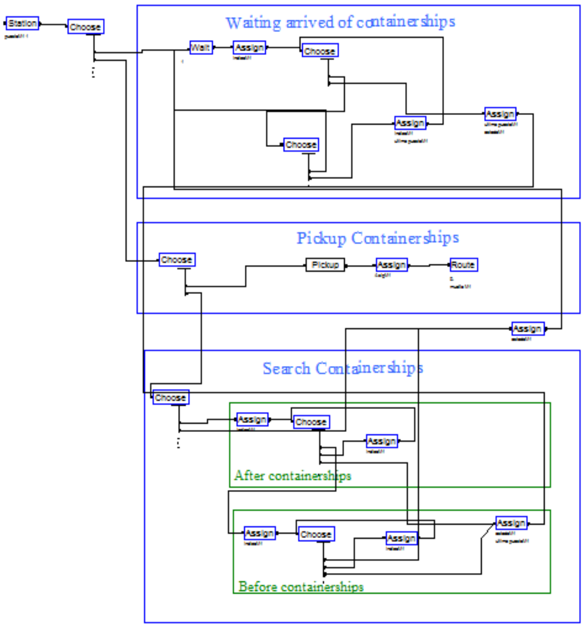

Figure 8: Tow vessels modules

5.5. Berths

The berth modules represent the handling operation time for each ship. This time depends on its characteristics and the amount of containers that need to undergo handling, containers' location and the resources available at that time. There are two berth modules which are exactly equal, one for each berth (Fig. 9). The container loading operations can only begin if the unloading operations have finished. The towboat is called again to carry the ships to the lock.

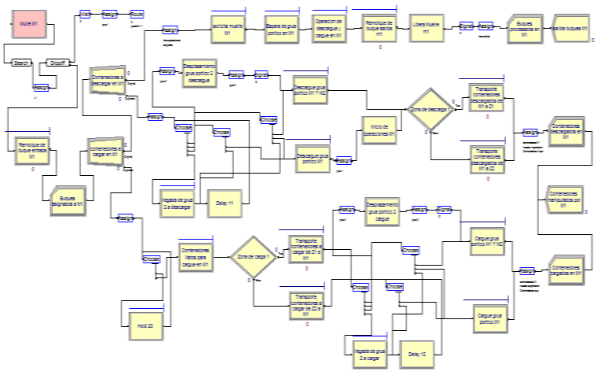

Figure 9: Berths modules

6. SIMULATION RESULTS

We have produced seven model replications presented across the previous sections, to verify and validate the simulation model proposal. Table 3 summarises the freight traffic by replication. An average of 32 containerships arrived at the port in a month in the simulation model. These ships were assigned to the berths 1 and 2 in similar quantity, this is because the container localization probability is the same by yard Batan 1 and yard Batan 2.

Table 3: Containership and container by simulation

Counters	Replications Number							Averg	Standar desviat.
	1	2	3	4	5	6	7		
Ships arrived	27	28	33	34	34	39	34	32,71	4,07
ships serve at Berh 1	17	12	16	15	13	18	17	15,43	2,23
ships serve at Berh 2	10	16	17	19	21	21	17	17,29	3,77
Containers unload	3497	3017	4437	3501	4021	4754	4217	3920,44	609,88
Cont. unload at Berh 1	2074	1068	1773	1322	1659	1657	2373	1703,76	436,71
Cont. unload at Berh 2	1423	1949	2664	2178	2362	3097	1843	2216,68	553,58
containers load	4317	4176	5225	4418	5557	5196	4251	4734,14	570,12
Containers load at Berh 1	2705	2031	2569	1690	2486	2213	1654	2192,59	420,40
Containers load at Berh 2	1612	2145	2655	2729	3071	2982	2597	2541,56	507,69

Table 4 show the handling time for each berth and for each model replication, we can observe that the results obtained the average handling time is 3.03 hours at the berth 1 and 3.04 hours at the berth 2 this is because the quay cranes are the same type (PANAMAX) with capacity of 30 containers/hour also the minimum and maximum handling time takes similar values in both berths because the probability that a ship has few containers to unload/load will arrive and that is located in the same yard is the same for both

Table 4: Service time

Replications Number	Handling time for each berths					
	handling time berth Batan 1			handling time berth Batan 2		
	Average	Min	Max	Average	Min	Max
No. 1	8,31	3,28	20,67	8,24	2,14	22,44
No. 2	6,53	3,26	14,63	7,13	3,34	23,42
No. 3	9,20	3,30	22,24	9,88	3,31	22,38
No. 4	6,76	3,30	21,93	8,10	3,31	22,37
No. 5	8,72	3,25	22,95	7,86	2,63	20,10
No. 6	8,76	2,14	30,06	9,67	3,33	22,47
No. 7	9,74	2,67	24,20	10,86	3,25	33,11
Average	8,29	3,03	22,38	8,82	3,04	23,75

Table 5 show the waiting time for each model replication, this time belong to the waiting time for each ships at the access channel (time queue) for a free berth, is very important minimise the waiting time in the container terminals because the ship lines need to go a other port as soon as possible. The average waiting time in the Seville inland port is 1,55 hours.

Table 5: Waiting time

Replications Number	Waiting time		
	Average	**Minimum**	**Maximum**
No. 1	1,28	0,00	12,06
No. 2	0,38	0,00	5,60
No. 3	1,99	0,00	27,36
No. 4	3,74	0,00	24,62
No. 5	0,33	0,00	5,69
No. 6	1,24	0,00	17,60
No. 7	1,89	0,00	20,39
Average	1,55	0,00	16,19

The information in figure 10 shows the service time in intervals of 5 hours. The simulation model shows that more than 50% of the ships with service time is between 5 and 10 hours.

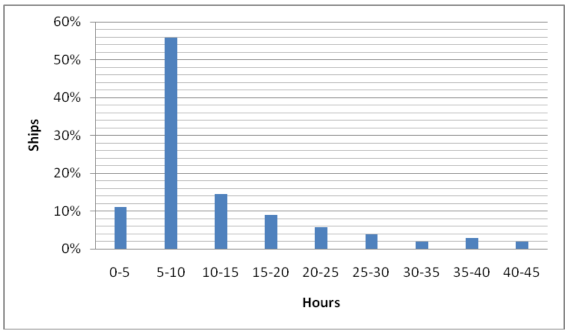

Figure 10: Ships by service time

7. CONCLUSIONS AND FUTURE WORKS

We have focused efficient planning and use of the berths to increase the port of Seville's competitiveness. By improving internal organisation and operations' management, a simulation model by supporting berth allocation has been proposed and examined.

We can conclude that the port facilities are able to serve the new freight traffic but for this to be achieved current berths systems must be improved. So is needing a system for reduced the average waiting time. The main reasons for this is because of better assignment management, improve the ships unload/load the containers in the berths closest to the yard where it is located a BAP-FCFS system would obtain a much better result.

REFERENCES

Ambrosino D, Sciomachen A, Tanfani E., 2004. Stowing a containership: the master bay plan problem. *Transport Research A*, 38, 81–99.

Steenken D, Voß S., 2008. Operations research at container terminals: a literature update. *OR Spectrum*, 30, 1–52.

Steenken D, Voß S, Stahlbock R., 2004. Container terminal operations and operations research - a classification and literature review. *OR Spectrum*, 26, 3–49.

Imai A. et al., 2001. The dynamic berth allocation problem for a container port. *Transport Research Part B* 35, 401-417.

Nishimura E. et al., 2001. Berth allocation planning in the public berth systems by genetic algorithms. *European Journal of operations research* 131, 282-292

Park Y-M. and Kim k., 2003. A Scheduling method for Berth and quays cranes. *OR Spectrum* 25, 1-23.

Liu J., Wan Y-M., Wang l., 2005. Quay Crane Scheduling at Container terminals To minimize The maximum Relative Tardiness of vessel Departures. *Naval Research Logistics* 53, 60-74.

Lim A., 1997. The berth planning problem. *Operations Research letters* 22, 105 – 110.

Imai A. et al., 2005. Berth allocation in a container port: using a continuous location space approach. *Transportation Research Part B* 39, 199 - 221

Imai A. et al., 2007. Berth allocation at indented berths for mega-containerships. *European Journal research of Operations Research* 179, 579-593

Imai A., Nishimura E., Papadimitriou S., 2003. Berth allocation with service priority. *Transportation Research Part B* 37, 437-457.

Brozzone, A.G., 1998, Harbour and maritime simulation. *Simulation* 71 (2), 72-73.

Chung, Y.G., Randhawa, S.U., McDowell, E.D., 1998. A simulation for a transtainer-based container handling facility. *Computers and Industrial Engineering* 15 (2), 113 -125.

Hayuth, Y., Pollatschek, M.A., Roll, Y., 1994. Building a port simulator. *Simulation* 63 (3), 179-189.

Cortés P. et al., 2007. Simulation of freight traffic in the Seville inland port. *Simulation Modelling Practice and Theory* 15, 256-271.

Ballis, A., Abacoumkin, C., 1996. A container terminal simulation model with animations capabilities. *Journal of Advanced Transportation* 30 (1), 37-57.

Ramani, K.V., 1996. An interactive simulation model for the logistics planning of container operations in sea ports. *Simulation* 66 (5), 291-300.

Yun, W.Y., Choi, Y.S., 1999. A simulation model for container terminal operation analysis using an object-oriented approach. *International Journal of Production Economics* 59, 221-230.

Laganá, D., et al., 2006. Solving simulation optimization problems on grid computing systems. *Parallel Computing* 32, 688 – 700.

Legato, P., Canonaco, P., and Mazza, R., 2009. Yard management by simulation and optimization. *Maritime Economics and Logistic* 11, 36 – 57.

Lai, K., and Shih, K., 1992. A study of container berth allocation. *Journal of advanced transportation* 26, 45-60.

http://www.apsevilla.com [accessed 15 May 2009]