ANALYSIS OF VARIOUS DISPATCHING STRATEGIES AT SHORT SEA CONTAINER TERMINALS

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ABSTRACT

Being advanced technologies, automated guided vehicles (AGVs) and automated lifting vehicles (ALVs) have been lately used in container terminals to improve efficiency as they are practical on the repetitive nature of the terminal operations. Due to their low berth deepness, container terminals in Turkey are built as artificially filled near the coasts. The most common layouts in these terminals are Π*, L*, or Ψ berth typed. In this paper, in order to analyze the effect of transporter number, transporter request rules and intersection rules on the performance of the short sea container terminals, an object-oriented simulation model is developed for berth type Π*, L* and Ψ. Actually, the effects of AGV dispatching rules on the determined performance criterion of total container handling in quay cranes is the issue we focus on. According to the results of the simulation, it can be said that terminal layouts have significant effects on the performance of the terminals and the number of the AGVs used.

Keywords: Short sea container terminals, AGV dispatching rules, object-oriented simulation

1 INTRODUCTION

Since the middle of the 20th century, more and more cargo such as furniture, toys, footwear, clothing, auto parts, electronics components, and computers is being containerized and export and import is increasing on a global scale. In today's just-in-time global supply chain, improving the efficiency of container shipping processes is more important than ever.

In seaports, container terminals are the places where container vessels are loaded and unloaded, and where the containerized cargo is temporarily stored while awaiting a future transportation.

These facilities can be classified as automated and non-automated considering the equipment technologies used. In automated container terminals, container info and automatic control technologies are used. These kinds of terminals have been established in Western Europe countries where work force is expensive. So, these terminals are more efficient than the others and also, the operation costs of these terminals are less than others. Moreover, in non-automated container terminals, the operations are carried out under the human control. In contrary, this kind of terminals has been established in South-East Asia countries where work force is cheaper (Steenken et. al., 2004).

In container terminals, three types of services such as import, export and transit are executed according to container trade types. One of these services is for import during which containers come by vessel and exit from gate; the other one is for export during which containers come by external transporters (XTs) and exit from berth by vessel; the last one is for transit during which containers come by vessel and exit by another vessel.

Different equipments are used while these services are being executed. In Fig. 1, services executed in a container terminal, transportation and handling operations and the equipments used during the operations are shown. Basically, three types of equipments are used in terminals. These equipments are; firstly quay cranes used for unloading/loading the container from/to vessel, secondly yard cranes used for stacking containers at yards for unloading/loading the container from/to transporter vehicle, and lastly the transporter vehicles used for transportation operations between berth and yard.

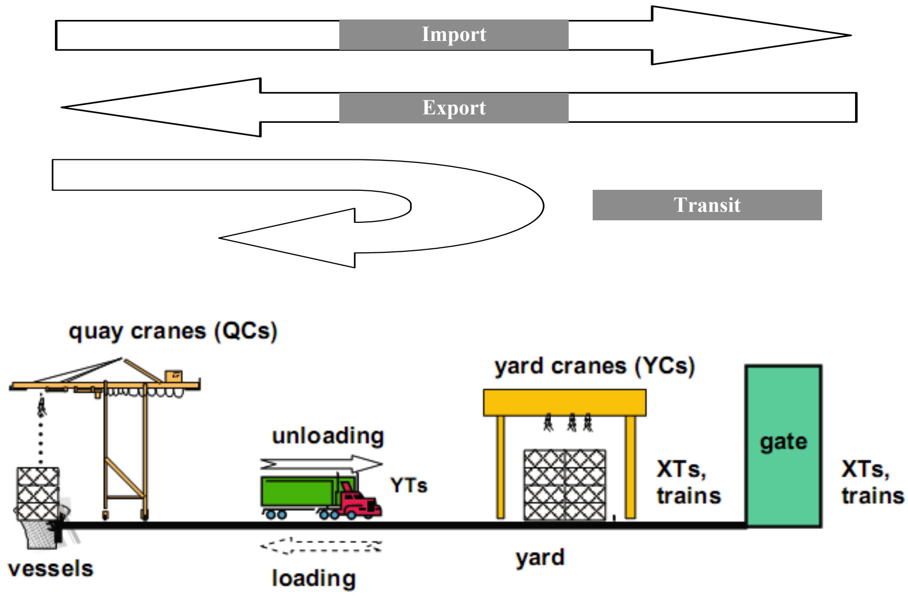


Figure 1. Terminal Services and Equipments (Petering and Murty, 2009)

In automated container terminals, AGVs are similar to conventional trucks, but they operate driverless on a pre-defined guide path. ALVs are vehicles which move over a container, lift it up and transport it to the designated storage location. Contrary to ALVs, AGVs need to interact with a crane. In recent years, Lift AGVs are the systems which can leave and take containers to the buffer areas without lifting them. In non-automated terminals, straddle carriers or conventional yard trucks (YTs) are used for moving containers inside the terminal. On the landside, many European container terminals have railway links which are not so common in most Asian countries (Kulak et. al., 2011).

In the literature, AGV dispatching rules were tested firstly by Egbelu and Tanchoco (1984). Additionally, Durrant-Whyte (1996) and Evers and Koppers (1996) are the first academic studies about AGV applications at container terminals. The design of AGV systems in container terminals is still a common problem. For comprehensive reviews of AGV systems in container terminal literature, we would like to refer to the surveys by Vis (2006) and Roodbergen and Vis (2009). Qiu et. al. (2002), Kim and Bae (2004), Bish et. al. (2005), Grunow et. al. (2006), Vis and Bakker (2008), Nguyen and Kim (2009) and Angeloudis and Bell (2010) are significant studies about AGV dispatching rules in automated container terminals.

Specifically, issues of logistics control in seaport container terminals have produced a wealth of publications in the scientific literature, cf. Stahlbock and Voß (2008) for a recent overview. Recently, there exist precious publications in the scientific literature especially about logistics control in seaport container terminals. Among the logistics control problems, the overall performance analysis of container terminals, the evaluation of alternative configurations, berth allocation, stowage planning, scheduling of the handling equipment, storage and stacking policies, quayside and landside transportation planning have been primarily examined. However, there is limited number of studies about layout analysis and layout effects on terminal performance.

In this study, AGV dispatching rules are tested for Π*, L* and Ψ berth typed container terminal layouts using simulation by the help of the performance criterion of the total container handling in quay cranes to demonstrate the effect of existing layouts on the performance of terminals under different transporter numbers, transporter request rules and intersection rules. Hence, an object-oriented simulation model has been developed by using Arena 10.0 Simulation Software. Some information about artificially filled type container terminals is given in the second section of the study. AGV dispatching rules are mentioned in the section 3 and the information about the designed container terminals is given in the section 4. In section 5, the simulation scenarios which have been developed for testing are mentioned and the results of these simulation scenarios are discussed with their statistically analysis. In the last part, the results of the study are presented and concluded.

2 ARTIFICIALLY FILLED TYPE CONTAINER TERMINALS

In the scientific literature, AGV applications in automated container terminals are used for the terminals in huge seaports. These huge seaports are all built in deep coasts, namely in natural ports. Normally, there exists only one major berth extending in parallel to the coast. Yet, yards are built perpendicularly or in parallel to the major berth in these terminals.

On the contrary, artificially ports, where there are shallow seas, may have several berths. Π, L, ╥ or Ψ berth typed are the most common ones among these types. Berth and yard layout types in the artificially filled container terminals are mentioned below:

- Π berth type: The entire terminal is placed in the port which is artificially filled as peninsula. Yard area is placed in the middle of three berths which surround the peninsula. The terminals in Haydarpasa and Izmir ports are the examples for this type.
- L berth type: While the yard area and one berth of the terminal are placed in the port, the other berth is built by filling the sea. Sometimes, this filled berth can be used as partial yard area. The container terminal which is placed in Mersin port is an example of this type.
- Ψ berth type: While the yard area of the terminal is placed in the port, berths are placed in the long peninsulas which are filled perpendicularly to the sea. Sometimes, the berth which is artificially filled can be also used as partial yard area. Kumport container terminal in Ambarlı port is an example of this type.
- ╥ berth type: While the yard area of the terminal is placed in the port, berths are placed in the long peninsulas which are filled horizontally to the sea. Sometimes, the berth which is artificially filled can be also used as partial yard area. Shangai ports in Yellow Sea are examples of this type.

It can be seen not only several areas in the terminal, but also horizontally or perpendicularly location of common yard area to the berths as a result of the fact that container terminals in these kinds of ports have several berths. It is pointed out in Vis and Anholt (2010), Polat et al. (2010) and Kulak et al. (2011) that the layout types effect the terminal performance in a significant way. In respect of the studies in the literature, due to this effect, AGV applications and dispatching rules in automated filled typed container terminals may differ.

3 AGV DISPATCHING RULES

In the frame of this study, AGV dispatching rules are analyzed using two different ways. These are: transporter request rules and intersection rules. Transporter request rules are used when a transporter is requested from the berth, yards, and gate. On the other hand, intersection rules used in order not to come across traffic jam or have an accident during AGVs' travel on the designed paths are shown in Fig. 2.

3.1 Transporter Request Rules

Smallest Distance: It is for selecting the available transporter nearest the requesting point.

Largest Distance: It is for selecting the available transporter farthest the requesting point.

Random: It is for selecting transporters randomly from the available transporter units.

Cyclical: It is for selecting the first available transporter unit beginning with the successor of the last unit selected.

3.2 Intersection Rules

FCFS – First Come First Served: The vehicle that arrived first at the end of its incoming link is given control of the intersection first.

LCFS – Last Come First Served: The vehicle that arrived last at the end of its incoming link is given control of the intersection first.

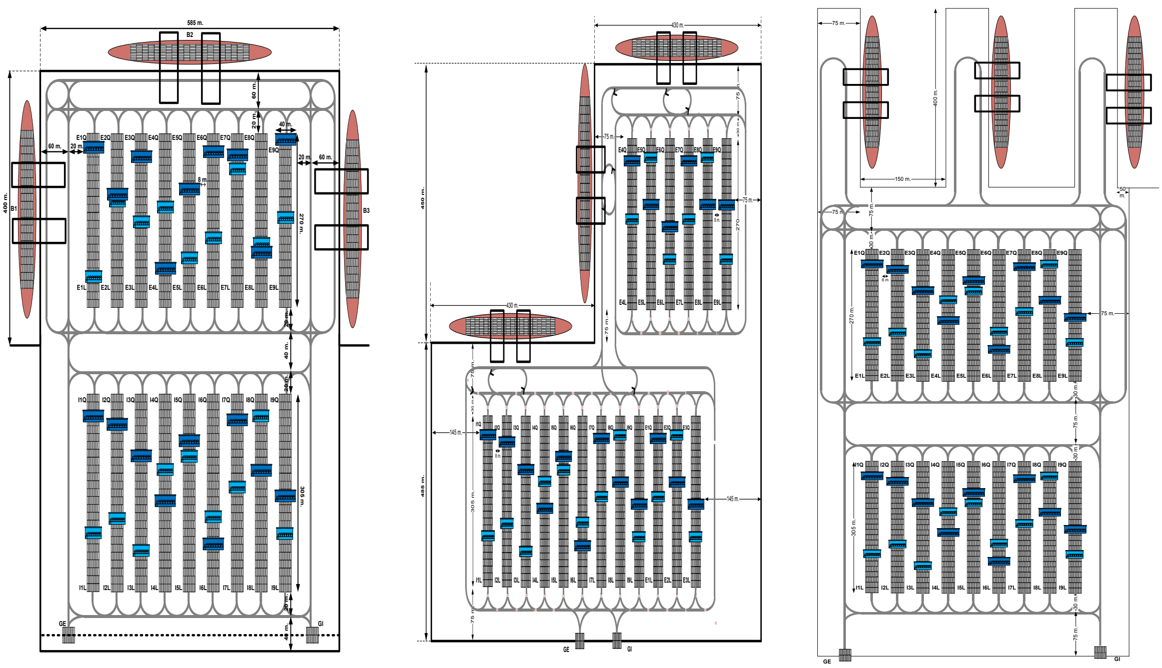
Closest: Giving the intersection to the vehicle closest to its travel destination.

HVF – High Value First: Giving the intersection to the vehicle whose controlling entity has the highest value of Attribute ID. The highest value means that the transporter is loaded with export container.

LVF – Low Value First: Giving the intersection to the vehicle whose controlling entity has the lowest value of Attribute ID. The lowest value means that the transporter is loaded with import container.

4 DESIGNED CONTAINER TERMINALS

In the structure of the study, large scaled Π, L and Ψ berth typed and also artificially filled container terminals which can be built in shallow coast areas have been designed. Layouts of these terminals which are designed as an automated container terminal are shown in Fig. 2 a, b and c respectively.



(a) Π berth typed **(b)** *L* berth typed **(c)** Ψ berth typed

Figure 2. Layouts of Designed Terminals

In each berth of these terminals, there are two dual automated quay cranes. Also, in the yard area there are 18 blocks (Π and Ψ berth typed – 9 blocks near to the gate for import containers, 9 blocks near to berths for export containers; L berth typed – 9 blocks near to the gate for import containers, 6 blocks near to berths for export containers and 3 blocks near to the other blocks). In each block, twin automated stacking cranes, which have telescopic design, are assigned. For export containers, each block length is 270 m. (44 TEU), width is 40 m. (10 TEU) and height is 13 m. (5 TEU). Additionally, for import containers, each block length is 305 m. (50 TEU), width is 40m. (10 TEU) and height is 13 m. (5 TEU). In this condition, simultaneous stack capacity of the each terminal is 42.300 TEU.

A simple presentation of AGV paths in the terminals are also shown in the figures above. AGV load/unload zones in blocks are located at the endpoints of each block. For export containers, container loading zone is located at the berth side and container unloading zone is located at the landside of block. For import containers, container unloading zone is located at the berth side and container loading zone is located at the landside.

In these container terminals, there are buffer areas which have the capacity of 20 containers at each block and 10 containers at each berth because of lift AGVs. Owing to these buffer areas, yard cranes and AGVs can run loading/unloading operations independently. Hence, it is possible to decrease waiting times of terminal equipments considerably. Optimum number of AGVs used in terminals has been obtained separately for each simulation scenario and for each berth typed terminal because of the differentiating number of AGVs according to the tested rules.

5 SIMULATION TESTS

5.1 Simulation Model

In the simulation model which has been developed by using Arena 10.0, vessels are the entities. Features of the vessels (loading/unloading amounts, vessel types – large, medium and small) are assigned and these vessels are allocated to berths in the first part of the model. In the second part, the operations executed at berths are mimicked. Loading / unloading processes of the containers in these vessels, and assignment of the containers unloaded from the vessel to the yards and AGV assignments are carried out. In the last part, yard area operations are simulated.

For the simulation tests, collected data are; inter arrival times of vessels, load to be charged onto a vessel, load to be discharged from a vessel, handling time of quay cranes, handling time of yard cranes, travel time of AGVs, average storage time in yard blocks (Import & Export), Import/Export ratio, equipment availability of quay cranes, equipment availability of yard cranes, equipment availability of AGVs. These data were analyzed using Arena Input Analyzer 10.0 and SPSS 16 following the concept of trace-driven simulation. Distributions with their parameters were determined with respect to minimum squared errors based on the Chi Square Test of the Arena Input Analyzer.

In this paper, we have some assumptions that normally ignore the minor problems but concentrate mostly on the major ones. Below are these major assumptions of the simulation model:

- YTs and AGVs can carry only one container
- Operating conditions of the terminal are not affected by weather conditions and they do not differ between the working shifts.
- We also assume that vessel arrivals at berths are unscheduled and thus, considered as random events and as a result of this, the collected data may differ.

In this context, the simulation tests are implemented under 3.000.000 TEU demand with 5 replications and one-year simulation time, and total container handling at QCs per year is used as the performance criterion.

5.2 Numerical Results for the Design of Π Berth Typed Terminal

In the first experiment set, the simulation model is used for analyzing transporter request rules in Π berth typed terminal. For this purpose, 4 different transporter request rules for AGVs are tested. In the scenarios, 'closest' is used as intersection rule. These scenarios are also tested with different transporter numbers in order to obtain the optimum transporter number. The effect of transporter request rules using different transporter numbers on total container handling at QCs per year is presented in Fig.3.

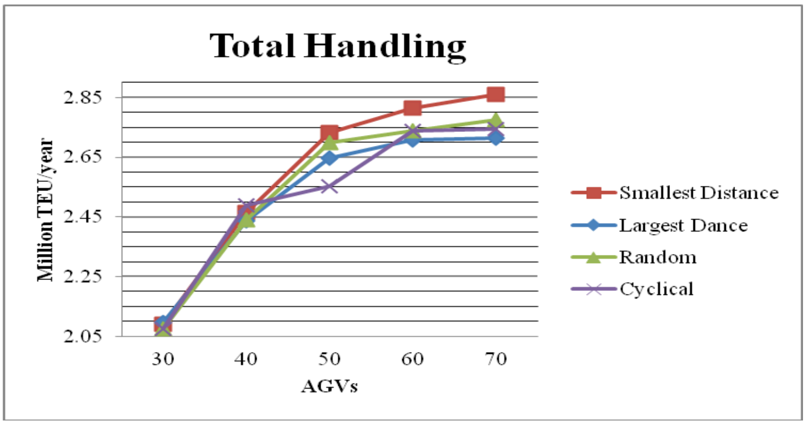


Figure 3. The Effect of Request Rules Under Different Transporter Numbers

As mentioned in Fig. 3, there is a significant difference between the request rules under different transporter numbers. In Table 1, the results of Tukey HSD tests which are carried out to obtain the differences above are in favor of which transporter request rule are presented. Simulation results which are related to 5 different transporter numbers are used in tests for transporter request rules.

Table 1. Tukey HSD Test for Transporter Request Rules

		Homogeneous subgroups (Alfa = 0,05)	
Transporter Request Rules	N	1	2
Cyclical	25	2520030,88	
Largest Distance	25	2520552,96	
Random	25	2545337,60	
Smallest Distance	25		2597987,20

According to Table 1, it is obvious that the transporter request rule which has the highest handling amount is the smallest distance. So, assigning AGVs to containers with smallest distance rule will provide higher handling amount as it provides time-saving and decreasing in waiting times. In Table 2, the results of Tukey HSD test which are used for obtaining the most appropriate transporter number under smallest distance rule are presented.

Table 2. Tukey HSD Test for Transporter Numbers

		Homogeneous subgroups (Alfa = 0,05)			
Transporter Numbers	N	1	2	3	4
30	5	2089241,60			
40	5		2463484,80		
50	5			2730870,40	
60	5			2815529,60	2815529,60
70	5				2858809,60

As mentioned in Table 2, it is clear that there is no notable difference between the numbers of 50 and 60 transporters and the numbers of 60 and 70. Therefore, it is more cost-effective use to analyze the ranges of 50-60. So, for 51-54-57-60 numbered transporters, Tukey HSD test is again carried out to find out the optimum number of transporters between the ranges of 50-60. In table 3, Tukey HSD test results are shown.

Table 3. Tukey Hsd Test for Transporter Numbers

		Homogeneous subgroups (Alfa = 0,05)	
Transporter Numbers	N	1	2
51	5	2737321,60	
54	5		2773305,60
57	5		2813152,00
60	5		2815529,60

In Table 3, there is a significant difference between the numbers of 51 and 54, 57, 60 transporters. However, there is no significant difference between the numbers of 54, 57 and 60 transporters. In this paper, although there is no feasibility study related to lift AGVs, the optimum number for these transporters are determined as 54 because of high purchase and installation.

In the second experiment set, the simulation model is used for evaluating the scenarios with defined intersection rules in terminals. For this reason, 5 different intersection ruled scenarios for the transporter number 54 and 4 different transporter request ruled scenarios are tested. In Fig. 4, the effect of intersection rules on the performance criterion under different transporter request rules is shown.

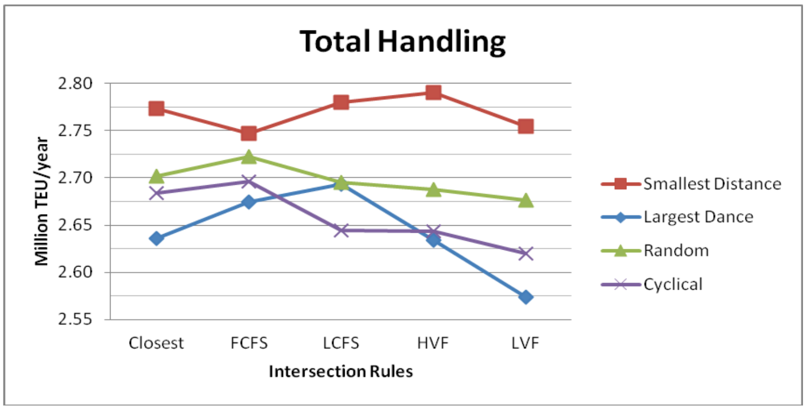


Figure 4. The Effect of Intersection Rules Under Different Transporter Request Rules

According to Fig. 4, transporter request rule and intersection rule which maximize total handling amount per year are selected for Tukey HSD test. Considering test results and Fig. 4, it can be said that the best transporter request rule is “smallest distance rule” among the other request rules. Smallest distance rule is different from the other transporter request rules in terms of being at %95 confidence level. In the same way, HVF is the best intersection rule at %95 confidence level among the other intersection rules.

The simulation tests which are applied on Π berth typed terminal are also implemented on the other berth typed terminals. Results of the tests according to the berth types are shown in Table 4.

Table 4. Results of Simulation Tests According to the Berth Types

Berth Type	**Optimum Number of AGVs**	**Best Transporter Request Rule**	**Best Intersection Rule**	**Total Handling under Best Rules (TEU)**
Π berth typed	54	Smallest Distance	High Value First (HVF)	2.789.965
***L* berth typed**	57	Cyclical	Last Come First Served (LCFS)	2.664.266
Ψ berth typed	96	Smallest Distance	Closest	2.159.527

6 CONCLUSION

In this paper, simulation models are developed to analyze transporter number, transporter request rules and intersection rules in Π, *L* and Ψ berth typed designed container terminals. Implemented tests show that the best scenario is; the scenario with using 54 lift-AGVs, “smallest distance rule” as request rule, “HVF” as intersection rule for Π berth typed terminal configuration, the scenario with using 57 lift-AGVs, “cyclical rule” as request rule, “LCFS” as intersection rule for L berth typed terminal configuration and the scenario with using 96 lift-AGVs, “smallest distance rule” as request rule, “Closest” as intersection rule for Ψ berth typed terminal configuration.

For Π berth typed terminal configuration, when the results are compared with Vis and Bakker (2006), smallest distance rule is familiar for transporter request rule in each study. However, in related study FCFS is proposed as intersection rule but, HVF is proposed in this study. The reason for this difference can be the different terminal berth types. In the Ψ berth typed terminal configuration, the amount of total handling under best rules is lower than the other types. The main reason for this is that the distances between yards and berths are different. These distances are particularly farther in Ψ berth typed than in Π and L berth typed. Even though it seems like a disadvantage, there are also some advantages of the Ψ berth typed terminal configuration such as their facility of being established at lower cost due to their amount of fill and of serving much more vessels with less space at the same time.

With the help of this study, we have identified that the transporter request and the intersection rules can behave differently according to terminal berth types. Consequently, the effect of these rules will be researched for the other artificial and natural berth types of container terminals. Furthermore, the effect of allocation strategies as a part of this research has also been studied on various types of container terminal layouts.

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