Analysis of Factors Influencing Ship's Maneuvering Times

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Ship maneuvering is like a musical piece where many internal and external factors must be managed simultaneously in a synchronized manner. While the prolongation of the maneuvering time increases hydrocarbon emission and operating costs, its acceleration threatens the safety of the maneuver. In the literature, there are many studies on the factors affecting the ship maneuver, but the number of studies on the effect of the factors influencing the ship maneuvering time is insufficient. This paper deals with the factors affecting berthing and departure maneuvers of ships in port areas on maneuvering time. The effects of environmental factors, ship structures, and human factors on the maneuvering time were examined separately. Contrary to popular belief, it has been revealed that the wind speed and direction, which are environmental factors, do not affect the maneuvering time in general. On the other hand, it has been found that length over all (LOA) and gross tonnage (GT), which are structural features of the ships, affect the maneuvering time. In human factors, it has been proven that the mean of the maneuvering times performed by the maritime pilots at the same jetty differs significantly from each other. In addition, variable regression analysis was performed in order to explain the relationship between ship's LOA and maneuvering time. For the purpose of this study, 3,998 ship maneuver data obtained from a pilotage organization were examined.

KEY WORDS
~ Maritime transport
~ Ship behavior
~ Ship maneuvers
~ Ship maneuvering time

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1. INTRODUCTION

Ship maneuvers are performed at a certain level of safety under environmental conditions. Maneuvering safety is not only related to environmental conditions, but also to berth features and ship particulars/characteristics (Nas and Altuğ, 2006).

To understand the importance of the study, it is first necessary to distinguish between the factors affecting ship maneuver and the ship maneuvering time. In this study, the effects of factors influencing ship maneuvering, such as wind, LOA, and gross tonnage, on ship maneuvering time were analyzed. Although there are many studies on the factors affecting ship maneuvering in the literature, there are few studies on the effect of these factors on ship maneuvering time. In addition, when the data were examined, it was found out that there were differences in the ship maneuvering times. It was discovered that even the same ships completed the maneuvers in different time spans. One of the aims of the study was to find out the reason for these differences. Ship maneuvering time affects port planning. Port stakeholders can mutually discuss differences in the maneuvering times. Meanwhile, the data on the maneuver operations obtained from a pilotage agency motivated us to carry out this study. These data refer to 3,998 maneuver data including the LOA, gross tonnage information, and the information about the wind speed-direction and operation times. Accordingly, regression analysis was performed to determine the relationship between the ship's LOA and its maneuvering time. In addition, the effects of environmental factors, ship structural features, and human factors on the maneuvering time were examined separately in the literature review on the factors affecting the ship maneuver.

Zhou et al. (2020) investigated the effects of wind and current on ship maneuvers with the regression analysis made with the data obtained from AIS. Xue et al. (2019) conducted a study based on Gray Relational Analysis Theory (GRA) to determine the degree of influence of wind speed-direction, current speed-direction, wavelength and water depth factors, which are environmental factors that affect the maneuver of autonomous and traditional ships. In this study, they concluded that the most influencing factor was wave direction, and the least influencing was wave height. On the other hand, Dang, Ho & Do (2018) analyzed the effects of wave, wind, and current on the ship maneuvering and stated that environmental factors were simulated in two different scenarios as large and small environmental impacts and stated that wind, current, and wave had effects on the maneuver.

In his study, Cınar (2020), wanted to determine which ships would be more appropriate to maneuver in different environmental conditions in the port area. In this direction, under the title of *Factors Related to the Port Area that Affect the Ship Maneuver*, the port area, width, depth, port entry depth, port navigation aids, height restriction, traffic condition, berthing area, and harbor lighting factors were determined.

Yucel (2020) determined the weights of the factors that make the docking/leaving-dock maneuvers of the ship difficult. In his study, depth, maneuvering-area type, condition of other ships at the jetties, use of tugboat, and LOA-GRT were evaluated during the analysis process.

Mei et al. (2020) created a ship maneuvering movement model by determining the specific coefficients of each of the environmental factors that cause the ships to drift. While creating the model, they based it on the wind, current, and wave data that affect the ship maneuver. In their study, Chen et al. (2013) stated that wind speed and direction, current, and wave had a symmetrical effect on ship maneuvering. They also concluded that wind had a greater effect on the drift distance and current had a greater influence on the drift angle. Szlapczynski and Krata (2018) introduced a conflict avoidance method called *Collision Threat Parameters Area* (CTPA). The inspected ships were affected by severe weather conditions. In this study, wind speed-direction and wave height were taken as variables and ship maneuvers were evaluated accordingly.

In the IMO's *Standards for Ship Maneuvering* circular, it is stated that ship maneuvers can be affected by factors such as wind, waves, and currents (IMO, 2002). In addition, the maritime pilot controlling the maneuver becomes an important factor as a human element. In other literature (MEB, 2017) supporting this, it is stated that a safe maneuver of the ship, regardless of tonnage, requires knowledge and experience. In addition, it is stated that only the knowledge of the maneuver is not sufficient to make a good maneuver, and an experienced captain should dynamically perceive and respond to the forces acting on the ship during the maneuver (MEB, 2017). Similarly, Cotter emphasized the human factor in ship maneuvers and considered ship maneuvering as the art of overcoming uncontrolled forces by using the forces at hand (Cotter, 1963). Also, Hekkenberg, van Dorsser and Schweighofer (2017) stated in their study that the ship's amount of propulsion power and the captain's behavior had a substantial impact on the attainable speed and fuel consumption of inland ships. As can be understood from this finding, performing a successful ship maneuver has its own fine touches. Therefore, it is expected that the maritime pilots and the ship master, who perform the maneuver operation, will have certain competencies. Central to these competencies is to perform port entrance, berthing, departure, and port exit maneuvers of ships at an acceptable level of safety (Nas, 2008). On the other hand, it is expected that the maneuver be completed as soon as possible by ensuring the efficiency in the use of the port area, berthing areas, and maneuver aids. As a result, the pilotage service given to the ship is a dynamic job and is done in varying ship type, quay, weather, sea and visibility conditions each time (Kahraman and Zorba, 2018).

Sukas et al. (2017) conducted a study on how to interpret the standard maneuvering tests proposed by the IMO. From their study it is understood that the estimations of the ship's maneuvering performance focus on the internal and environmental factors related to the ship's design, while the competence of the ship master and maritime pilot, who controls the ship's maneuvering, is ignored. In a study on the effect of human element on ship maneuvers, the relationship between fast berthing and ship accidents was examined (Oraith Hassan Mohammed, 2020). It was found out that the ship maneuvering speed can affect ship accidents at a rate of 64%.

The historical assumption that berthing speeds are strongly related to ship sizes appears to be unconfirmed. It was also found that there was no evidence to suggest that a fully loaded vessel had slower berthing speeds compared to empty vessels or partially ballasted vessels. In addition, it was stated that there was no relationship between wind speed (environmental factors) and berthing speed in the sheltered area. Furthermore, in the same study, it was concluded that especially strong (tidal) currents could result in docking at a much higher speed (Roubos, Groenewegen and Peters, 2017). Although the relationship between tides and berthing speed was determined here, no information was presented regarding the occurrence of this maneuver at an acceptable safety level. Moreover, in another study in which the risk assessment of the ship guidance process based on the cloud model in tidal ports was conducted, it was concluded that the ship's maneuvering safety could be greatly affected by the tide due to tidal ports (Guo et al., 2020). Wen Kai Kevin Hsu stated that accidents occurred most frequently during port berthing processes, and in his study, he proposed a *safety index* (SI) with a fuzzy AHP model to evaluate the *safety factors* (SFs) of the ship's berthing operations at the quay (Hsu, 2015).

In the literature, no research has been found that reveals the relationship between ship maneuvering time and the influencing factors. This lack of the literature creates the validity and reliability problems in the statistical modeling in port operations (Deniz Özkan, Uzunoğlu Koçer and Nas, 2022). It also creates uncertainties in port operation planning and assignment problems. In this study, the factors affecting ship maneuvering times were examined from the literature. On the other hand, it is understood that studies in this field are insufficient in the literature. For this reason, the opinions of experts were also considered. In the interviews with the experts, their opinions about the factors influencing ship maneuvering times in the port area were considered. It was found that besides environmental factors and the number of tugboats, fatigue of the personnel performing the maneuver also affected the maneuvering process. In addition, it was stated that the maneuvering styles of the pilots could also be influential on ship maneuvering times.

Ship operation data were requested from a port operator to statistically determine the relationships between ship maneuvering time and the factors influencing it. From the data obtained, the hypotheses were developed based on the literature, and expert opinions were tested using real port operation data.

2. RESEARCH METHODOLOGY

In this research, hypotheses were developed based on the related literature and expert opinions were tested by using real ship maneuver data from a port. These experts are the ship pilots who maneuver the ships in ports and who supported the work with their own expertise. The collected data are ship maneuvering data at jetties with similar berth features in a busy tanker terminal. The data include three years of maneuvering data on a total of three jetties.

Statistical analyses in the study were used in the SPSS 24 (Statistical Package for the Social Sciences) program, which is widely used in scientific studies. Tables other than Table 3 show the data obtained from this program.

XLSTAT program was used for Regression Analysis, and the analysis results are shown in Figure 2 and Figure 3. XLSTAT software relies on Microsoft Excel for the input of data and the display of results. This makes the software very convenient to share data and results. Computations are done using autonomous software components that are optimized for speed and efficiency. The XLSTAT results are benchmarked against other statistical packages so to always have reliable findings. The Addinsoft statistics add-ins offer a wide range of statistical and data analysis functions, ranging from descriptive statistics to multivariate data analysis. Many statistical add-ins for MS Excel exist. However, XLSTAT is the one that offers the largest number of analytical options(Gajbhiye, Waghmare and Parikh, 2017).

2.1. Research Model

In the study, the factors affecting the ship maneuver time were grouped according to the literature and expert opinions, and the research model shown in Figure 1 was developed. In the model, wind speed and direction were evaluated under the title of environmental factors, and length overall (LOA) and gross tonnage of the ship were evaluated under the title of ship structure. Maritime pilots are included in the model under the *human factor*, and the departure and berthing operations of the ships and the jetties are also included under this title.

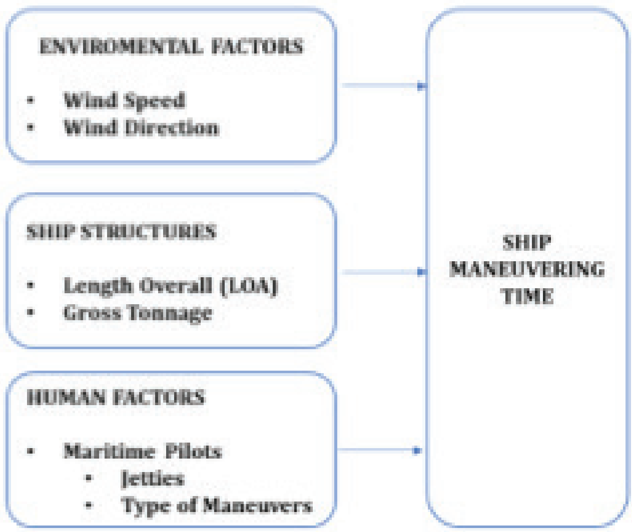

Figure 1.
Research model.

2.2. Hypotheses Development and Tests

Five main hypotheses were developed in order to analyze the relationships between the variables, which was shown in the research model. Each developed hypothesis is explained below with its sub-hypotheses based on the literature.

It had been found that there was a strong correlation between wind speed and difficulty of ship maneuvering (Jing et al., 2021). On the other hand, Roubos et al. did not reach the conclusion that the wind speed had an effect on the ship maneuvering speed (Roubos, Groenewegen and Peters, 2017). In addition, in the mathematical model developed by Park and Kim regarding ship berthing times, they suggested that effective berthing was not dependent on wind force (Park and Kim, 2014). In order to verify these different results, the following hypothesis was developed. Also, H_1 hypothesis was developed as two separate sub-hypotheses for both berthing and departure maneuvers.

- H_1: There is a significant relationship between wind speed and ship maneuvering times.
- $H_{1.1.}$: There is a significant relationship between wind speed and ship berthing maneuvering time.
- $H_{1.2.}$: There is a significant relationship between wind speed and ship departure maneuvering time.

Jing et al. (2021) found that there was a weak correlation between *wind direction* and the *difficulty of ship maneuvering*. In this direction, H_2 hypothesis has been developed in order to determine the relationship between the *jetties, maneuver types* and *wind direction* where maneuvers are performed with the mean value of maneuvering times.

- H_2: There is a significant difference between the mean value of ship maneuvering times under windward and leeward wind conditions at the jetties.
- $H_{2.1.}$: There is a significant difference between the mean value of the ship berthing times performed under windward and leeward wind conditions at Jetty A.
- $H_{2.2.}$: There is a significant difference between the mean value of the ship departure times performed under windward and leeward wind conditions at Jetty A.
- $H_{2.3.}$: There is a significant difference between the mean value of the ship berthing times performed under windward and leeward wind conditions at Jetty B.
- $H_{2.4.}$: There is a significant difference between the mean value of the ship departure times performed under windward and leeward wind conditions at Jetty B.
- $H_{2.5.}$: There is a significant difference between the mean value of the ship berthing times performed under windward and leeward wind conditions at Jetty C.
- $H_{2.6.}$: There is a significant difference between the mean value of the ship departure times performed under windward and leeward wind conditions at Jetty C.

In the study carried out by Mizuno at al., the aim was to perform the ship maneuver in minimum time by using the mathematical ship motion model. The full length and gross tonnage of the ship's structural features were included in the calculations (Mizuno et al., 2007). On the other hand, in the study conducted by Zhou et al. (2020), in which the effect of environmental conditions on the ship maneuvering process was examined, it was found that with the increase of the LOA of ships, the more affected by environmental factors such as wind and current they were (Zhou et al., 2020b) . This situation led us to the hypothesis that *gross tonnage* and s*hip's LOA* could be related to *maneuvering time*. In this context, the main hypotheses H_3 and H_4 have been developed. As previously, the main hypotheses were each analyzed as two separate sub-hypotheses for the berthing and departure maneuvers.

- H_3: There is a significant relationship between ship gross tonnage and ship maneuvering times.
- $H_{3.1.}$: There is a significant relationship between ship's gross tonnage and ship berthing maneuvering time.
- $H_{3.2.}$: There is a significant relationship between ship's gross tonnage and ship departure maneuvering time.
- H_4: There is a significant relationship between ship's LOA and ship maneuvering times.
- $H_{4.1.}$: There is a significant relationship between ship's LOA and ship berthing maneuvering time.
- $H_{4.2.}$: There is a significant relationship between ship's LOA and ship departure maneuvering time.

In a study in which the maneuvering times of ships were analyzed (Okazaki and Ohtsu, 2008), minimum time calculation methods were developed. In these calculations, it is recommended that the captains and pilots controlling the ship should do the berthing processes through automatic systems instead of the stress of maneuvering as soon as possible. In another study on the minimum berthing time methods of ships, the geometric features of berthing were determined and the attempt was made to determine which ships completed the berthing maneuver in a shorter time (Okazaki, Ohtsu and Mizuno, 2000). In this context, The H_5 main hypothesis has been examined under separate sub-hypotheses for maritime pilots' maneuvering times at each jetty and maneuver types.

- H_5: There is a significant difference between the mean value of the ship maneuvering times performed by the Maritime Pilots at the Jetties.
- $H_{5.1.}$: There is a significant difference between the mean value of the ship berthing times of the maritime pilots at jetty A.
- $H_{5.2.}$: There is a significant difference between the mean value of the ship departure times of the maritime pilots at jetty A.
- $H_{5.3.}$: There is a significant difference between the mean value of the ship berthing times of the maritime pilots at jetty B.
- $H_{5.4.}$: There is a significant difference between the mean value of the ship departure times of the maritime pilots at jetty B.
- $H_{5.5.}$: There is a significant difference between the mean value of the ship berthing times of maritime pilots at jetty C.
- $H_{5.6.}$: There is a significant difference between the mean value of the ship departure times of maritime pilots at jetty C.

2.3. Data Collection

The data used within the scope of the research are secondary-source data used in port projects made at Dokuz Eylul University Maritime Faculty and for whose usage permits have been obtained. Similar ship characteristics in the selected port and ship maneuver data obtained at jetties close to each other were used. The data include a total of 3,998 ship berthing and departure operations carried out by 6 maritime pilots at 3 jetties between 01 January 2010 and 28 November 2013. The data analyzed in the study were taken from the Ship Operations Tracking System of the port. The data were requested from the port operation authorities, but only the data on the specified dates were obtained. In the study, *LOA, gross tonnage, wind speed, wind direction, maneuver type, maneuvering time, maneuvered jetty, maritime pilot*, were accepted as the variables of the research.

2.4. Findings

Secondary-source data obtained during the research process were analyzed using the SPSS 24 program. Jetties are coded as A, B and C due to the confidentiality of the data, and each maritime pilot is coded as 1, 2, 3, 4, 5, and 6. Jetties A, B, and C are jetties that have similar features and serve tankers. Their positions are shown in Figure 2. The largest jetty is Jetty C and is listed as B and A respectively. Statistical data on the number of maneuvers and ship dimensions at the selected jetties of the port are shown in Table 1. As seen in Table 1, the most frequently used jetty is B, and it is understood that the jetty used by the largest ships is C.

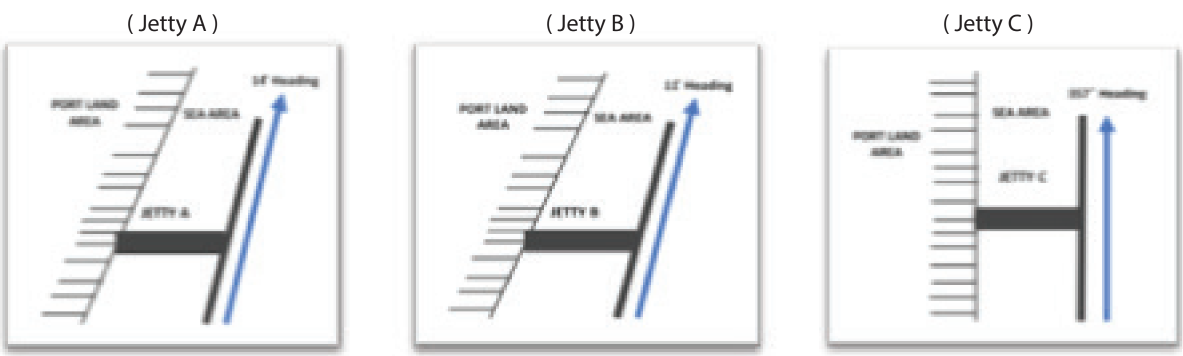

Figure 2.
Jetties and positions.

Table 1.
Frequency analysis of numbers of ship maneuver performed at jetties.

FREQUENCY ANALYSIS OF SHIP MANEUVER				
Jetty Code	Numbers of Maneuvers	Percentage (%)	Mean LOA (m)	Mean GRT (mt)
A	1,507	37.69	149.30	16,966.82
B	1,735	43.40	128.30	9,257.38
C	756	18.91	238.70	61,271.09
Total	3,998	100%	157.08	21,975.58

In the study, the maritime pilots were analyzed using their code numbers instead of their names. Accordingly, the frequency analyses of the number of maneuvers performed by the maritime pilots maneuvering on the jetties are shown in Table 2. According to Table 2, it is understood that the maritime pilot with the highest number of maneuvers is the pilot code 4, while the one with the lowest number of maneuvers is the pilot code 1.

Table 2.
Frequency analysis of maritime pilots' maneuver numbers.

BERTHING MANEUVERS			DEPARTURE MANEUVERS		
Pilot Code	Number of Maneuvers	Percentage (%)	Pilot Code	Number of Maneuvers	Percentage (%)
1	194	09.66	1	178	08.94
2	487	24.25	2	459	23.06
3	364	18.13	3	376	18.89
4	518	25.80	4	528	26.53
5	230	11.45	5	239	12.01
6	215	10.71	6	210	10.55
Total	2,008	%	Total	1,990	%

Wind data, which are thought to affect the ship maneuvers during the operation, are included in the analysis as speed and direction. Considering the geographical direction of each selected jetty, it has been considered that the maneuvers are carried out under windward and *leeward wind* conditions. In addition, wind speeds during the maneuver are also considered as another variable. The analysis of the *berthing and departure maneuvers* among the ship maneuvers is shown in Table 3.

Table 3.
Wind directions considering ship's position at jetties.

WIND DIRECTIONS			
Leeward	Windward	Forward	Aftward
NE	NW	NNW	SSE
ENE	WNW	N	S
E	W	NNE	SSW
ESE	WSW	-	-
SE	SW	-	-

3. HYPOTHESES TESTS

The statistical relationship between the wind speed with the mean of maneuvering times was analyzed by applying the correlation test in the H_1 hypothesis. For this purpose, primarily the variables were subjected to the normality (Kolmogorov-Smirnov) test. By the tests performed, it was found that none of the variables showed a normal distribution. For this reason, the *Spearman correlation test* was preferred for the hypotheses. The results of each hypothesis were classified according to *jetties* and *maneuver type*. The results are shown in Tables 4. In the H_1 hypothesis, in which the relationship between *wind speed* and *maneuvering time* was tested, it was found that the relationship between them had different significance levels according to the type of maneuvering. No significant relationship was found between *maneuvering time* and *wind speed* in berthing maneuvers at any pier. On the other hand, a weak significant correlation was found in the *departure maneuvers* performed only at *jetty A* and *jetty B*. In general, it is understood that there is no significant relationship between *maneuvering time* and *wind speed*.

Table 4.
Correlation test results between maneuvering time with wind for each jetty.

	JETTY A	JETTY B	JETTY C
	$H_{1.1.}$	$H_{1.1.}$	$H_{1.1.}$
MANEUVERING TIME FOR BERTHING (Correlation Coefficient / Sig.)	0.056/0.125	-0.029/0.394	-0.049/0.337
	$H_{1.2.}$	$H_{1.2.}$	$H_{1.2.}$
MANEUVERING TIME FOR DEPARTURE (Correlation Coefficient / Sig.)	0.086/0.019*	0.124/0.000*	0.084/0.109

In the previous hypothesis tests, a clear relationship between the *maneuver time* and *wind speed* could not generally be determined. In H_2 hypothesis, the effect of *wind direction* on *maneuvering time* was attempted to be analyzed. As stated before, considering the geographical directions of the jetties, wind directions are classified as *windward* and *leeward*. In the H_2 hypothesis, it was examined whether there was a significant difference between the means of maneuvering time performed in the wind conditions that were *determined* as windward and leeward. For this purpose, primarily the variables were subjected to the normality (Kolmogorov-Smirnov) test. In the tests performed, it was determined that none of the variables showed a normal distribution. Thereupon, the data of the mean of maneuver times of each wind direction were analyzed with the *Mann-Whitney U test*. The results of each hypothesis were classified according to jetties and maneuver type, and are shown in Table 5. According to the test results, it has been concluded that there is no statistical difference between the mean of maneuvering time of the windward and leeward winds in the ship maneuvering performed at all jetties.

Table 5.
Mann-Whitney U Test result mean of maneuvering times according to wind direction.

Hypothesis		Jetty Code	Number of Maneuvers	MEAN of MANEUVERING TIME			CONCLUSION	
				Mean Time (min)	Windward (min)	Leeward (min)	Significant (p)	Conclusion
BERTHING	$H_{2.1.}$	A	763	46.8	49.7	47.6	.307	HYPOTHESIS REJECTED
	$H_{2.3.}$	B	862	38.4	35.2	38	.291	
	$H_{2.5.}$	C	383	77.3	79.5	81	.560	
DEPARTURE	$H_{2.2.}$	A	744	24.4	23.4	24.1	.773	HYPOTHESIS REJECTED
	$H_{2.4.}$	B	873	20.6	20.4	20.2	.941	
	$H_{2.6.}$	C	373	33.3	32.5	32.8	.921	

The statistical relationship between the ship gross tonnage and LOA with the mean maneuvering times was analyzed by applying the correlation test in H_3 and H_4 hypotheses. For this purpose, primarily the variables were subjected to the normality (Kolmogorov-Smirnov) test. In the tests performed, it was found that none of the variables showed a normal distribution. For this reason, the *Spearman correlation* test was preferred for the hypotheses. The results of each hypothesis were classified according to the jetties and maneuver type. The results are shown in Tables 6, 7, and 8.

Table 6.
Correlation test results of maneuvering time for jetty A.

	GROSSTON	LOA
	$H_{3.1.}$	$H_{4.1.}$
MANEUVERING TIME FOR BERTHINGS (Correlation Coefficient / Sig.)	0.817/0.000*	0.807/0.000*
	$H_{3.2.}$	$H_{4.2.}$
MANEUVERING TIME FOR DEPARTURES (Correlation Coefficient / Sig.)	0.689/0.000*	0.693/0.000*

Table 7.
Correlation test results of maneuvering time for JETTY B.

	GROSSTON	LOA
	$H_{3.1.}$	$H_{4.1.}$
MANEUVERING TIME FOR BERTHINGS (Correlation Coefficient / Sig.)	0.648/0.000*	0.649/0.000*
	$H_{3.2.}$	$H_{4.2.}$
MANEUVERING TIME FOR DEPARTURES (Correlation Coefficient / Sig.)	0.543/0.000*	0.522/0.000*

Table 8.
Correlation test results of maneuvering time for jetty C.

	GROSSTON	LOA
	$H_{3.1.}$	$H_{4.1.}$
MANEUVERING TIME FOR BERTHINGS (Correlation Coefficient / Sig.)	0.582/0.000*	0.581/0.000*
	$H_{3.2.}$	$H_{4.2.}$
MANEUVERING TIME FOR DEPARTURES (Correlation Coefficient / Sig.)	0.242/0.000*	0.243/0.000*

In H_3 and H_4 hypotheses, in which the relations between the structural features of the ship, such as LOA and GRT, and the maneuvering time were tested, it was found that the relations between them were significant, positive, and moderate in each type of maneuver. *Univariate regression analysis* was performed to measure the relationship between LOA and maneuvering time. In the previous tests of normality (Kolmogorov-Smirnov), it was found that the variables did not show normal distribution. For this reason, *nonparametric regression analysis* was preferred. The regression curves developed according to the maneuver type are shown in Figures 3 and 4. In addition, the linear equations of the regression curves were analyzed in the XLSTAT program, and the regression formulas of the relations between LOA and maneuvering time according to the maneuver type were also obtained and shown under their own curves.

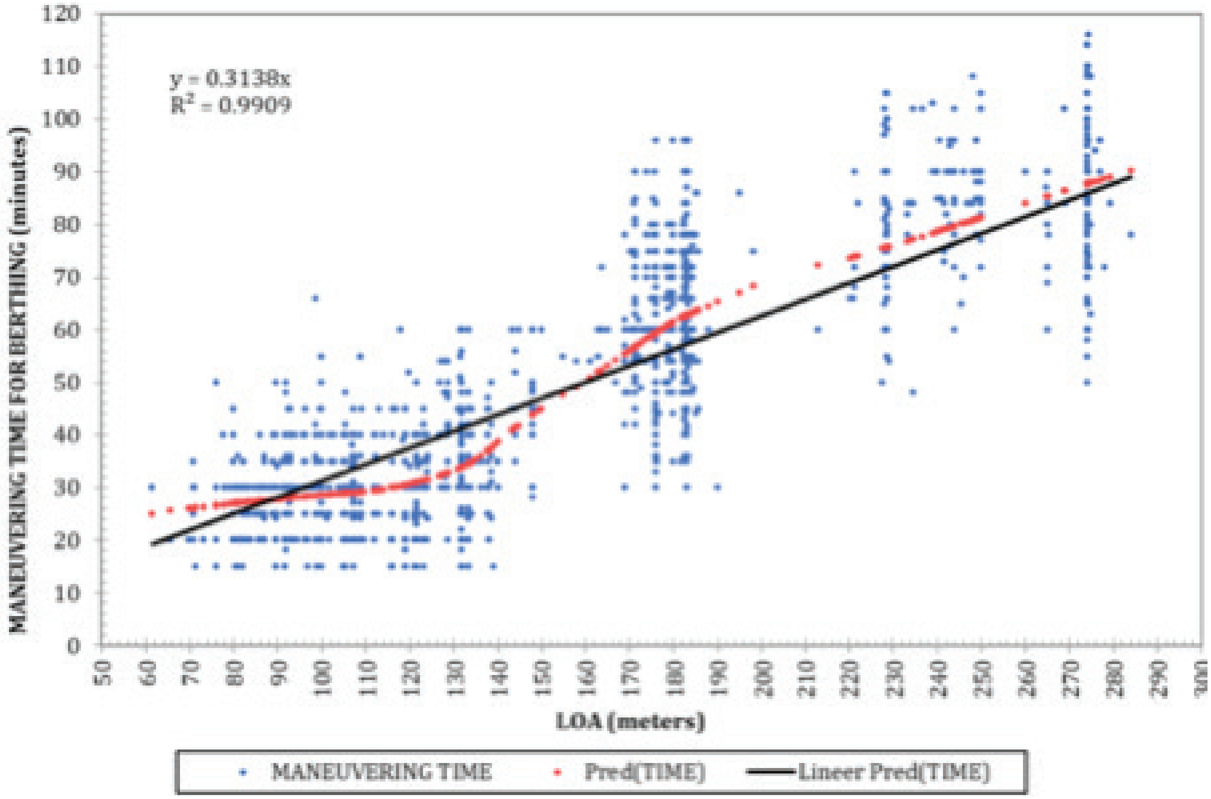

Figure 3.
Nonparametric Regression Analysis results between LOA and maneuvering time for berthing operations.
Maneuvering Time for Berthing=0.3138 (Ship's Lenght Overall).

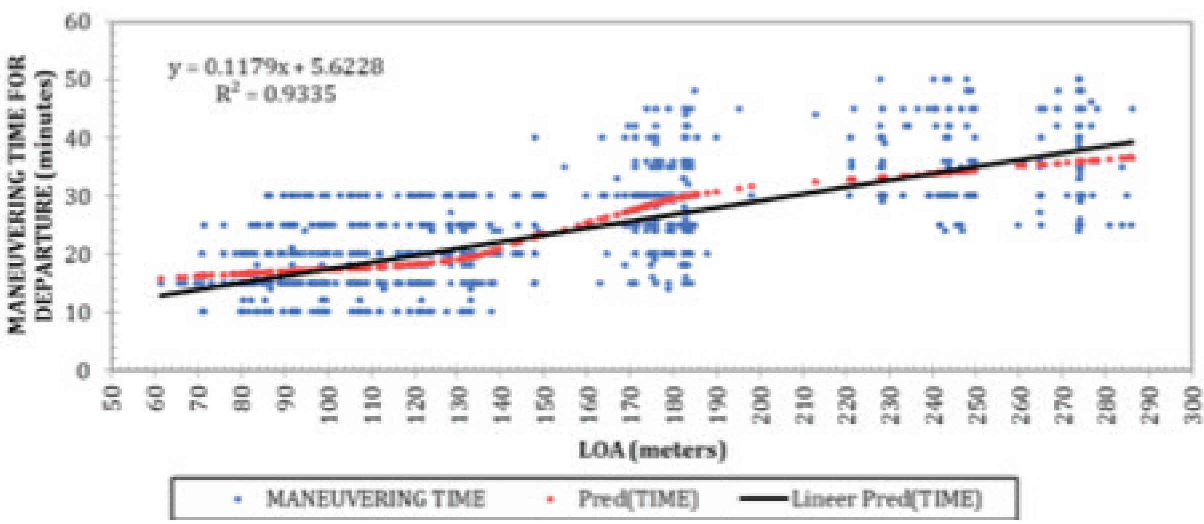

Figure 4.
Nonparametric Regression Analysis results between LOA and maneuvering time for departure operations.
Maneuvering Time for Departure=0.1179 (Ship's Lenght Overall)+5.6228.

In H5 hypothesis, it was examined whether there were significant differences among the means of the maneuvering times of the pilots. For this purpose, primarily the variables were subjected to the normality (Kolmogorov-Smirnov) test. In the tests performed, it was found that none of the variables showed a normal distribution. Thereupon, the data of the mean of maneuver times of each pilot were analyzed with the *Kruskal-Wallis test*. The results of each hypothesis were classified according to jetties and maneuver type. The results are shown in Tables 9, 10, and 11. According to the tables, it is understood that the pilot with ID number 5 performed maneuvers at jetties A with B and had the shortest mean of maneuvering time in both berthing and departure maneuverings at these jetties. On the other hand, it is understood that the pilot with ID number 1 has the longest mean of maneuvering time in the departure maneuverings performed at all jetties. In addition, it is understood that pilot with ID number 3 has the longest mean of maneuvering time in berthing maneuverings performed at all jetties. When H_5 hypothesis was evaluated, it was concluded that the difference between the mean of maneuvering times of each pilot was significant. Eventually, these results show us that pilots have independent maneuvering styles in terms of maneuvering speed.

Table 9.
Kruskal-Wallis test results for mean of maneuvering times of pilots at jetty A.

Hypothesis		Normality Test sig. (Kolmogorov-Smirnov)	Pilot ID	Number Of Maneuver	Mean Time (min.)	df	CONCLUSION	
							p(significant)	Conclusion
BERTHING	$H_{5.1.}$	.000	1	69	50.5	5	.000	HYPOTHES IS ACCEPTED
			2	185	46.0			
			3	139	56.3			
			4	191	45.1			
			5	97	32.2			
			6	82	51.2			
			Total	763	46.8 min			
DEPARTURE	$H_{5.2.}$	.000	1	61	29.2	5	.000	HYPOTHES IS ACCEPTED
			2	171	23.9			
			3	136	25.3			
			4	206	26.2			
			5	99	16.3			
			6	71	25.5			
			Total	744	24.4 min			

Table 10.
Kruskal-Wallis test results for mean of maneuvering times of pilots at jetty B

Hypothesis		Normality Test sig. (Kolmogorov-Smirnov)	Pilot ID	Number Of Maneuver	Mean Time (min.)	df	CONCLUSION	
							p(significant)	Conclusion
BERTHING	$H_{5.3.}$	.000	1	85	35.7	5	.002	HYPOTHES IS ACCEPTED
			2	190	38.6			
			3	143	42.0			
			4	219	39.8			
			5	133	33.4			
			6	92	38.7			
			Total	862	38.4 dk			
DEPARTURE	$H_{5.4.}$	.000	1	84	22.4	5	.000	HYPOTHES IS ACCEPTED
			2	179	19.4			
			3	155	21.9			
			4	223	22.2			
			5	140	16.9			
			6	92	20.9			
			Total	873	20.6 dk			

Table 11.
Kruskal-Wallis test results for mean of maneuvering times of pilots at jetty C.

Hypothesis		Normality Test sig. (Kolmogorov-Smirnov)	Pilot ID	Number Of Maneuver	Mean Time (min.)	df	CONCLUSION	
							p(significant)	Conclusion
BERTHING	$H_{5.5.}$	.000	1	40	76.1	5	.003	HYPOTHES IS ACCEPTED
			2	112	73.0			
			3	82	86.3			
			4	108	74.6			
			5	0	0			
			6	41	79.3			
			Total	383	77.3			
DEPARTURE	$H_{5.6.}$	.000	1	33	38.5	5	.000	HYPOTHES IS ACCEPTED
			2	109	31.9			
			3	85	29.7			
			4	99	34.5			
			5	0	0			
			6	47	36.7			
			Total	373	33.3			

4. DISCUSSION AND CONCULSION

It has been found out that the statistical studies in which ship's port maneuvers are analyzed are extremely limited in number. For this reason, this research will contribute to filling the gap in the literature on maritime transportation engineering and port management. In this study, environmental factors, ship structures and human factors influencing ship maneuvers were taken as independent variables and their effects on maneuvering times were examined. Many new sub-variables such as ship type, ship age, current effects, tide and maneuvering aids used can be added within the scope of the 3 main factors, as well as new main factors such as terminal types. The main factors and sub-variables selected in this study constitute the limitations of the study. The *maneuvering time*, which is taken as a dependent variable, constitutes an output of all maneuvering factors. Apart from this, although dependent variables such as maneuvering satisfaction of the parties, maneuver safety and risk level can be defined, the maneuver time variable used in this research is based on deterministic measurements.

The main factors addressed in the model and hypothesis tests developed based on the literature were evaluated in terms of ship maneuvering time. It has been found that wind speed and direction, which are considered independent variables, do not affect the maneuver time as expected. In general, it is understood that there is no significant relationship between maneuvering time and wind speed. It has been found that the results obtained in this study support the results of Park et al. (2014) and Roubos et al. (2017). Contrary to expectations, it was found that the wind direction did not have an effect on the ship's maneuvering time. According to the test results, it has been found that there is no statistical difference between the mean of maneuvering time of the windward and leeward winds in the ship maneuvering performed at all the jetties. This result was found to support the results of Jing's (2021) study. The reason why the effect of environmental factors on the ship's maneuvering time was not very low or significant was interpreted as the fact that the ship's machinery and the tugboat force used were strong enough to meet the effect of the wind during maneuverings.

The effect of ship's structural factors, such as LOA and GRT values, on ship maneuvering time has been investigated. It was found that the relations between LOA / GRT and maneuvering time were significant, positive, and moderate in each type of maneuver. This result was found to support the results of Zou et al. (2021) study. In addition, a formula was developed using the results of regression analysis between LOA and maneuvering speeds. It is thought that the developed formula can be used in statistical modeling studies in port management.

Maneuvering times of the pilots who took over the conn of the ship in port maneuvering operations were analyzed. It has been found that the mean of maneuvering time performed by the different pilots differs significantly. Eventually, these results show us that pilots have independent maneuvering styles in terms of maneuvering times. Tonnage restriction is applied for the ships that the pilots will maneuver due to their service time. Due to this restriction, the pilot with ID number 5 is not allowed to maneuver at jetty C, the largest one. Trying to speed up the ship's maneuvering or putting the pilots in a performance race in this regard will cause great risks. The most important factor here is that the pilot completes the maneuvering safely within reasonable time using his own maneuvering style.

In this study, the constraints related to the factors that may affect the ship maneuverings arise from the data obtained. It is thought that the repetition of similar studies in terminals under wave, current and tide effect is important to fill the gap in the literature.

CONFLICT OF INTEREST:

The authors declare no conflict of interest.

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