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# EXAMINATION OF CONTAINER TERMINAL LAYOUT WITH METHOD STUDY

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***ABSTRACT***

*Container terminals are complex facilities where many operations take place simultaneously. In order to carry out these operations efficiently, terminal layout plans should be designed according to the physical and characteristic features of the terminal. Layout plans can be reconstructed in cases where the existing terminal is expanded or in cases where it is required to increase the productivity of the terminal to manage the increasing container throughput. For strategic decisions and long-term planning, knowing how the layout design revisions would affect the terminal's operation and productivity is critical for terminal managers. One of the most effective methods for increasing productivity in enterprises is the work study. In this direction, to improve terminal productivity, the analysis of the terminal is carried out by using the method study, which is one of the work study techniques. Alternative layouts have been proposed for the terminal layout after a detailed analysis and critical evaluation of terminal movements.*

***Keywords:*** *Container Terminal*, *Work Study*, *Layout*, *Method Study*, *Productivity*.

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# KONTEYNER TERMİNALİ YERLEŞİM PLANININ METOT ETÜDÜ İLE İNCELENMESİ

***ÖZ***

*Konteyner terminalleri aynı anda birçok operasyonun gerçekleştiği karmaşık yapılardır. Bu operasyonların verimli bir şekilde sürdürülebilmesi için terminal yerleşim planlarının terminalin fiziksel ve karakteristik özelliklerine göre dizayn edilmesi gerekir. Yerleşim planları mevcut terminalin genişletildiği durumlarda ya da artan iş hacminin daha rahat yönetilebilmesi adına mevcut terminal verimliliğinin arttırılmak istenmesi durumlarında yeniden oluşturulabilir. Yerleşim planı değişikliklerinin terminalin işleyiş ve verimliliği üzerinde nasıl bir etkisinin olacağının önceden bilinmesi alınacak stratejik kararlar ve uzun dönemli planlamalar için oldukça önemlidir. İşletmelerde verimliliği artırmaya yönelik kullanılan yöntemlerden en önemlilerinden biri iş etüdü yöntemidir. Bu doğrultuda terminal verimliliğinin artırılması için çalışmada iş etüdü tekniklerinden metot etüdü yöntemi kullanılara terminalin analizi gerçekleştirilmektedir. Terminal hareketlerinin detaylı analizi ve eleştirel bir bakış açısıyla değerlendirilmesiyle terminal yerleşim planı için alternatif diziliş düzenleri önerilmiştir.*

***Anahtar Sözcükler:*** *Konteyner Terminali, İş Etüdü, Yerleşim Planı, Metod Etüdü, Verimlilik.*

## 1. INTRODUCTION

Maritime transport has a significant cost advantage compared to other modes of transport in international trade. While it is estimated that 80 percent of the cargoes are transported by sea worldwide, it is seen that the share of container transportation in maritime transportation is increasing every year (Statista, 2021). With the increase in the demand for container transportation, sea and port infrastructure systems for this transportation technique are also developing. The most important hubs that link the sea and land connection of this transportation are the container terminals. Since container terminals are high-cost investments, they should be operated with high performance and terminal operations should be managed quickly and effectively to minimize waiting times for ships. For these reasons, it is necessary to constantly monitor and measure berth, yard, and gate operation processes and their related workflows. In this direction, the specific needs of each port system should be determined according to efficiency criteria and studies should be carried out to improve productivity.

In container ports, the distances between quays and storage yards, between storage yards and gates, and between other terminal units should be determined according to their capacities, occupancy rates, and the import/export/transit categories of the container. This paves the way for reconsidering the layout of the units in the port and making changes to increase productivity. In this direction, the productivity of the container terminal is increased by determining the optimum layout and the current layout is improved with the existing handling equipment without making new investments. Generally, the layouts stay the same for a long time unless there is a physical or structural change in the terminal. Layout plans can be changed in case of new port establishment, in cases where the existing terminal is expanded towards the land or seaside, or in cases where it is required to improve the productivity of the existing terminal to manage the increasing container volume more easily.

Productivity improvement techniques are the most important tools used to reach the required efficiency level (Kayar and Akalin, 2014). The methods used to improve productivity can be divided into behavioral methods and technical approaches (Tutar, 2015). Behavioral methods include applications on human productivity and are mostly related to increasing motivation of business psychology, while in technical approaches, the main purpose is the use of resources at the minimum level (Kayar and Akalin, 2014; Tutar, 2015). Work study, which is one of the technical approaches, is also used to increase terminal productivity.

In the literature, it is seen that work study techniques are used in various studies to improve productivity. Sütçü *et al.* (2019) carried out a simulation application within the framework of time study data made in reorganization activities aimed at increasing productivity and effectiveness in some production processes of a furniture factory. Şenyiğit *et al.* (2021) identified the processes that need to be improved by using method study and time study techniques in the application processes of three different product types produced in a furniture firm for resource planning and productivity improvement. Sabir and Dönmez (2013) were able to reduce the scope of work of a yard spinning mill by using work study techniques. Deste and İlhan Küçük (2021) examined the operation of a machine used in sheet cutting within the scope of work study techniques, identified inefficiencies, and stated how the design of the new machine should be. Akbilek (2017) developed a new layout plan with existing equipment to increase productivity in a food machine production facility in line with the increasing demand and customer expectations.

There are also various studies in the literature regarding the increase in productivity and the use of work study techniques in container terminals. The term facility layout plan under the work study, can also be considered for container terminals (Wiese, 2011). Schmidt *et al.* (2005) visualized the existing layout and possible expansion plans in line with the needs of the terminals by using time and method studies in layout planning for medium and small-sized terminals. Koh *et al.* (1994) have developed a simulation model that will enable the possibility of making changes before starting the operation in a container terminal with the time study technique, obtaining more efficiency with fewer resources, determining the speed of the yard vehicles, and calculating the movement times. Rajamanickam and Ramadurai (2015) made work measurements for the simulation model they created to determine the causes of traffic congestion in the Chennai port and used the time study method to obtain data such as gate-in/gate-out, speed, and waiting times of trucks to use in the simulation program. Visser *et al.* (2013) conducted a motion and time study for a loading operation on a ship to optimize the crane capacities and the distribution of the load to the ship, which is an important issue in port operations, and determined the ideal loading configuration.

In container terminals, vehicles such as loading/unloading, transport, and stacking are high in terms of both quantities and movement numbers. For this reason, a change that can be made in the port layout and the efficiency arrangements of other operations related to it will provide high-cost advantages in the medium and long term. Accordingly, considering the work processes and efficiency in container terminals, an optimum layout planning problem arises. Within the scope of this study, method study techniques were used to solve this problem and layout alternatives that could be made with current resources were suggested.

## 2. METHODOLOGY

Method study which is one of the work study techniques is used to develop the layout of the container terminal in this study. Method study is the systematic recording and critical examination of existing and proposed methods of doing a job to develop and implement easier and more effective methods and reduce costs (Kanawaty, 1992). The aim of the method study is to determine the methods with the highest worker and worker-machine productivity without putting the worker at risk in terms of both health and safety (Top, 2001). Method study deals with issues such as refining processes and methods, adjusting facility designs, and promoting better working conditions. It is used to identify and eliminate the factors affecting productivity. The following steps are applied in the implementation of the method study (Kanawaty, 1992).

1. Selection of the work or process to be studied
2. Recording every data regarding the current process
3. Examining and criticizing the recorded processes in detail
4. Evaluating the result and developing a new method
5. Installing new method
6. Supervising the application of the new method

Productivity improvement techniques allow for reaching higher productivity efficiency at less cost. Work study is a general term consisting of applications that systematically investigate all sources and factors that affect a certain event or activity in terms of economy and effectiveness to create an opportunity for improvement and comprehensively examine human work (Kanawaty, 1992). It provides an increase in the productivity of the enterprises by means of organizing the work, standardizing it, or correct analysis of production data (Atan, 2005). Work study consists of method study and work measurement techniques. When used correctly, these techniques can help a business make the best use of its available resources to achieve its objectives. Although the processes of observation, analysis, measurement, and recording are generally thought of as on-the-job activities, it is often possible to evaluate a job or task before it is carried out (Irwin, 2001).

In a method study, information about a process is recorded with flowcharts. In this study, work flow charts were used to determine the factors affecting the layout efficiency in container terminals, and a case study was conducted in this direction.

### 2.1. Container Terminals and Terminal Layout

Container terminals are port facilities that specialize in container handling. They basically provide loading, unloading and storage services for inbound and outbound containers. They are the transfer points of the containers with the ship and the terminal hinterland. They generally serve container ships and are equipped with special equipment for loading/unloading these ships. In Figure 1, a container handling system is shown schematically for the terminals using rubber-tired gantry (RTG) cranes in the storage area and terminal tractors for intra-terminal transportation.

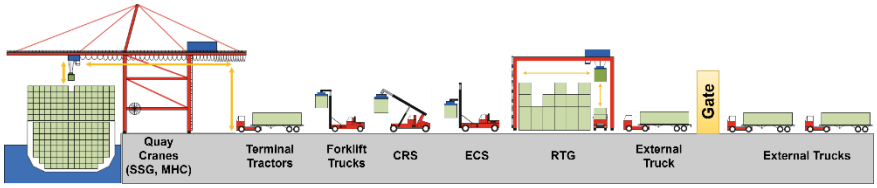


**Figure 1:** Container terminal handling system (Kara *et al*, 2021).

Other types of equipment used in this system are SSG (Ship to Shore Crane), MHC (Mobil Harbour Crane), CRS (Container Reach Stacker), ECS (Empty Container Stacker), and forklift trucks. MHC and SSG are quay cranes used for loading/unloading/shifting containers onto ships. RTG is a yard crane used for the storage of containers. CRS, ECS, forklift trucks and terminal tractors are used to transport containers between the quay and the container storage area. External trucks gate in export containers from the terminal hinterland to the storage area and gate out import containers from the storage area to the terminal hinterland.

All these equipment in the container terminals work simultaneously with each other and must be distributed to the terminal area in the most efficient way. In this context, the design of the terminal area which is also expressed as the terminal layout design is a crucial parameter to managing the operations productively. Generally, quay operations are managed between the ship and the quay on the seaside. Storage areas are located in the center of the terminal between the quay and the gate, and container blocks occupy most of the storage areas.

### 2.2. Method Study for Container Terminal Layout

Work study stages are also valid for method study. After the selection of the work, the recording process starts. The workflow charts used at this stage allow both the recording of the processes and the examination of their differences with the next stages (Kanawaty, 1992). Under the method study, facility layout is considered as the planning and placement of the machinery and equipment in the factory, from the raw material purchase to the final product distribution point, with the lowest cost, the easiest workflow, and the shortest distance possible (Mallick and Gaudreau, 1966).

Method study aims to increase efficiency and reduce costs by making the best use of available resources. All the stages of method study can be applied to a container terminal and its layout. In this direction, flow diagrams and work flow charts are used to record the operations and container flow in the current layout of the container terminal. These

diagrams show the container terminal layout and operation processes in detail. Thus, terminal operation processes are critically examined and factors that negatively affect productivity are identified and efforts are made to eliminate them. The stages of the method study for the development of container terminal layout are summarized in Figure 2.

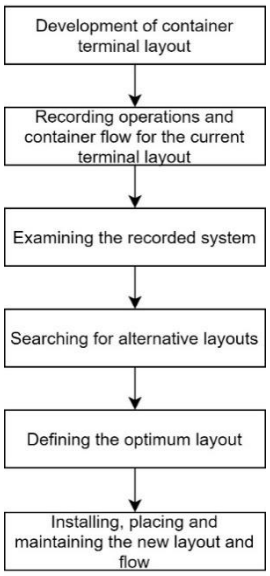


**Figure 2:** Stages of Method Study for Developing Optimum Container Terminal Layout.

The operation processes at the container terminals are divided into two as inbound (import and transit) containers and outbound (export and transit) containers from the terminal and are described below in the tables and form of workflow charts.

**2.2.1. Operation Processes and Container Flow in a Container Terminal (Recording)**

In this section, all processes occurring in a container terminal for inbound and outbound containers are recorded as the second stage of container terminal layout stages given in Figure 2. It is considered that the container handling system use RTG cranes in the storage area and yard towing trucks (YTT) within the terminal for intra-terminal transportation.

In Table 1, the steps of the inbound container from the quay to the storage yard are recorded.

**Table 1:** Operation Processes from the Quay to the Yard for the Inbound Containers.

| Process order | Process Name |
|---|---|
| 1 | The arrival of the ship |
| 2 | Assignment of the import or transit container to the storage yard |
| 3 | Unloading containers from the ship by quay crane |
| 4 | Requesting yard towing truck (YTT) for the quay crane |
| 5 | Loading container onto the YTT by quay crane |
| 6 | Taking the container to the pre-assigned yard block by YTT |
| 7 | The arrival of the YTT at the yard block and waiting in the rubber tyred gantry (RTG) queue |
| 8 | Unloading container from YTT to the storage area by RTG |
| 9 | Storing containers in the yard block |
| 10 | Getting containers from the quay crane by YTT again until the vessel operation is over. |

In Table 2, the steps that may occur in line with the possibility of gating out the container full or unloading to Container Freight Station (CFS) after the storage process are listed.

**Table 2:** Operation Processes from the Yard to the Gate and CFS for the Inbound Containers.

| Process order | Process Name |
|---|---|
| 1 | Storing containers in the yard block |
| 2 | Processing of the import container either gate-out or CFS discharge |
| 3 | Loading the full gate-out container to the external truck by RTG, loading the CFS unloaded container to YTT by RTG |
| 4 | Transporting the full container to the gate by an external truck and gate-out |
| 5 | Transporting the full container to the CFS by YTT which should be unstuffed at the CFS area. |
| 6 | Transporting the empty container to the empty container area by YTT |

All container movements between the quay and the gate or CFS for the inbound containers mentioned in both Tables 1 and 2 are shown with the workflow chart in Figure 3.

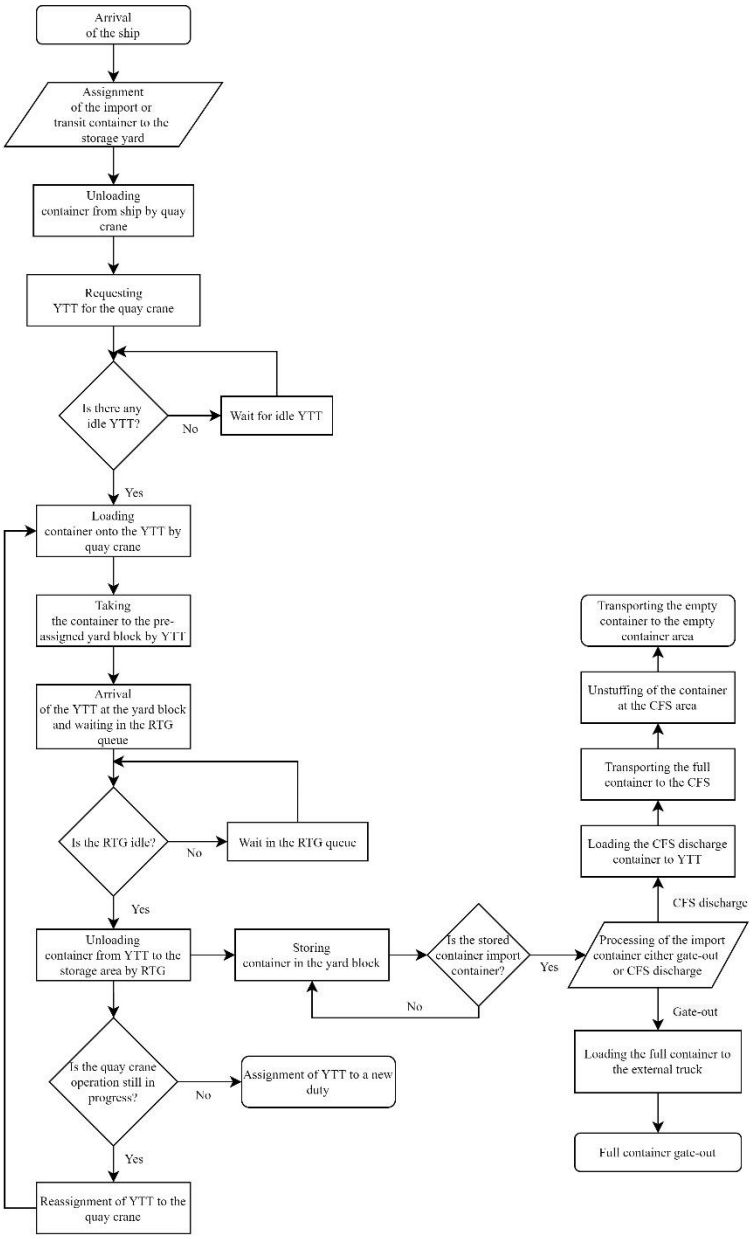


**Figure 3:** Container Flow for the Inbound Containers from the Quay to the Gate.

Operation processes are also divided into two for outbound containers to be loaded on the ship. The first is the processes between the

entrance of the container through the gate and the storage areas described in Table 3.

**Table 3:** Operation Processes from the Gate to the Yard for the Outbound Containers.

| Process order | Process Name |
|---|---|
| 1 | Gate-in of the container |
| 2 | Assignment of the container to the storage yard or CFS area and transporting by the external truck |
| 3 | Unloading the full container to the storage area by RTG and gate-out of the external truck |
| 4 | Unloading the full container to the CFS area, gate-out of the external truck, storing and processing container in the CFS |
| 5 | Storing containers in the yard block |

The cases in Table 4 take place sequentially with the arrival of the ship on which the container waiting in the storage area will be loaded.

**Table 4:** Operation Processes from the Yard and CFS to the Quay for the Outbound Containers.

| Process order | Process Name |
|---|---|
| 1 | Assigning the container from the storage area to the ship |
| 2 | Requesting YTT for RTG |
| 3 | Loading the container onto YTT by RTG |
| 4 | Transporting the container to the quay by YTT |
| 5 | Unloading the container from YTT and loading it on the ship by the quay crane |
| 6 | Taking containers from RTG and bringing them to the quay by YTT until the end of the ship loading operation |
| 7 | Ship departure after the loading operation |

For the outbound containers described in Table 3 and Table 4, all container movements from the gate to the ship departure are shown in the workflow chart in Figure 4.

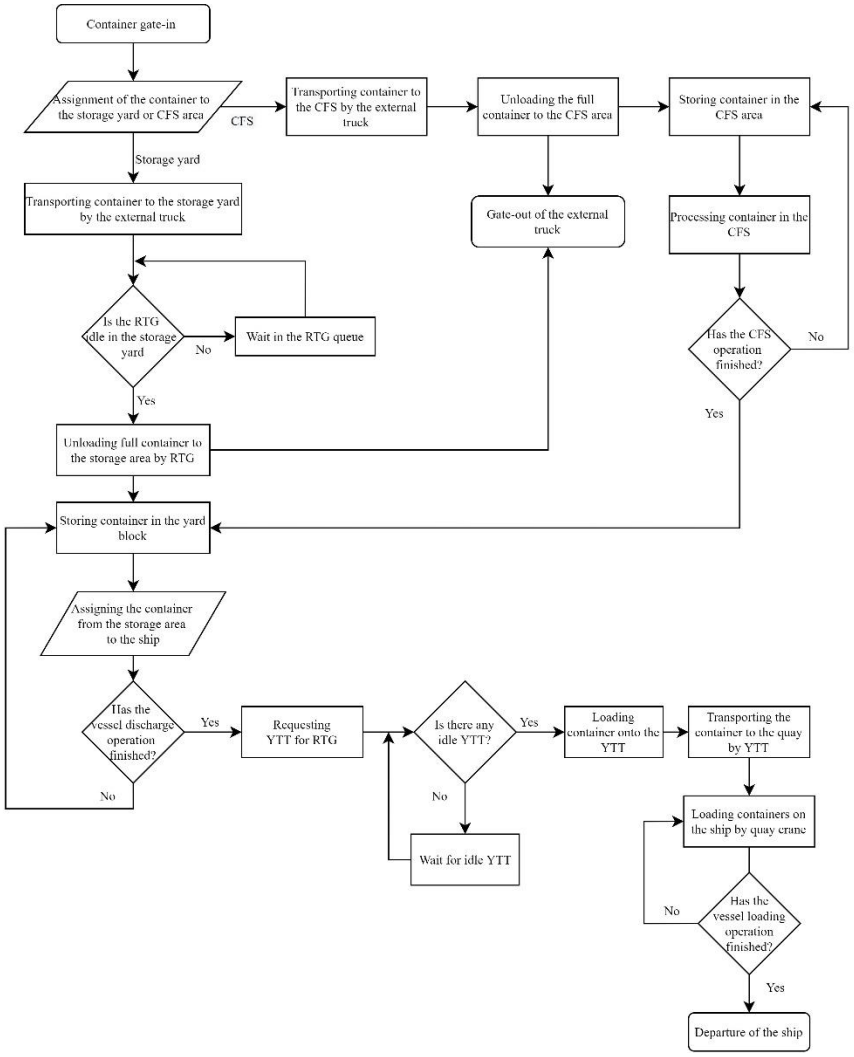


**Figure 4:** Container Flow for the Outbound Containers from the Gate to the Quay.

### 2.2.2. Development of Optimum Layout (Examining / Searching / Defining)

There are various techniques used to examine the processes in traditional method study. The most important of these is the critical examination-investigation technique. In this technique, it is aimed to criticize the process by asking primary and secondary questions. In this direction, as a

result of the questions asked, the viability of alternatives for the container terminal layout was examined.

With the examination of the questions asked and recorded data, alternative solutions are searched to define the new method. In a container terminal, the containers are commonly stored in a mixed manner which means import/export/transit containers are stacked in the same container block. After the examination of the current terminal layout, it is decided to create alternative storage area layouts according to container categories.

While defining the optimum layout, the alternatives are criticized compared to the current layout. To compare the layout alternatives, time measurement could be used to calculate the tranportation time of a container between quays and storage yards. Minimizing the unit transportation time would increase the productivity of the terminal with the existing equipment.

## 3. CASE STUDY

In the study, the layout of a container terminal with a high cargo handling volume was examined. The terminal has two CFSs and two gates. There are RTG cranes used in the storage areas and terminal tractors used for transferring containers in terminal. It has been observed that the containers are stored in a mixed manner in the storage areas without making any category distinction, and it is schematized as in Figure 5. In order to examine the selected process, first of all, the recording of the data was carried out. In this context, it is seen that there are three storage areas, four quays, two CFS areas and two terminal gates in the investigated terminal. The records show that the container movements between these points are consistent with the work flow charts shown in the previous methodology section.

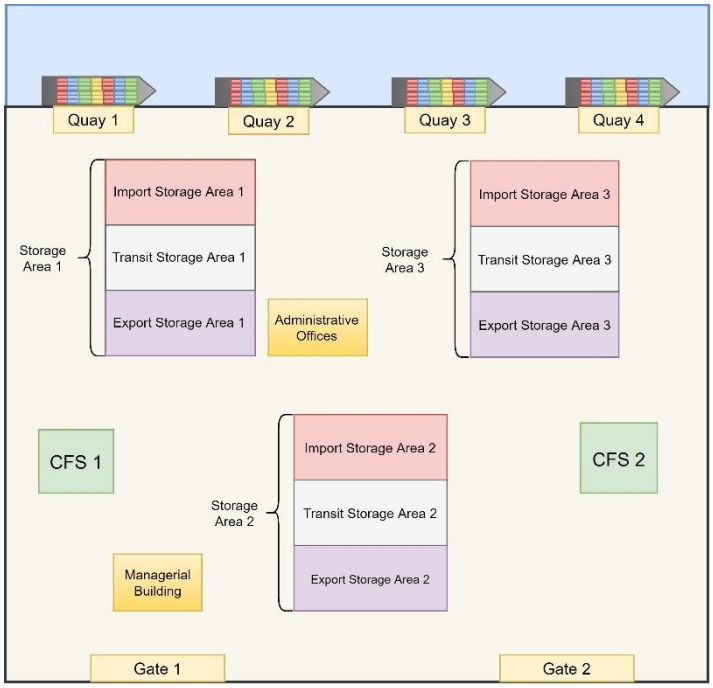


**Figure 5:** The Schematized Layout of the Current Terminal.

The existing terminal area, layout, and container movements were examined in detail and alternative layouts were designed for the terminal in the light of this information. Another aspect of the study was determining the positions of the full container areas where the most movements take place while developing the terminal layout. Generally, while creating the terminal layout import containers are placed close to the terminal gate, export and transit containers are placed close to the quay, and CFS and empty container fields are placed close to each other, as it increases the terminal operation productivity. For the storage of import, export and transit containers, a storage place can be designed either in the same yard or in the different yards. In this direction, storage yard layout alternatives for import, export, and transit containers can be seen in Figure 6.

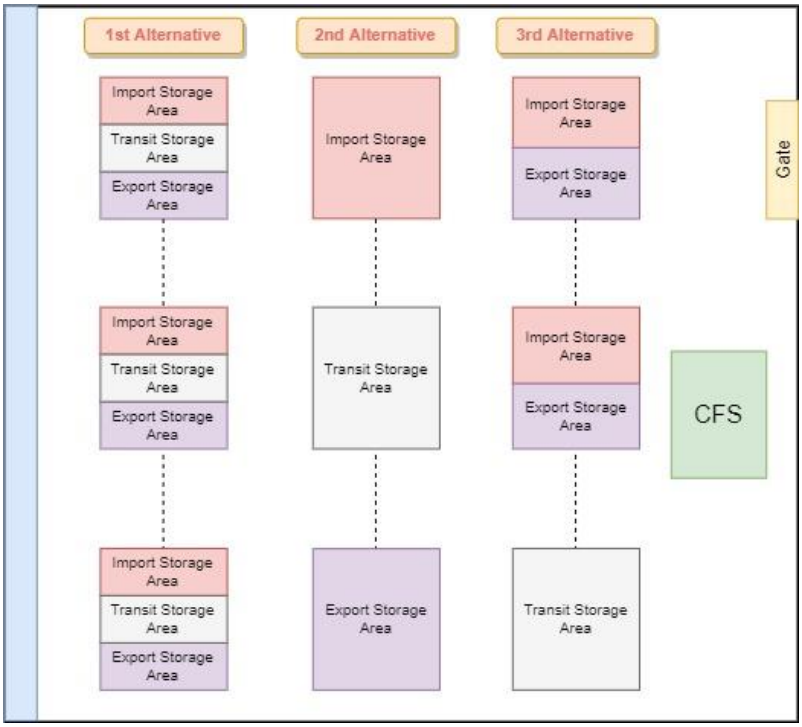


**Figure 6:** Storage Yard Layout Alternatives for Import, Export, and Transit Containers.

In the existing terminal, import, export, and transit containers are stored in the same yard or block in a mixed manner and there is one layout alternative. While developing the new method, alternative layout formations are summarized in Table 5. The first alternative shows the current layout. As the new layout design, there are six different layouts in the second alternative and nine in the third alternative.

**Table 5:** Alternative Storage Layouts for the Current Terminal.

| Layout Plans | Scenarios | Storage Area 1 | Storage Area 2 | Storage Area 3 |
|---|---|---|---|---|
| 1 | First Alternative | Import-Export-Transit | Import-Export-Transit | Import-Export-Transit |
| 2 | Second Alternative | Import | Export | Transit |
| 3 | | Export | Import | Transit |
| 4 | | Import | Transit | Export |
| 5 | | Export | Transit | Import |
| 6 | | Transit | Export | Import |
| 7 | | Transit | Import | Export |

| | | | | |
|---|---|---|---|---|
| 8 | Third Alternative | Import-Export | Import-Export | Transit |
| 9 | | Import | Export-Transit | Export-Transit |
| 10 | | Export | Import-Transit | Import-Transit |
| 11 | | Transit | Import-Export | İthalat-Export |
| 12 | | Import-Export | Transit | Import-Export |
| 13 | | Export-Transit | Export-Transit | Import |
| 14 | | Export-Transit | Import | Export-Transit |
| 15 | | Import-Transit | Import-Transit | Export |
| 16 | | Import-Transit | Export | Import-Transit |

Whether the alternative layouts are advantageous over the existing layout would be determined as a result of the calculations and measurements. However, in container terminals, which are dynamic structures, it may be necessary to use different alternatives to achieve maximum productivity, depending on the intensity of operations and terminal characteristics. The results to be found separately for alternative scenarios and layouts will allow the terminal to determine in advance the unit transportation time per container that it will encounter in a possible layout change. In this case, the calculations to be made for alternative layouts would be a reference for the terminal managers to make decisions.

## 4. DISCUSSION AND CONCLUSION

The productivity of container terminals has been increasingly important in recent years. One of the most important factors affecting operational productivity is the terminal layout. However, the terminal layout should be designed in accordance with the current characteristics and purpose of each container terminal. Planning the storage yards while designing the terminal should ensure the least movement of the container in the terminal. In this way, operational productivity is improved.

Container terminals are dynamic systems that have high investment and operating costs and are affected by economic developments. Terminal managers should determine appropriate strategies over time and use the resources they have in the best way to increase their profitability and reduce costs while meeting customer demands in a competitive environment. Regarding this, work study practices in container terminals enable the factors that negatively affect productivity to be identified and eliminated, thus increasing operational productivity. In this context, the method study technique was used to examine the existing layout in detail. In method study, the critical examination technique is mostly used for the development of the new method and it has been

suggested that the storage yards can be used in different scenarios as an alternative to the mixed-use of the fields for the current terminal.

While the study will help to make an assessment about the current situation of the terminal, it will also be able to show the possible impact of the capacity increase on the terminal productivity before making any investments. On the other hand, it will be possible to predict what kind of consequences a new gate or CFS area to be built at the terminal will cause. Another point in the study was to determine the locations of the standard container areas where the most of container movements were taken. After the layout of the standard container storage areas is determined, the storage areas of the special purpose containers which has a lower rate compared to standard containers, can be planned at the more idle areas of the terminal.

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