İşletme Bilimi Dergisi
Journal of Business Science

ISSN : 2148-0737
Publisher : Sakarya University

Vol. 12, No. 2, 185-195, 2024
DOI: https://doi.org/10.22139/jobs.1511719

Research Article

A Study on the Effect of Waiting Time of Ships at Anchor on Efficiency Measurement in Ports

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Received: 06.07.2024
Accepted: 19.08.2024
Available Online: 22.08.2024

Abstract: Maritime transportation has an important share in international trade. With the advancement of communication and technology, speed has become a very important parameter in customer demands. Both the production and logistics sectors are making improvements to reduce lead times in response to this demand. The initial investment cost is quite high in ports, which play an important role in maritime trade. In addition, the return on investment is long. In order to shorten the return on investment and increase the profitability of the port, the port should be operated efficiently and effectively. On the other hand, the services provided at ports are directly related to the foreign trade performance of countries. Additional ship waits at ports will lead to additional costs, thus reducing the competitiveness of countries. The fact that ports are complex and dynamic service businesses causes efficiency measurements to be multivariate. Accordingly, this study focuses on only one specific area of the highly complex issue of port performance measurement. In this context, firstly, the basic literature on efficiency measurement in ports is given in the study, then, within the scope of the constraints of the study, Torosport Ceyhan's ship anchorage waiting times over a two-year period are focused and a research process is carried out in this context. According to the findings obtained by Pareto analysis in the Six Sigma approach, it was revealed that the most important reason for the ships waiting to dock at the port was "pier occupancy (56.8%)".

Keywords: Port, Ship Waiting Time, Efficiency, Pareto Analysis

1. Introduction

Efficiency is the relationship between the inputs and outputs of the goods or services produced. Among the main objectives in achieving productivity, the priority is to improve the quality of the output obtained as a result of the production of goods or services, as well as to minimize environmental impacts in the production and consumption of the product or service, and not to harm nature. In addition, improving the living and working conditions of the employees in the enterprise and ensuring the optimal balance between the inputs and outputs of the enterprise for the profitability of the enterprise and achieving the appropriate production levels are the priority issues for the enterprises. This study focuses on the efficiency of ports, which are critical infrastructure in maritime transportation activities. At this point, the importance of ports should be emphasized first.

Maritime transportation is the most dominant mode of transportation serving global trade. This claim is based on the fact that maritime transport is preferred by over 80% of total global transportation (United Nations Conference on Trade and Development [UNCTAD], 2023). The main reasons for the overwhelming preference of maritime transport over other modes of transport are the necessity arising from the fact that almost 70% of the earth is covered by seas, as well as the nature of maritime transport and its full adaptation to economies of scale and distance. Thanks to high-capacity ships specialized according to cargo types, unit transportation costs are so low that no other type of transportation can reach. Especially for liquid and dry bulk cargoes (crude oil, petroleum products, iron ore, coal, cereals, etc.), economies of scale reach their peak and unit transportation costs fall considerably (Fulser, 2015). Despite this contradiction, the most important reasons why maritime transportation is preferred at such a high rate are the economies of scale provided by maritime transportation, the economies of distance and the necessity of covering 70% of the earth's surface with water.

Cite as(APA 7): Kadıoğlu, S. O., Esmer, S., & Yorulmaz M. (2024). A study on the effect of waiting time of ships at anchor on efficiency measurement in ports, *İşletme Bilimi Dergisi*, 12(2), 185-195. DOI: 10.22139/jobs.1511719

Sea transportation is carried out by merchant ships. Commercial ports are coastal facilities where merchant ships receive services, berth to receive or discharge cargo, transfer cargo to or from the seaway, road, rail or pipelines, provide basic logistics services to the cargo and create added value for the cargo. From this perspective, it would not be wrong to say that ports are "the most important transportation infrastructure".

Due to the time and cost pressures in global trade, the importance of ports and the measurement of port efficiency are becoming increasingly important. Shipowners and ship management companies operating commercial vessels tend to build ships with higher capacity in order to increase their profitability from economies of scale. As a matter of fact, there have been significant capacity increases in ship sizes for almost every type of cargo in recent years. These capacity increases have also led to a continuous increase in expectations for ports. Therefore, it is a requirement of competition that the port has the qualifications and service infrastructure required by the age. The port that best responds to the structural changes in the sector, as well as the demands and expectations of port users, will have a competitive advantage and will be easier to be selected by its users.

All production and service businesses want to continue their activities efficiently. As a service business, ports provide various service activities for ships and cargoes. The degree of satisfaction of port users shows the level of efficiency. Therefore, ports should provide services that will satisfy their users and at the same time provide the most appropriate infrastructure and service level according to the type of ship and cargo to be handled. There are many studies in the literature for this purpose.

From the perspective of the selection of a port-by-port users, there are two main approaches to port performance measurement (Rezaei et al., 2019). The traditional approach involves the direct measurement of port performance indicators through direct observation, interviews with port experts and questionnaires, and quantitative analyses are used to measure and interpret the relationships between the factors obtained through the research process. In these studies, decisions made by port management and their impact on port users are usually evaluated. (Tongzon, 1995, Wiegmans & Dekker, 2016, Bichou & Gray, 2004, Bichou, 2006; Calderinha & Felicio, 2014).

From a port selection perspective, the second approach, which is often preferred in the literature, is to evaluate port performance from the perspective of the decision maker (not the port). Such studies focus on the selection criteria of the port and measure the perceptions of port users. These studies are also quite common in the literature. Although such studies are mainly seen in the selection of container terminals (Chang et al., 2008; Yeo et al. 2014; Lirn et al., 2004; Nir et al., 2003; Murphy & Daley, 1994; Tiwari et al., 2003; Onwuegbuchunam, 2013; Ugboma et al., 2006; Garcia-Alonso & Sanchez-Soriano, 2009), there are also studies on the selection of dry bulk terminals (Balci et al., 2018). This research covers both approaches.

Regardless of the type of study conducted in this field, one of the common features of all studies is the evaluation of port operation processes. The main purpose of the operation processes in ports is to change the transportation mode of the cargo and to meet the demands of the cargo and the ship. The starting point of the operations is the physical transfer of the cargo from sea or land to the port site. In seaborne operations, the arrival of the ship at the port anchorage area and the issuance of a letter of readiness (NOR) means that the ship is ready for port operations. In this process, it is expected that the berths and equipment are suitable, and the pilot is expected to berth the ship. At this point, the transition to berth operations is made.

The time the ship occupies the berth is expected to be minimum. This is an expected result for ship, cargo and port authorities. Because the time the ship spends at the berth is one of the most important efficiency indicators. The most basic service provided while the ship is at the berth is the loading or unloading of the cargo to or from the ship. This operation is supported by inland transportation and

temporary storage operations in the port area. In the import process, operations are carried out within the scope of gate operations when the cargo is removed from the port area if the customs procedures related to the cargo are permitted, or when the cargo arrives at the port from outside in the export processes. As can be understood, operations within the port complement each other. In fact, the total operation speed of the port is related to the speed and efficiency in each link of these operations.

Esmer (2019) categorized the operations in ports into 5 groups. Assuming that the cargo comes from the seaside, these operations can be classified as ship, dock, inland transportation, storage and gate operations. If the cargo comes from the land side, this order is reversed. The basic processes regarding the sequence of operations in the scenario where the cargo comes from the sea are as follows:

- Within the scope of ship operations, the services received from the port facility by the ships calling at the port can be mentioned. In this context, it first arrives at the port administrative area, if necessary, it adds its queue at the anchorage area, and then it is docked with the help of pilots and tugboats. When the ship's work at the dock is finished, the ship leaves the dock and the port area with the help of the pilot and continues on its route. The time the ship waits for berthing after arriving at the port is expected to be minimum, as well as the time it waits for departure after the end of the operations at the dock. Among the 5 basic port operations mentioned, only this operation is directly assigned to the ships.
- After the docking of the ships, cranes are assigned and the process of unloading the cargo on the ship or loading the cargo on the ship begins. Depending on the amount, volume, type, density and weight of the cargo, these operations and the equipment used in these operations vary. Although there are ports in the world that have terminals where different types of cargo are handled, the berths of these cargo terminals have the necessary equipment for the relevant cargo.
- After unloading the cargo from the ship, the cargo should be transferred to the temporary storage area as soon as possible. In this way, uninterrupted unloading of other cargo on board is ensured. In these operations, which are called internal transportation, various transfer vehicles are used depending on the type of cargo. For example, pipelines for liquid cargoes and AVGs (Automated Guided Vehicle) for containers ensure the transfer between the dock and the storage area or tank.
- The cargo is then temporarily stored at the port until the necessary customs clearance is completed. Depending on the cargo, various equipment can be used to stack the cargo in the storage area. Temporary storage has a maximum duration in accordance with the relevant laws. Cargoes that are not nationalized within this period are confiscated by public authorities.
- After the completion of customs procedures, the process of taking the cargo from the storage area and delivering it to the buyer through the port gate begins. The port gate acts as a control at this point and takes its place in port operations as the first or last link in the process.

There are many decisions and performance indicators for ship operations in ports. This study focuses on ship operations in ports and the variables that cause the waiting time of ships at anchor and the variables that cause waiting. In this context, the reasons and durations of the ships waiting at anchor in Torosport Ceyhan within a 24-month period between 2022-2023 were analyzed.

2. Ship Waiting Times in Efficiency Measurement in Ports

Time is a resource. As such, consumers have to make decisions regarding the use of time when purchasing and consuming goods and services (Leclerc et al., 1995). Naturally, waiting times in time-based ports are the most critical variables in the efficiency measurement of ports. The issue has been examined in many studies (Sheikholeslami et al, 2013; Jovanovi et al, 2005; Shahpanah et al, 2014; Jones & Blunden, 1968).

Delays in port operations can occur for many reasons. These delays directly affect the productivity of the port. Variables such as the handling speed of the ship served at the dock, the speed of the truck feeding the crane, the docking time of the ship coming to the port to receive or unload cargo, and the waiting time of the ship at anchor are time-dependent and directly affect the productivity measurement of the port. Vessel waiting times are critical for ports in terms of customer satisfaction, efficient use of port infrastructure and environmental factors. Ship waiting times are a process that starts with the ship's Notice of Readiness (NOR) and ends with its berthing at the dock. With the NOR given by the captain of the ship arriving at the anchorage area of the port, he declares that his ship is ready for loading and unloading operations. This is also a starting point for the ship's port time.

For various reasons, the ship may not be docked immediately. These reasons may include unavailability of the berth, bad weather conditions, shipowner and customer disputes, bill of lading and customs declaration procedures, product control, delay in pilot and towage service. These factors may vary from port to port and from region to region. For this reason, it would be more appropriate to conduct and evaluate these variables that will cause waiting in ships for a certain port region.

The statistics of the waiting times of ships calling at ports around the world in the port anchorage area can be followed on a country basis to have information about the performance of the ports of the relevant country. Considering the services received by dry bulk cargo ships from ports in world ports, according to UNCTAD (2022) data, it is seen that the highest waiting time in loading operations is in Brazilian ports with 184 hours, and the highest ship waiting time in unloading operations is in Brazilian ports with 181 hours. Türkiye, where the application port in the study is located, has 58 hours of loading and 72 hours of unloading performance in terms of waiting times of bulk cargo ships. With this data, Türkiye has a good value compared to the average of other countries. A similar calculation was made for tanker ships. According to UNCTAD (2022) data, Belgium has the highest average tanker holding time in loading with 81 hours, while Kuwait has the highest average vessel holding time with 115 hours. Türkiye's average data for this vessel type is 39 hours for loading and 36 hours for discharging.

2. Ship Waiting Times in Efficiency Measurement in Ports

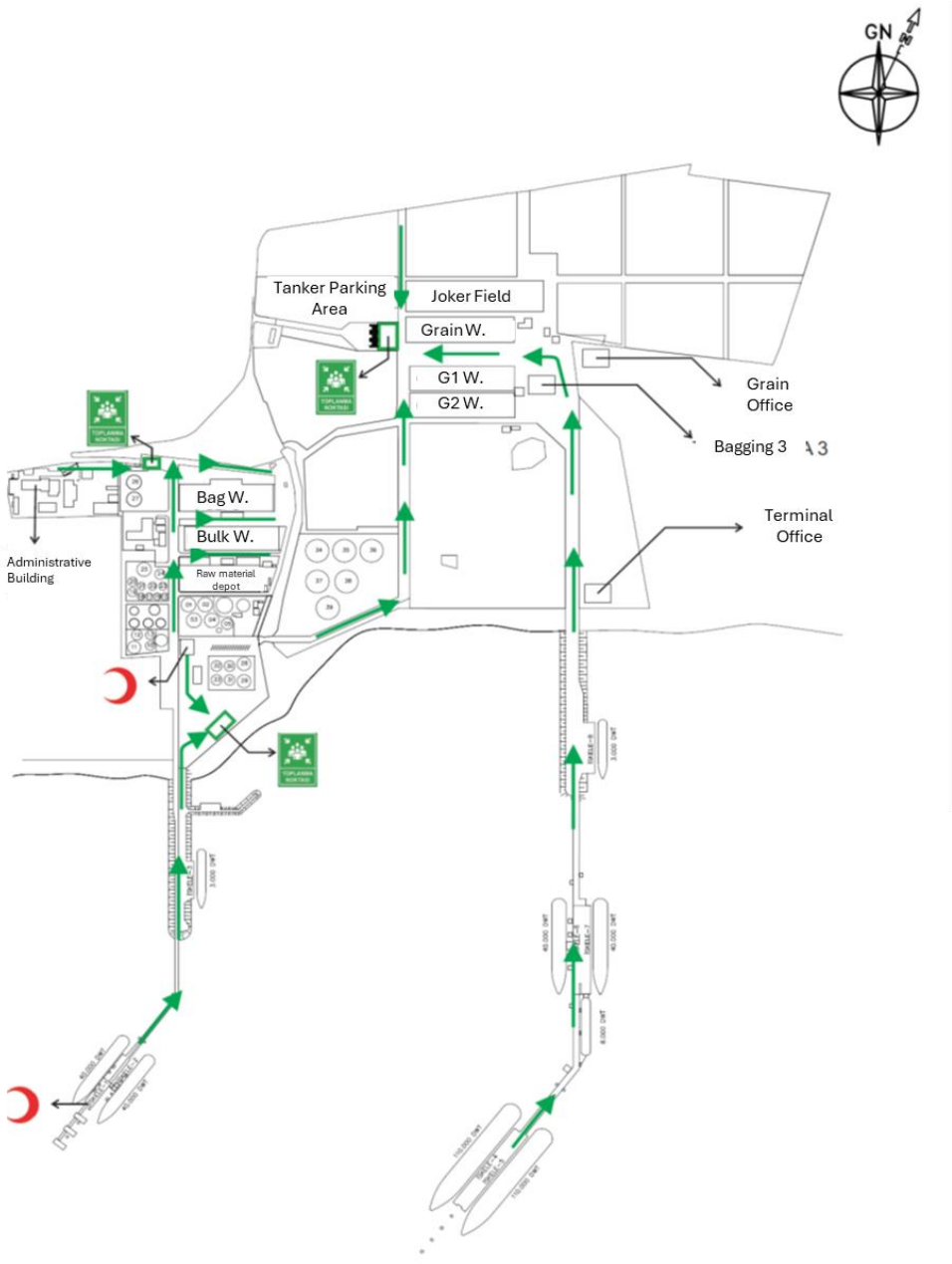
Applied as a scientific method, Six Sigma is a systematic method that involves improving business processes according to customer needs and using data to make improvements continuous (Kumar et al., 2006). The most important output of the method is the realization of the goal of "zero defect" in product or service production processes. For this purpose, systems are systematically examined, data are analyzed with statistical methods, quality measurements of processes are made, and processes are improved (Sobottka et al., 2010). Six Sigma method is widely used in the literature. The method has five basic steps: define (1), measure (2), analyze (3), improve (4) and control (5) (Yazıcı et al., 2019). In this study, it is aimed to operate this process.

Identification phase. At this stage, the research problem is defined. In this way, the wishes and expectations of port users are also determined.

The main motivation of the research is to reduce the inefficiency caused by ship waiting times, thus increasing efficiency for both port and port users. For this reason, the research is based on a concrete port and concrete events. Therefore, the study analyzed the data on vessel waiting times at a port in Türkiye and investigated the reasons for these waiting times. Torosport Ceyhan, which is located in Ceyhan district of Adana province and whose general layout plan is shown in Figure 1, was selected as a sample. The selection of this port was influenced by the fact that it is an exclusive port serving third parties and that it serves the industrial and commercial hinterland of the region in which it is located. Torosport Ceyhan is a port that handles both liquid and solid bulk cargo. Torosport Ceyhan has a total of 9 berthing berths. Five of these berths can handle liquid cargoes while four berths can handle dry bulk cargoes.

Figure 1

Torosport Ceyhan Port General Site Plan



The research process was based on two main objectives. These objectives are as follows:

Objective 1. To identify and statistically describe the vessel waiting times in a given time period,

Objective 2. To identify and analyze the reasons for the identified vessel waiting times.

In order to achieve these objectives, a data collection process needs to be defined and this data needs to be subjected to a measurement/evaluation process.

Measurement Phase: Measurement is the second phase of the Six Sigma method. In this phase, data about the system is collected to determine the current situation and to understand the root causes of the problem.

Within the scope of Objective 1, the existing data collection procedure at the port was examined and data was obtained through the existing port automation in accordance with the research objectives. In

this context, the anchorage waiting times of the ships arriving at Torosport Ceyhan in the 24-month period between January 2022 and December 2023 were tracked before docking at the port. Since the maritime sector is affected by seasonality and some cyclical effects other than seasonality can also affect the ship berthing process over time, 2 full years were taken as the data collection period. The statistical analysis of the data obtained is presented in the findings section of the study.

Analysis Phase. The data obtained during the measurement phase is analyzed during the analysis phase. In this way, the root causes that prevent errors or the system from functioning at the desired level are identified. The basic logic in data analysis is to compare the business performance with the business objectives, to identify the differences and to make various analyzes for the research purpose.

The causes of the waiting times identified within the scope of Objective 1 (within the scope of Objective 2) were also queried through the existing port automation system. The data obtained as a result of the inquiries were subjected to Pareto analysis within the scope of Six Sigma studies. Pareto analysis is an important stage of the Six Sigma method. Since the root cause is identified with this analysis, the starting point of the problem solution is also determined. To do this, the frequencies of the factors that cause the problem are listed, and then the cause that affects 80% of the problem is determined. It is expected that there will be a small number of factors that cause 80% of the problem, therefore, by focusing on these factors, it is possible to reduce the impact of the problem by 80% (Coşkun, 2009). The results of the Pareto analysis conducted within the scope of the research are presented in the findings section of the research.

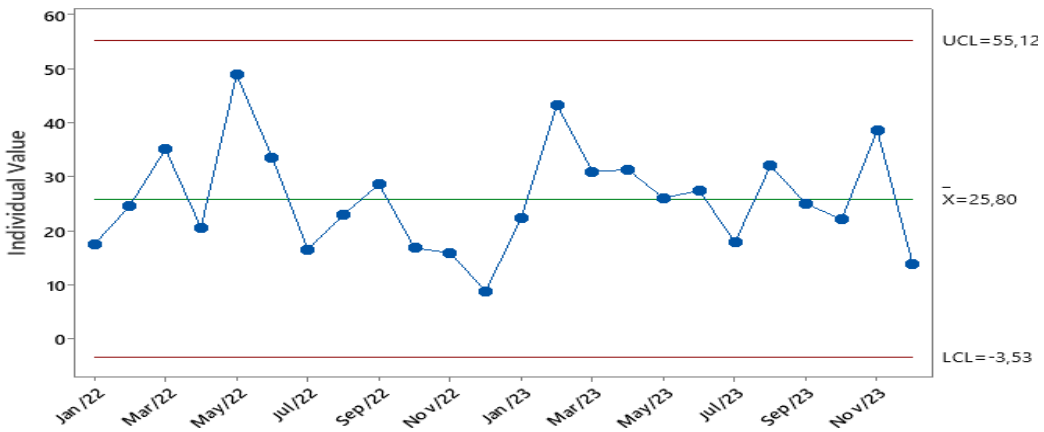
The two remaining processes in the Six Sigma methodology are the improvement and control phases. In the improvement phase, which follows the analysis phase, solutions are developed to eliminate the identified problem, and then these solutions are implemented. In the last step, the control mechanism, which is one of the basic steps of quality processes, is operated. In this way, it is understood whether the problem has been solved or not, and even whether the solution is permanent or not. The findings regarding these processes are presented in the conclusion section of the study.

3. Research Findings

Approximately 350 ships call at Torosport Ceyhan annually. According to the data obtained within the scope of Objective 1, in the 24-month period between 2022-2023, although the waiting time of the ships at anchor varies, the average waiting time at anchor is determined as 25.80 hours per ship as seen in Figure 2. This data is below the aforementioned average for Türkiye.

Figure 2

Torosport Ceyhan 2022-2023 Anchor Waiting Times (h)



On the other hand, within the scope of Objective 2, the reasons for these waiting times were investigated and prioritized through Pareto analysis. According to this, the highest reasons for waiting are as follows:

- Pier occupancy (56.8%),

- Bad weather conditions (11.8%),

- Agency instructions (7.6%),

- Bill of lading standby (5.5%),

- Customs clearance (4.7%),

- Other reasons (13.6%)

The reasons for the ships to wait at anchor are also shown in Figure 3 as a Pareto diagram. In Figure 3, the situations that cause the waiting times of the ships at Torosport Ceyhan are ranked according to their importance levels using the Pareto diagram and the cumulative ratios of waiting times and waiting times are shown. According to the detected waiting times, they are ranked from the left side from the largest to the smallest. According to the diagram, the most common cause of waiting time is "pier occupancy", which accounts for 56.8% of the total waiting time.

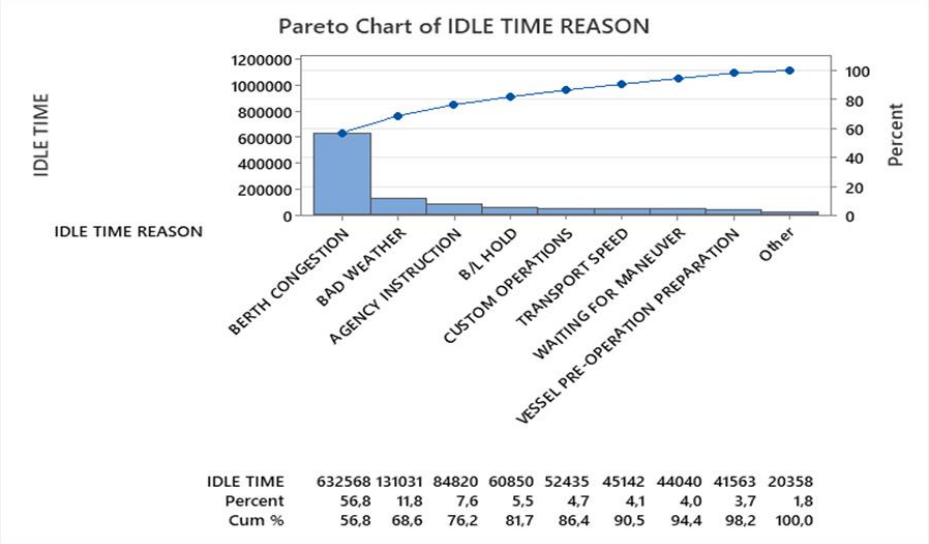
Some of these variables that cause ships to wait at anchor can be classified as "port based" and some as "non-port based". The identified reasons for waiting at anchor and explanations regarding these reasons are presented below.

- Pier Occupancy: It has been determined that pier occupancy is the main reason for the vessels to wait at Torosport Ceyhan anchorage area with a very dominant rate of 56.8%. As mentioned, there are 9 berthing berths in the port. This number is quite high when compared to the general number of port facilities in Türkiye. Despite this, the fact that pier occupancy is shown as the highest reason for ship waiting is an indication of the intense demand for the port. As a matter of fact, the port is one of the ports with the highest cargo handling volume in Türkiye, especially in the liquid chemical cargo type.
- Bad weather conditions: It was identified as the second most important reason with 11.8%. Weather conditions are a global variable with critical impacts on vessel and cargo operations.
- Agency instructions: This was identified as the third most important reason with 7.6%. The root cause of this problem is usually customer and shipowner dispute. The Port can add deterrent clauses to the contracts with the customer that can prevent these delays and increase the customer's motivation to solve the problem.
- Waiting for the bill of lading: The bill of lading, which represents the cargo and is a valuable document, sometimes takes a long time to arrive at the port from the place of issue. As can be seen, it was identified as the fourth most important reason with 5.5%. This is not an issue that the port management can take measures.
- Customs procedures: It was identified as the fifth most important reason with 4.7%. Customs procedures can be delayed for a wide variety of reasons, including the working order of the relevant public administration or delays in sample control procedures. The port operator is usually not primarily responsible for these reasons. However, the port operator can take corrective/preventive measures in the event of a slowdown caused by itself. Through the relevant non-governmental organizations, it can take initiatives before the relevant institutions to facilitate and accelerate the processes in customs procedures.
- Other reasons: With a total of 13.6%, other reasons include product shipment problems (4.1%), pilot waiting (4%), vessel readiness (3.7%) and other unexpected reasons. In order to minimize

shipment problems, in-port storage services could be improved. Other reasons are generally beyond the control of the port authority.

Figure 3

Reasons for Ships to Wait at Anchor



4. Conclusion and Evaluation

Ports are service producing enterprises. Efficiency measurement for service-producing enterprises is much more abstract than for product-producing enterprises. At this point, especially the perceptions of port users and their satisfaction levels in return for the services they receive are decisive. On the other hand, the fact that the services provided in ports are highly dependent on physical conditions, tools and equipment increases the relative effectiveness of productivity measurement. At this point, as in all process analyses, defining port service processes, considering the main halves of the processes, and determining the independent and dependent variables of each process make these efforts relatively more concrete and measurable. This is the basic approach philosophy in this study.

Within the scope of the study, first, the main operations in the ports were decomposed so that it was determined which of these operation processes to focus on. Measurements related to ship waiting are related to ship operations. At this point, the reasons why ships wait after arriving at anchorage areas were investigated. Although it may be a beautiful sight for some viewers, it is normally not desirable for merchant ships to wait for whatever reason. These ships should be on a cruise with their cargoes and carry out their operations without waiting in areas such as canals, straits or ports where they have to stop. In this study, the reasons for waiting at ports are analyzed through a case study.

With the analysis, a pilot port was selected and the existing data set in this port was subjected to various analyzes according to the research objectives. According to the research findings, the waiting of ships in port anchorage areas cannot be attributed only to port-related reasons. In addition to the operational weaknesses of the port, natural determinants such as weather conditions also have an important place in terms of the reasons for ships to wait at anchor. Moreover, the port is not the only party in a ship operation. Related customs units and ship agents may also cause ships to wait due to defects or failures. At this point, it would be appropriate to define the reasons for ships to wait at anchor as port based and non-port-based factors.

According to the findings of the study, it was revealed that ships were waiting at the port due to pier occupancy as a port-based factor. This factor also has the highest rate. The elimination of this problem of course depends on the construction and commissioning of additional piers in the port. Otherwise, the

port is likely to lose customers due to long waits. As a matter of fact, an investment is being made in this direction at the port and new piers are planned to be put into service in the near future. First of all, it is critical to analyze the factors that cause pier occupancy and evaluate the efficiency of the operation processes at the pier. On the other hand, this may also be a capacity problem. A concrete solution to this problem could be for the port to offer more berthing space. All other factors are non-port-based factors, and it should not be concluded that the port has no responsibility for non-port based factors. The port authority can minimize the waits caused by these problems by improving the communication and data exchange between the parties. For example, harsh weather conditions, rain, or high winds are sufficient reasons to stop ship and cargo operations. It is usually not possible to overcome adverse weather conditions. In fact, it is expected that weather conditions will become harsher and weather-related interruptions will increase even more due to changing climatic conditions in the world with global warming. However, effective berth planning can be done with instant ETA information that ships will share with the port while on voyage and artificial intelligence-supported planning programs.

This study was conducted on a specific port. Comparative analyses can be made by conducting similar applications with different ports. In addition, in the continuation of this study, especially qualitative research processes can be designed to evaluate the wishes and expectations of port users on the subject. Listening to the voice of the customer will always yield useful results.

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Article Information Form

Authors Contributions: All authors contributed equally to the writing of this paper. All authors read and approved the final manuscript.

Conflict of Interest Disclosure: No potential conflict of interest was declared by the authors.

Supporting/Supporting Organizations: No grants were received from any public, private or non-profit organizations for this research.

Ethical Approval and Participant Consent: It is declared that during the preparation process of this study, scientific and ethical principles were followed and all the studies benefited from are stated in the bibliography.

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