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The Influence of Yard Trucks on Berth Operations in Smaller Container Terminals

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ABSTRACT

Nowadays smaller container terminals are facing an increase in traffic and ship sizes and are consequently subject to extreme pressure form ship-owners that require rapid and efficient transhipment operations in the port, the achievement of which is only possible with the assignment of the proper type and number of quay cranes to each ship and with a good level of synergy between the cranes and the transfer mechanisation. The latter has a significant impact on the cranes working and waiting times and affects the entirety of berth operations. Existing terminals that cannot afford to invest in new modern horizontal transport technologies are most commonly using yard trucks that provide less efficient port transfer operations. That is why in the paper a simulation approach has been used in order to determine how a different number of yard trucks assigned to a single quay crane can affect the productivity of that crane and the productivity of the whole berth subsystem.

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1 Introduction

Container transport has increased drastically on the global scale over the last ten years. The total weight of cargo transported by container vessels surpassed 1.7 billion tons in 2017. At the same time all container ports handled 752 mil. TEU, of which approximately 588 mil. TEU were transshipped by the hundred largest world ports, leaving 164 mil. TEU to be shifted through smaller ports [8]. As consequence smaller ports are gaining more importance in the maritime business. Nevertheless, they are under huge pressure, as ship-owners are continuously enlarging ship size. This comes as a consequence of the cascading effect that has affected all shipping routes [5]. The decisions taken by the carriers are directly affecting the productivity of the terminal system and its efficiency. They can change the vessel size in a service or even chose to leave the port with just a few weeks' notice [1]. Smaller ports are therefore forced to provide better terminal capacities and good operational productivity if they want to preserve the existing services or provide new ones. Their existing efficiency is often not sufficient for accepting such ships, yet at the same time ship-owners demand facilitation of rapid transshipment and reduced costs in the ports. Although the efficiency of a terminal depends on the well-organized coordination between all subsystems, the time that a ship will spend in the port depends mostly on the productivity level and efficiency of the berth subsystem. However, the proper functioning of the berth depends in large part on the chosen number and type of horizontal transport for transfer of container units from quay to yard and vice versa. This affects the quay productivity as it can determinate if the quay crane (QC) will be able to effectuate the unloading/loading or not. Consequently, it has an impact on the whole berth productivity level. Furthermore, they are affecting yard operations and its occupancy ratio.

In smaller ports the most common type of transfer mechanization are yard trucks (YTs). Yard trucks are manned vehicles that pull chassis carrying containers. They are unable to lift containers, thus require a crane for loading and unloading. This means that an accurate synchronization between QC and YT is necessary in order to avoid crane waiting times [4]. Smaller ports often lack equipment, which makes it even more difficult to properly coordinate the operations.

The purpose of our paper is to determine how a different number of YTs can modify the berth productivity level of a small container terminal. Special focus has been trained on the QC performance. For this reason, a hypothetical container terminal has been created in FlexSim CT 3.3 software. The main characteristics of the model have been taken from the northern Adriatic (NA) ports of Koper, Trieste and Rijeka. However, the largest share of data was obtained from the port of Koper. In this way realistic simulations were possible. The handling operations in the model were based on QC-YT-YC connection.

2 Problem description

The layout of a seaport container terminal consists of three subsystems (berth, yard and gate) each one serving a specific functional purpose (Fig. 1). The processes and operations of the three terminal subsystems have been detailed by Vis and De Koster [9], Murty,Liu,Wan and Linn [6] and others.

The berth subsystem represents the most important part of the container terminal, since the number and size of ships that will arrive at the terminal depend on the capacity of the factors within this subsystem [3, 7]. Along with the infrastructure, the productivity level at the subsystem is of crucial importance. According to Zeng and Yang [10] the most important measurements to take into account are ship productivity, quay productivity and quay crane productivity. Those can have a significant impact on the turnaround time of the ship in a container terminal. The turnaround time includes berthing, unloading, loading and departure processes [10]. The efficiency of processes on the berth subsystem depends in large part on the number and type of utilized horizontal mechanization and the strategy of their coordination between the berth and storage areas. In a container terminal, the most important problem is the coordination between the loading and unloading operations of the vessels and the storage of the containers in the yard [1]. In order to shorten the ship's time in the port, it is first necessary to allocate the correct number of QCs to a ship. This depends on the type of ship and its length, the predicted moves in the port and also on the port shifts. In most smaller ports the main problem is the allocation of an insufficient number of QCs to a ship, extending the ship turnaround time in the port. Nevertheless, when the right number of QCs has been allocated, they do not necessarily achieve the maximum possible or even the average recommended efficiency if there is poor complementarity with the transfer mechanization.

Most of the smaller ports use YTs for transfer operations. The main reason is that they are very flexible and low-priced even if a little bit less effective [4]. In practice, YTs can be assigned to a group of QCs, but in most cases they are assigned to a specific QC. This means that QC has to be assigned an appropriate number of YTs, in order to maintain its productivity. As YTs are not self-lifting vehicles the main problem is that they do not allow “buffering”; therefore the QC must wait for the YT to pick up or drop off a container [2]. This leads to a lot of empty runs, as most QCs in smaller ports perform single-cycle movements [11]. This necessitates adept synchronization among the elements of port equipment. If the QC does not have the appropriate number of YTs allocated, its working and waiting time can be affected. This has an impact on the productivity of an individual QC, but also on the duration of all shore operations and thus on the berth occupancy, the crucial indicator in obtaining new services and eventually reducing terminal costs.

The main research question is therefore whether it is possible to improve the operation of the berth by increasing the number of YTs allocated to an individual QC. To answer that question, we have built a simulation model and performed several simulations that gave us interesting results. The model formulation and the obtained results are presented in the following sections.

3 Model formulation

The terminal model consists of one continuous quay that has been divided into two berths, one of 250 meters

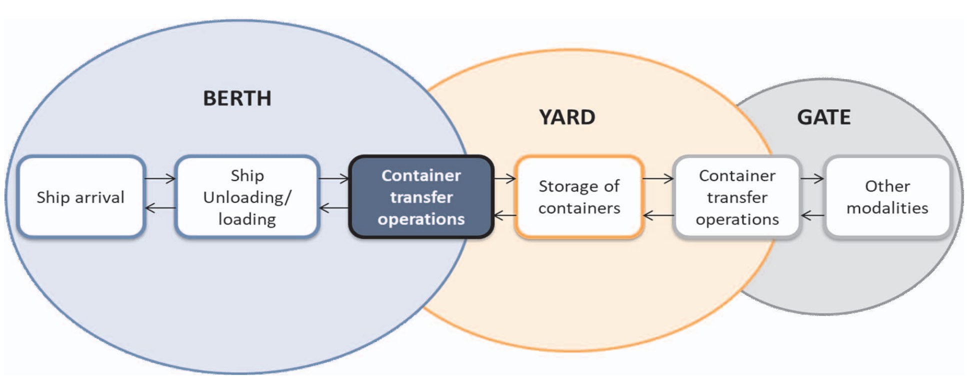

Figure 1 Container terminal subsystems

Source: Adapted from source [7]

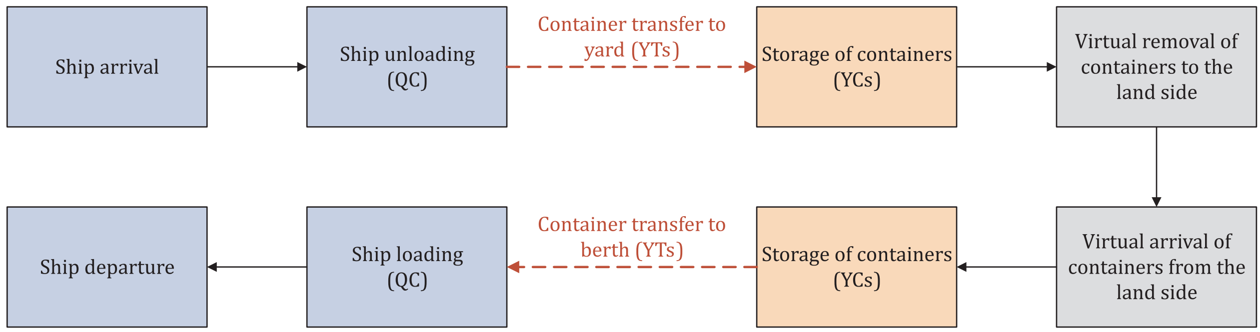

Figure 2 Simulation sequence of the model

Source: Authors

and one of 350 meters. The first berth is equipped with four Panamax (P) QCs and is intended for Panamax and Feeder ships, while the second berth is intended for Post-Panamax ships and has placed four Post-Panamax (PP) QCs. All QCs perform single cycling operations. The horizontal transport operations between sea and yard side of the terminal and vice versa are done by YTs.

The storage area is placed parallel to the quay and is divided into sections for import, export and empty containers. Operations with full containers are done by RTG, while empty containers are handled with reach stackers. "Resifting" is not performed in the simulations.

3.1 Simulations

The created model has been entered with all the data regarding the containers that have arrived at the terminal with the ships (import) and the data about the containers that had to be loaded on the ship and leave the port (export). As our aim was to examine the ships' side operations along with the yard content the berth has been chosen as the "data driver", while the yard has been acting as a central hub since every container must visit the yard before moving to its destination. The gate operations have been abstracted by the software according to the input data. The simulations therefore covered two terminal subsystems with all berth-yard-berth operations.

In this way, the simulations involved the arrival of ships and their discharge, the removal of containers onto the storage area and their positioning to the final slot, as also the operations in reverse order (Fig. 2).

The ship arrival schedule consisted of thirteen services that included Feeder, Panamax and Post Panamax ships. The latest were the most important as they transported more than 60% of the containers. Upon arrival each ship has been assigned with an appropriate number and type of QCs. The schedule is shown in Table 1.

Table 1 Deployment of QCs on specific ship type

Type of ship	Number and type of QC
Feeder ships	1-2 P
Panamax ships	2-3 P
Post Panamax ships	3-4 PP

Source: Authors

The performed simulations had three scenarios each with different number of YTs for every QC. In the 1st scenario five[1] YTs were serving every QC, in the 2nd scenario ten[2] YTs were serving every QC and in the 3rd scenario sixteen[3] YTs were allocated for every QC.

With the created model we were able to simulate the impact of the different number of YTs to the berth performance. The analyzing parameters were:

- QC working time
- QC waiting time
- QC productivity
- Berth occupancy ratio

The main goal of this research was to determine how a different number of YTs can affect the QC efficiency and change the whole berth productivity. In the second phase the goal was to establish the number of YTs that will enable QCs to achieve results that would be acceptable by ship operators in smaller ports. That is at least 25 moves per hour for PP QC and 20 moves per hour for P QC. Such simulations are of high practical relevance for terminals that want to know how big their horizontal fleet has to be in order to assure good berth productivity and in so allow the ship to leave the port quickly.

1 Five YTs per QC are most often used in smaller container ports.

2 Ten YTs gave us relevant differences in comparison with five YTs per QC.

3 Sixteen YTs per QC allowed us to approach the productivity that is acceptable for ship-owners.

4 Data

Simulations in all three scenarios were conducted for a period of one week or until the completion of the transhipment operations on the last scheduled ship. The annual throughput of the terminal amounted to 630,000 TEU per year. Due to the use of probability distribution different simulation runs of the same scenario did not give us identical results, which is why several simulation runs were performed for each scenario. The reported results are the average of the simulation runs of the scenario. The obtained results are shown in the Fig. from 3 to 6.

At the first berth (250 m), ships of up to 2,300 TEUs and a length of up to 220 meters have arrived, while the second berth (350 m) was dedicated to larger Post Panamax ships with a length of approximately 300 meters. The terminal has been busy every day with a different number of ships.

1st scenario

During the analyzed week, P QCs handled 3,306 TEUs, accounting for 27.25% of all transshipped TEUs, while PP QCs accounted for the remaining three quarters. The average occupancy of the QCs during the simulated week was 43.47%, while the average working time of PP QCs reached 62.88%. As the efficiency of QC depends also on the availability of the YT to pick up or drop off a container, QC waiting times are of crucial importance for the implementations of the assigned manipulations. The average waiting time for all eight QCs was 11.44%, which is not much, but if we focus only on the PP QCs, the waiting time percentage rises to 19.56%, which already prolongs the ship's time in the port. On the other hand, P QCs accounted for only 3.32% of waiting time, meaning that five YTs are sufficient for them. The average productivity of all eight QC was slightly less than 20 moves per hour, which is acceptable for the smaller QCs and in line with the actual achievements in nearby ports, while such low productivity is unacceptable for PP QCs. This affected the berth occupancy, which amounted to 62.70%. As the maximum limit to still achieve optimal results on the berth is set at 65%, it is still within the acceptable range. Nevertheless, at the second berth, where large ships are mooring, the actual occupancy (74.06%) exceeded the allowed limit.

2nd scenario

In the 2nd scenario ten YTs were assigned to each QC. During the simulation, the software used only three of the four available P QC to serve Panamax and feeder ships at the first berth. This means that the increase of YTs on a single QC accelerated the movements and increased the efficiency of P QCs. Consequently, fewer QC were needed for the same number of containers (as in the 1st scenario).

The QC thus worked on average 43.43% of the simulation time, which is comparable to the results in the 1st scenario. The three smaller QC were occupied for 27.99%

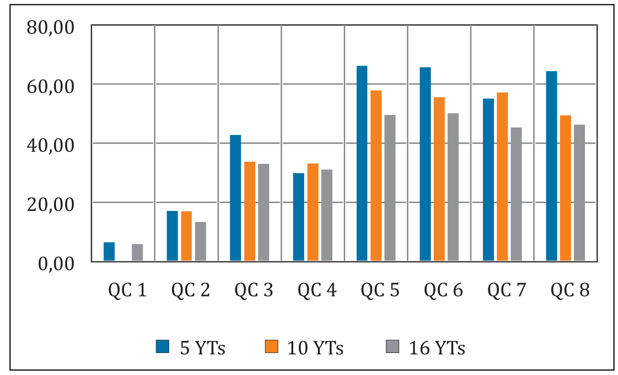

Figure 3 QC working time (%)

Source: Authors

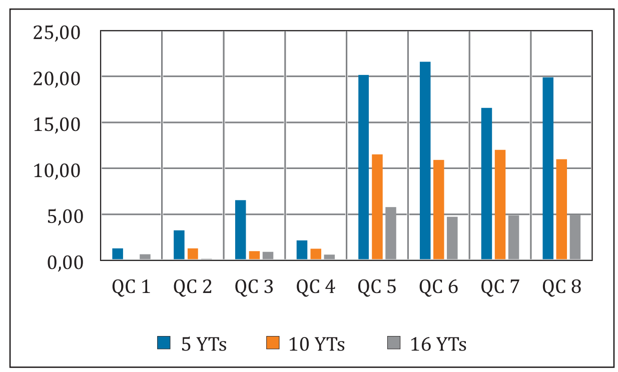

Figure 4 QC waiting time (%)

Source: Authors

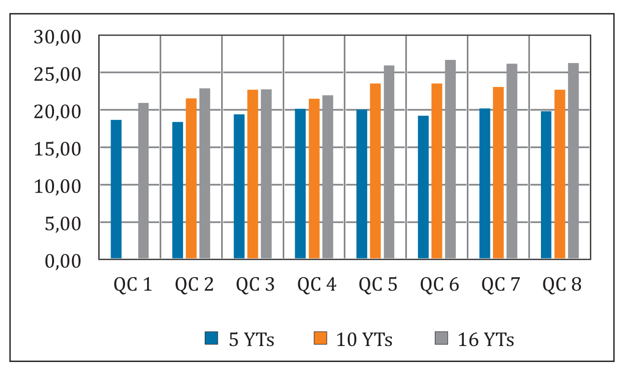

Figure 5 QC productivity (moves/hour)

Source: Authors

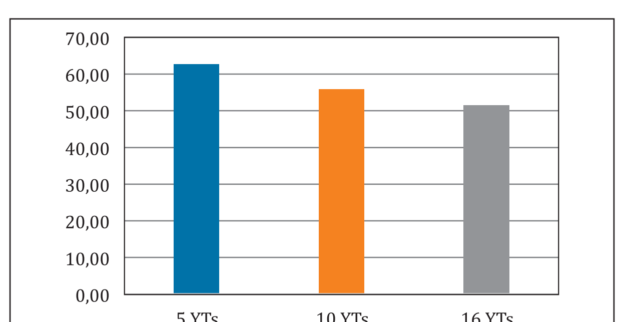

Figure 6 Berth occupancy ratio (%)

Source: Authors

of the time, while the large one worked for 55.01% of the time, which is 12.5% less than in the previous simulation. Nevertheless, this was to be expected since PP QCs accounted for 73.45% of all movements. The QC waiting time was still a lot higher in PP QCs (11.36%). Small QCs had almost no waiting times (1.20%). All those facts improved the average QC productivity, which raised to 23 moves per hour. Again this was enough for the P QCs, while still insufficient for PP QCs. Nevertheless, the berth occupancy ratio decreased in comparison to the 1st scenario to 55,86%, making possible the acquisition of new services and an increase in the annual throughput.

3rd scenario

The new increase of transfer mechanization per single QC decreased even more the working and waiting times of QCs, which positively affected the berth productivity.

This time all eight QC were used again. P QCs have accounted for 27.05% of the total throughput. The average working time of all QC decreased to only 34.32%, which is attributable mainly to the low occupancy of P QCs. The first and second QC were occupied only for 5.85% and 13.32% of the time, while the other two worked slightly more; nevertheless, this percentage did not exceed one third of the working time of the simulation (33.07% and 31.09%, respectively). This was achieved exclusively by increasing the number of YTs to every QC. In that way small QCs always had a free YT and did not have to wait for one.

As can be seen from Fig. 4, the waiting time of P QCs did not exceed one percent in the 3rd simulation. Furthermore, the total percentage of PP QCs working time decreased to 47.81%, while their waiting time slightly surpassed 5%. This led to an improvement in the productivity of QCs. Small QC reached 22 moves per hour, while the large one reached 26 moves per hour, exceeding the achievements of nearby ports. The berth occupancy ratio plunged to 51.43%.

5 Results

The simulations showed that the terminal achieved the best results on the quay in the 3rd scenario when sixteen YTs were serving QC, while the worst results were achieved in the 1st scenario with five YTs on a single QC.

Nevertheless, the situation in the yard area was the opposite. In all three scenarios, the productivity of YCs remained very similar (app. 20 move/hour), as was also the utilization of the blocks (app. 60%), while great differences were observed in the average waiting time for YTs. In the 3rd scenario the average waiting time on the export blocks increased by 113.84%, on the import blocks by 71.64%, and on the blocks for empty containers by 163.18% compared to the 1st scenario. This means that the yard is working best with fewer YTs on a single QC and that the two subsystems are in contrast and require different conditions to achieve optimal operations.

6 Conclusion

The article presents the results of a study performed on a hypothetical container terminal of smaller dimensions. The main purpose was to determine how a different number of YTs can affect the productivity of a single QC and consequently the productivity of the whole quay. The study was performed using three scenarios, each with a different number of YTs assigned to a single QC; that is, five, ten and sixteen.

As nowadays ship-owners demand ever-faster port operations that allow a quick departure of the ship from the port, the operators must in the first phase opt for those conditions that allow better productivity on the berth even with the risk of poorer operational results in the yard area. Nevertheless, it is important to find a point that will allow a balance between the two subsystems. So, despite the fact that in our simulations we achieved the best results by placing sixteen YTs on a QC, in practice it is not to be expected that such a small port would invest so much, as the costs would be too high and the coordination of such a number of YT would be too difficult. Furthermore, it would negatively affect the operations in the yard area. Therefore, the most suitable choice would be to allocate ten YTs per QC. This would enable the achievement of good results within both subsystems and still allow the acquirement of new services.

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