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Estimating the ship traffic in the Istanbul Strait through economic growth of region countries

İstanbul Boğazı'ndaki gemi trafiğinin bölge ülkelerinin ekonomik büyümeleri aracılığıyla tahmin edilmesi

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Abstract

The current study predicts the future course of ships passing through the İstanbul Strait. In this direction, considering that the world economy is the biggest factor in the demand for maritime transport, the relationship between the GDPs and trade volumes of the Black Sea states, and ship traffic is analyzed using regression estimation in two separate models. The included countries are Bulgaria, Georgia, Romania, Russia, Turkey and Ukraine. Then, considering the growth forecasts published by the IMF for the relevant states, it was estimated how much an increase in traffic would be in 2026 compared to 2020. Considering the coefficients obtained from the two models, in 2026, the GDP model proposes a 20.02% increase, and the trade volume model proposes a 28.8% increase in ship tonnage passing the strait. These results reveal the importance and necessity of strategies and projects developed to regulate the rise in strait traffic.

Keywords: Strait, Passage, Istanbul, Economic Growth

Jel Codes: C22, O11, R41

Öz

Bu çalışmanın amacı, İstanbul Boğazı'ndan geçen gemi miktarının gelecekteki seyrini tahmin etmektir. Bu doğrultuda, dünya ekonomisinin deniz taşımacılığına olan talepteki en büyük etken olduğu düşünülerek, Karadeniz devletlerinin GSYİH'leri ve ticaret hacimleri ile gemi trafiği arasındaki ilişki regresyon analizi kullanılarak iki ayrı modelde analiz edilmiştir. Araştırmaya dahil edilen ülkeler Bulgaristan, Gürcistan, Romanya, Rusya, Türkiye ve Ukrayna'dır. Daha sonra IMF'nin ilgili ülkeler için yayınladığı büyüme tahminleri dikkate alınarak 2026 yılında 2020 yılına göre trafikte ne kadar artış olacağı hesaplanmıştır. Elde edilen katsayılar göz önünde bulundurulduğunda, boğazdan geçen gemi miktarı 2026 yılında GDP modeline göre %20,2, ticaret hacmi modeline göre ise %28,8 artış gösterecektir. Bu sonuçlar, boğazdaki artışı düzenlemek için geliştirilen strateji ve projelerin önemini ve gerekliliğini ortaya koymaktadır.

Anahtar Kelimeler: Boğaz, Geçiş, İstanbul, Ekonomik Büyüme

JEL Kodları: C22, O11, R41

Introduction

The Istanbul Strait is one of the most important and busy natural narrow waterways globally. In addition to military and commercial ships carrying cargo and dangerous goods every day, regional voyages that transport millions of passengers between the city's two sides are organized. All this intensity continues every day despite the geographical condition of the strait, its narrowness, strong currents, sharp bends and uncertain weather conditions (Directorate General of Coastal Safety, 2021). Also, the local traffic between two sides of the strait, which has many transit ships per day, increases in parallel with the increasing population. Moreover, due to the developing technology and changing production techniques, there is an increase in ships' length, width, and tonnage passing through the strait. Considering that some ships carry dangerous cargo, this situation complicates the strait traffic due to adverse weather conditions, climatic changes, environmental concerns, and an increased probability of accidents. Above all, it is more critical that above 10 million people living in Istanbul may face huge dangers caused by Maritime Traffic at any moment. There were 461 maritime accidents in the Istanbul Strait between 1953 and 2002 (Akten, 2003, p. 263), and 584 accidents happened between 2001 and 2015 (AAKKM, 2020). Depending on these statistics and studies on this issue, maritime accidents increase in parallel with the increasing ship traffic (Weng, Liao, Wu, and Yang, 2020; Görçün and Burak, 2015;Ulusçu, Özbaş, Altıok, and Or, 2009). With the Turkish Straits Vessel Traffic Service (TSVTS) established in 2003, there has been a significant decrease in maritime accidents in the Strait. Still, the growth in marine trade predicted until 2023 will increase the risk of accidents (Kodak and Acarer, 2021, p. 202). It is obvious that the dangers to be caused by the accident that will occur because of this high tanker traffic, in the historical and natural environment of the Turkish Straits, will be high. Even these dangers will not be less dangerous than the dangers that will arise because of the possibility of an earthquake in Istanbul, which is spoken from time to time. The risks experienced in the Independenta (1979) and Nassia (1994) accidents that occurred in the Istanbul Strait in the past years can be given as an example (Kubilay, 2014). In addition to marine pollution and deaths caused by accidents, the Strait was closed to sea traffic for a long time. Hundreds of ships accumulated at the entrances of the Strait, urban transportation and city life were greatly affected. To make the heavy maritime traffic in the straits safer Turkish Straits Vessel Traffic Services has been established since 2003.

It is planned to conduct the Canal Istanbul project in a few years. Some people discuss the construction of this channel. This study reveals the Istanbul Strait's traffic load shortly. Considering the accidents above and their consequences, it becomes essential to determine the Istanbul Strait's traffic load in the future. To estimate the traffic, we used the economic and commercial volumes of the countries bordering the Black Sea, based on the derived demand structure of maritime transport. Because of the economic and commercial activities in the region increase, the demand for maritime transportation will increase with increasing demand for raw materials and final products. The included countries are Bulgaria, Georgia, Romania, Russia, Turkey and Ukraine in alphabetical order. Therefore, we used tonnage volume data to estimate the traffic rather than the number of ships. This application is due to the growth in average ship sizes in the last decades. Although the number of vessels passing through the strait seems to be decreasing, average ship sizes are increasing, and the total tonnage passing is rising. We estimated two separate logarithmic regression models as the tonnage of ships passing through the strait is a dependent variable, and total GDP and total trade volume of six countries are independent variables. Then, we made forecasts about the tonnage of ships passing through the strait by using the growth values up to 2026 by the IMF. In this way, the shipload in the channel has been empirically modelled, and predictions have been made for the possible needs for developing traffic-relieving systems and projects. According to the results we have obtained, it has been determined that the vessel traffic that will pass through the Istanbul Strait in 2026 will increase significantly in terms of tonnage.

The second part of the study investigates factors affecting navigation in the Istanbul Strait. In the third part, the traffic structure in the strait is presented, and possible reasons for the change in average ship size is discussed. In the fourth part, factors affecting the demand for maritime transport are examined. The dataset and method used in the research are introduced in the fifth part. Finally, the regression model results are presented in the sixth part.

Factors affecting the ship's navigation in Istanbul Strait

Among the 265 straits globally, the Turkish Straits are unique in terms of their physical, hydrographic and oceanographic structure (İstikbal, 2001, p. 77). The Istanbul Strait is the sea passage located in the Turkish Straits Region and connects the Black Sea to the Maramara. The Strait is the busiest waterway in the world after the Strait of Malacca in terms of the number of ships crossing, and it is the only waterway that stands out with the danger of maritime accidents among its peers on the world maritime trade network (Köse, Başar, Demirci, Güneroğlu, and Erkebayet, 2003; Rodrigue, 2004; Görçün and Burak, 2015; Akkaya Bas, Christiansen, Amaha Öztürk, Öztürk, and McIntosh, 2017; Altan and Otay, 2017; Korçak and Balas, 2020). Maritime accidents increase in parallel with the increasing ship traffic (Weng et al., 2020; Görçün and Burak, 2015; Ulusçu et al., 2009). The physical features of the Strait restrict the manoeuvrability of ships passing through the region and trigger the occurrence of accidents (Kodak and Acarer, 2021, p. 183). Taking a pilot in the Strait is not compulsory for every ship. The lack of pilotage is the most significant risk factor for Strait (Özbaş, Or, Altıok, 2013, p. 558; Ulusçu et al., 2009). The current system, wind direction and wind speed dynamics affect maritime traffic in the region. A ship passing through the Istanbul Strait, one of the most challenging routes for vessels on the world maritime trade network, must make a wide-angle turn at eight different points (DNV, 2013). The passage is 17 nautical miles long, has an average width of about 7,5 cables and has the feature of being a waterway with a high accident risk due to its narrow and curved shape and its variable currents (Akten, 2003, p. 263). There are four different currents in the Strait: surface currents, undercurrents, reverse currents and Orkoz, which adversely affect navigational safety by making it difficult for ships to manoeuvre (Kodak and Acarer, 2021, p. 185). According to the daily wind directions obtained from the Turkish State Meteorological Service, the dominant winds from the north strengthen the southward currents and weaken the manoeuvrability of the ships. The strait resembles a river with abrupt and angular windings. Due to the infrastructure works conducted in the Strait, the ships' waiting times increase, making it difficult to control the ship traffic. In addition to the traffic problem, this intensity would increase the number of ship accidents (Köse et al., 2003, p. 606; Or, Sevilir, Erkut, 1999, p. 47–60). Many small vessels fish in the fairway of Istanbul strait, and at night, these and numerous other small plates move about unlit. Another hazard is the random use of searchlights by ferries trying to avoid this craft. A traffic separation scheme has been established through Istanbul Strait. Eddies occupy some bays. The current typically occupied the whole strait and occasionally reached a strength of 7 knots (Admiralty Sailing Directions, 2010, p. 112). Ships crossing the Istanbul Strait in the north-south direction or vice versa must change course at least 12 times. The safe passage depth in the Strait is 30–60 meters on average, and the deepest point is 110 meters off Kandilli. The depth is not a significant risk factor in ship crossings (İnceli, 1968, p. 12). We can list the most risky regions that adversely affect the navigation in the Istanbul Strait, which has many shallows, capes, bays and even islets as follows: Salacak, Kandilli, Arnavutköy, Akıntı, Kanlıca, Yeniköy capes, Bebek, İstinye, Beykoz, Tarabya Bays, Sarayburnu, the Maiden's Tower, Umuryeri, Yeniköy, Büyükliman shoals, and in addition to these, the Maiden's Tower, Kuruçeşme, Bebek, Dikilitaş islet that makes navigation difficult and require a lot of attention can be counted (İnceli, 1968, p. 12; Türk Boğazları Seyir Güvenliği, 2000).

Such an intense and risky passageway has also found a vast place in the academic literature. The studies conducted on the topic of the Istanbul Strait are presented in Table 1. The table shows the name, authors, type, and study results in chronological order. Most accidents and collision issues have been examined empirically and theoretically in the studies. As a result of the investigations, it has been determined that factors such as traffic density, difficulty in manoeuvring, terrible weather conditions, lack of piloting, local traffic density increase the probability of an accident and, therefore, the risk. Based on these accident and collision events and statistics, measures to reduce risk and increase safety and the use of low-risk routes are suggested. In addition, there are also studies examining the effects of traffic in the Istanbul Strait on natural life and revealing its adverse effects.

Table 1: List of Studies Examining Ship Traffic in Literature

Name of study	Author	Method	Result of work
Exploring effects of ship traffic characteristics and environmental conditions on ship collision frequency	Weng et al., 2020	Empirical	It has been determined that the probability of collision at sea is directly related to traffic density, narrow manoeuvring space and terrible weather conditions.
Reducing the probability for the collision of ships by changing the passage schedule in Istanbul Strait	Korçak and Balas, 2020	Empirical	Collision probability, which causes a risk, was assessed for Istanbul Strait, and the schedule change as a risk reduction option was evaluated and found beneficial.
Strait of Istanbul, significant accidents and abolishment of the left-hand side navigation	İstikbal, 2020	Theoretical	The most significant 3 of the accidents that happened in the Strait before 1982 were investigated, and it was determined that the traffic order applied contributed to the occurrence of accidents.
The fundamental diagram of ship traffic in the Singapore Strait	Kang, Meng, and Liuet, 2018	Empirical	Singapore Strait ship traffic diagram was built based on AIS data.
Web-Based GIS for Safe Shipping in Istanbul Bosphorus Strait	Gümüşay, 2018	Theoretical	The web-based GIS is integrated into the navigation system and contributes to reducing accidents.
Maritime Traffic Analysis of the Strait of Istanbul based on AIS data	Altan and Otay, 2017	Empirical	AIS data is collected to understand navigation patterns of ships and give the necessary input to assist in predicting maritime risk.
Analysis And Modeling Of Maritime Traffic And Ship Collision In The Strait Of Istanbul Based On Automatıc Vessel Trackıng System	Altan, 2017	Empirical	Maritime traffic in the Istanbul Strait was analyzed, and the locations with the highest probability of collision and accident were determined.
The effects of marine traffic on the behaviour of Black Sea harbour porpoises (Phocoena phocoena relicta) within the Istanbul Strait, Turkey	Akkaya Bas et al., 2017	Empirical	The traffic in the Strait hurts the nutrition and routes of porpoises.
A cellular automaton model for ship traffic flow in waterways	Qi, Zheng, and Ganget, 2017	Empirical	The ship traffic flow model was built to improve marine transportation efficiency and safety.
Risk of Navigation for Marine Traffic in the Malacca Strait using AIS	Zaman, Kobayashi, Wakabayashi, and Maimun, 2015	Empirical	AIS data was used to determine the level of risk in Malacca Strait. This study also conducted safety measurements.
Formal Safety Assessment for Ship Traffic in the Istanbul Straits	Görçün and Burak, 2015	Empirical	Maritime traffic negatively affects safety at sea
Comprehensive scenario analysis for mitigation of risks of maritime traffic in the Strait of Istanbul	Özbaş et al., 2013	Empirical	Risk factors in the Istanbul Strait were evaluated. Lack of pilotage is a significant source of increased risks in the Strait of Istanbul
Examining and Improving Transit Vessel Routes in Istanbul Strait by using Geographic Information System	Başaraner, Yücel, and Özmen, 2011	Empirical	Safe navigational routes were determined based on GIS and other criteria' spatial analysis and visualization processes.
A Study on Local Traffic Management to Improve Marine Traffic Safety in the Istanbul Strait	Aydoğdu, Yurtoren, Park, and Park, 2011	Empirical	Proposed Local Traffic Separation Schemes (LTSS) to improve navigation safety
Risk Analysis of Congested Areas of Istanbul Strait via Ship Handling Simulator	Yurtören and Aydoğdu, 2009	Empirical	The danger posed by local traffic to transit ships and the most dangerous place at the southern entrance of the strait has been identified.
Risk analysis of the vessel traffic in the Strait of İstanbul	Uluscu et al., 2009	Empirical	Local traffic density and pilotage turned out to be two main factors affecting the risks at the Strait of Istanbul
Ship Traffic through Gibraltar Strait	Mavor, 2009	Theoretical	The traffic density in the Strait of Gibraltar was observed, and it was determined that the traffic lanes were not used enough.
Environmental effects of maritime traffic on the İstanbul Strait	Birpınar, Talu, and Gönençgilet, 2008	Theoretical	The heavy traffic on the Istanbul Strait poses a risk to the environment.
Simulation of marine traffic in Istanbul Strait	Köse et al., 2003	Empirical	Pipeline works will increase traffic in the Istanbul Strait.
The Strait of Istanbul (Bosphorus): The Seaway Separating The Continents With Its Dense Shipping Traffic	Akten, 2003	Theoretical	New regulations are needed for Istanbul Strait Traffic to prevent possible accidents in the future

Factors affecting straight passage have been extensively studied in the literature. It has been stated that the most crucial factor that increases the risk and the probability of an accident and collision is traffic density. Based on this determination, maritime transport will continue to be used in the future due to its advantages related to the cost advantage per unit. For this reason, besides the factors affecting the passage of the ships, it is essential to determine how many ships prefer the strait passage according to which macro events. In this way, predictions about how much the traffic density in the strait may increase in the future can be developed, and policy development processes can start early. Unlike the general literature, our study predicted the possible traffic density in the future by examining the effect of the regional economies on demand for ships based on the derived demand structure of maritime transport. In this way, we aimed to play a complementary role by adding a new dimension to the strait passage literature.

Before moving on to the analysis, it would be helpful to examine the traffic density in the strait and what kind of ship is preferred mainly because statistical data show that the average tonnage has increased despite the decrease in the number of ships. It is also essential to understand the theoretical reasons for this situation that seems otherwise.

Ship traffic in the Istanbul Strait

The Istanbul Strait is open to international maritime traffic. According to the Montreux Convention, freedom of transit and navigation is granted to commercial vessels in peacetime, regardless of their flag and cargo. The traffic of the Istanbul Strait has intensified with the increase in their fleets after the independence of the countries with a coast to the Black Sea, the opening of the Eastern European countries to the Black Sea by using the Danube-Rhine waterway, and the participation of river ships in the Strait traffic. Due to technological developments in the shipbuilding industry and the introduction of Caspian oil to the international market, significant increases have occurred in the size, tonnage, types and amounts of dangerous cargo carried in recent years. Table 2 presents the number of ships passing through the Istanbul Strait according to ship types. When the changes from 2006 to 2020 are examined, significant increases are seen in the number of bulk carriers (58%), livestock (293%), chemical tanker (57%), and vehicle carrier ships (521%). However, there are severe decreases in the numbers of the barge (76%), general cargo ship (49%), passenger ship (95%), refrigerated ship (94%) and RORO vessels (49%).

Table 2: The Statistics of Vessels Passed the Istanbul Strait According to Their Ship Type

Years	Barge/Barge Carrier	Bulk Carrier	Cement Carrier	Container Ship	Ferry	General Cargo Ship	Livestock Carrier	Naval	Passenger Ship	Refrigerated Cargo Carrier	RORO Vessel	Other Tanker, TTA	Chemical Tankers, TCH	LPG/LNG Tanker	Tug	Vehicle Carrier	Other
2006	63	5,419	13	2,401	4	33,082	141	168	1,658	908	436	7,659	1,680	814	294	14	126
2007	47	5,145	6	2,727	1	34,822	136	166	1,702	819	441	7,204	2,050	800	253	92	195
2008	52	5,978		2,773	1	32,735	70	200	1,147	805	713	6,564	1,975	764	313	189	117
2009	53	6,635		2,014		30,840	147	180	786	623	350	6,557	1,876	866	304	78	113
2010	28	5,863	3	2,292	1	30,876	243	114	631	602	457	6,464	1,711	1,099	293	42	152
2011	17	6,341	4	2,718	3	29,288	238	94	481	441	599	6,216	1,660	1,227	245	47	179
2012	2	7,163	2	2,707	1	27,126	390	129	583	248	492	5,912	1,779	1,336	274	37	148
2013	19	6,898	1	2,868	1	25,521	432	196	474	204	406	5,685	1,561	1,760	241	47	218
2014	12	7,263	4	3,073	4	24,107	391	237	649	65	431	5,587	1,618	1,540	231	93	224
2015	17	7,485	8	2,664	2	22,412	434	318	444	24	377	5,825	1,576	1,232	282	17	427
2016	6	7,664	4	2,734	1	21,344	585	342	291	40	352	6,033	1,681	989	237	16	234
2017	18	8,206	6	2,659	1	21,163	544	237	336	46	396	6,212	1,878	742	262	45	227
2018	3	8,501	12	2,561	1	19,269	508	176	367	34	245	6,014	1,950	623	384	88	367
2019	9	8,811	9	2,642	2	18,637	530	178	250	59	266	5,934	2,462	561	270	113	379
2020	15	8,592	18	2,633	1	16,864	555	205	74	52	222	5,252	2,653	530	175	87	476

Source: UAB (2021)

The increase or decrease in the number of ships can be evaluated from several different perspectives. First, since shipping has a derived demand structure (Lun, Lai, and Cheng, 2010, p. 2; Branch and Robarts, 2014, p. 183), increasing or decreasing demand for a particular commodity/product also affects the need for that type of ship. Second, the increase in technology and efficiency increases ship size (Ma, 2020, p. 124). Both efficient fuel technologies in ship machinery and the investments in ports that can handle larger ships have made it possible to operate larger ships (Yap, 2020, p. 144). Additionally, the tendency to specialize in ships for specific cargoes has increased to reduce the cost of transportation per unit (Stopford, 2009, p. 471). Third, changes in production and supply chain philosophies have led to changes in demand for raw materials/intermediate/finished goods. Because some product groups are concentrated in some production centres, all these factors can explain differences in ship numbers. However, the decrease in the numbers does not mean reducing cargo traffic transported by sea. Therefore, examining Table 3 helps understand the subject.

In Table 3, variables related to the number of ships passing through the Istanbul Strait, the total tonnage of the vessel and their average capacity are presented between 1994 and 2020. As can be seen, the highest number of ships was reached in 2006. However, the highest tonnage was born in 2019. While the number of vessels decreased by 25% in 2019 compared to 2006, the capacity of ships increased by 34%. This situation has emerged because of the increase in ship dimensions. As shown in Table 3, while the number of vessels decreases, the average ship size increases, and this situation confirms the increase in ship sizes.

Table 3: Statistics of Vessels Passed Istanbul Strait by Number and Tonnage

Years	Number of Vessels	Total Gross Tonnage	Average Ship Size	Years	Number of Vessels	Total Gross Tonnage	Average Ship Size
1994	18,720			2008	54,396	515,639,614	9,479
1995	46,954			2009	51,422	514,656,446	10,008
1996	49,952	156,100,000	3,125	2010	50,871	505,615,881	9,939
1997	50,942	281,100,000	5,518	2011	49,798	523,543,509	10,513
1998	49,304	276,800,000	5,614	2012	48,329	550,526,579	11,391
1999	47,906	293,300,000	6,122	2013	46,532	551,771,780	11,858
2000	48,079	309,400,000	6,435	2014	45,529	582,468,334	12,793
2001	42,637	318,200,000	7,463	2015	43,544	565,216,784	12,980
2002	47,283	389,400,000	8,236	2016	42,553	565,282,287	13,284
2003	46,939	400,216,805	8,526	2017	42,978	599,324,748	13,945
2004	54,564	433,852,000	7,951	2018	41,103	613,088,166	14,916
2005	54,794	468,046,000	8,542	2019	41,112	638,892,062	15,540
2006	54,880	475,796,880	8,670	2020	38,404	619,758,776	16,138
2007	56,606	484,867,696	8,566				

Source: Akten (2003); Egemen (2004); UAB (2021)

To better understand the increase in the average sizes of ships in the strait traffic, it is necessary to examine the overall ship size trend in the world. Therefore, the average ship sizes generated by ship tonnages and vessel numbers obtained from UNCTAD (2021) statists are presented in Figure 1. The data cover the period between 2011 and 2021. Based on the average values of ship sizes in 2011, there were increases in the size of all types of ships in 2021. These increase rates are 25.5% in the total fleet, 30.9% in oil tankers, 11.3% in bulk carriers, 1.2% in general cargo, 40.1% in container ships and 10.7%.

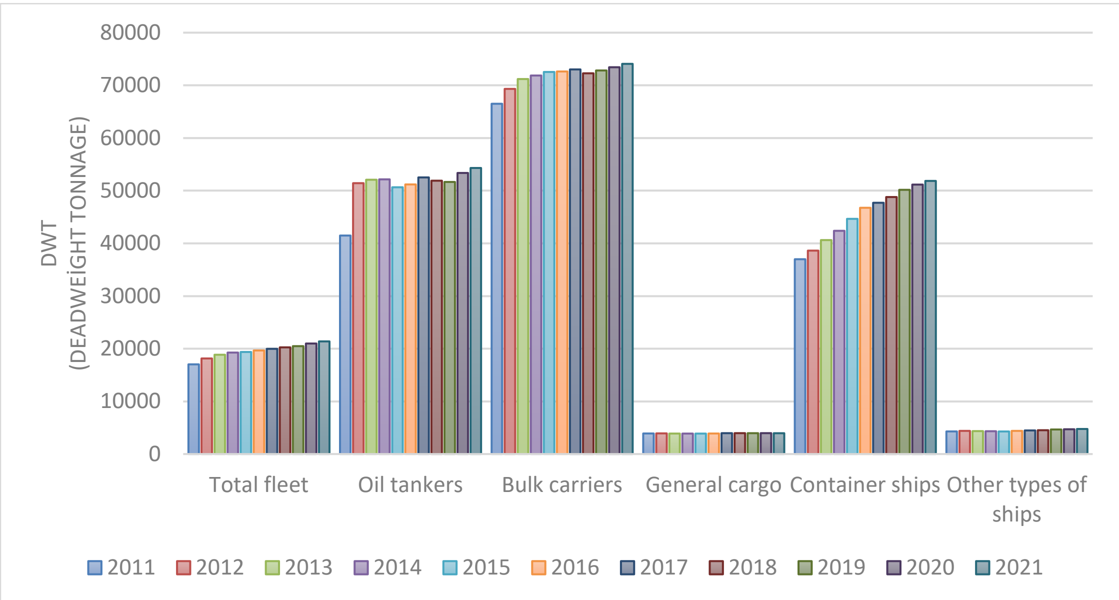

Figure 1: Average Size Trends in Major Ship Types

Source: UNCTAD (2021)

The main reason for the growth in ship sizes is to form economies of scale and reduce transportation costs per unit. Ship size and voyage-related expenses do not increase proportionally. Therefore, larger ships have lower transport costs per unit (Stopford, 2000, p. 158). For this reason, larger vessels are preferred, especially if cargo is to be brought from long distances because transport costs per unit are cheaper (Açık and Başer, 2017).

Additionally, as the ship size increases, labour and capital productivity increase. In terms of labour productivity, no matter how big the ship gets, the number of workers working on it does not grow at the same rate. This productivity, in turn, causes an increase in the amount of cargo carried per labour and, therefore, in labour productivity as the size of the ship increases. In terms of capital cost, first, larger ships provide a more significant advantage in the shipbuilding phase. As the ship size increases, construction cost per DWT (Deadweight Tonnage) grows less. For example, when the average prices between 1965 and 2015 are examined, the cost per DWT of VLCC type tanker is 60% cheaper than the cost of the Handy type tanker (Ma, 2020, p. 123). In another example, if we compare the technical sizes of the different types of ships, we can see the benefit of economies of scale. Length is 40%, breath is 86%, and draught is 53% more in VLCC than Panamax tanker, but the size of VLCC is %330 more in terms of DWT (Wijnolst and Wergeland, 2009, p. 389).

But of course, it is wrong to say that the giant ship is always more advantageous. Factors that primarily affect ship size are the depth and width of canals, waterways, and ports' physical structures and handling capacities. It is difficult for large ships to pass through narrow channels. Even if they pass, they must find a dock whose draft and berth is suitable for large ships. Additionally, the port's cargo handling efficiency should also be high. Otherwise, the ship will have to stay in port for long days. Considering that the vessel earns money during their voyages at sea, this waiting time negatively affects profitability. Also, this waiting time negatively affects the capital cost of the ship. Apart from these, there must be sufficient demand for large cargo volumes and suitable parcel sizes. Therefore, the vessel must be substantially full to take advantage of economies of scale. Otherwise, the per-unit transport cost will be higher because larger ships' overall prices are higher (Ma, 2020, p. 142).

There has been an increasing trend in the average ship sizes since 1950, as shown in Figure 2, which presents the overall trend in ship sizes. Furthermore, although the index decreased in the 1970s due to the reduction in tanker sizes in general, it reached very high levels again in the following period. In conclusion, this information and data are sufficient to explain the increasing trend in the size of ships passing through the Istanbul Strait.

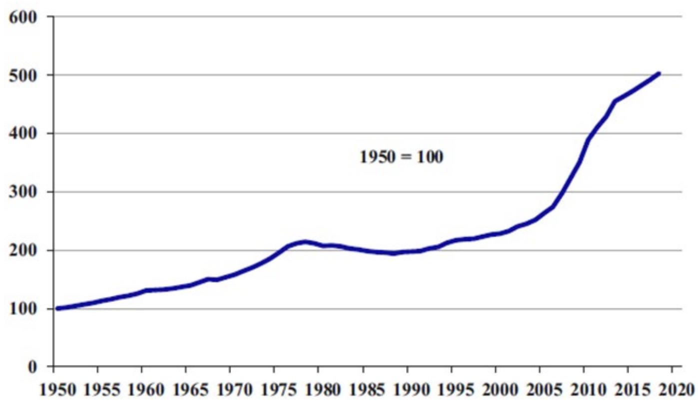

Figure 2. Index of Average Vessel Size

Source: Ma (2020:122)

As mentioned, the main reason for demanding several sizes of ships is economic activities. Therefore, it would be appropriate to say the economic structure that generates the demand to develop a model to predict strait traffic.

Demand for maritime transportation

Demand for shipping is derived demand (Branch, 1988, p. 1). Therefore, there is no direct demand for sea transportation. However, there must be a demand for goods or raw materials in different regions of the world so that there will be a demand for sea transportation. Therefore, the transport of raw materials from the other areas to countries specialized in production and the transportation of final products produced here to market countries are always provided by a combination of transportation modes. Sea transport is the mode with the lowest cost per unit over long distances, thanks to high volume transport (Wijnolst and Wergeland, 2009, p. 389).

For this reason, approximately 90% of the cargoes carried in the world are transported by sea transport (Rodrigue, 2013, p. 28). Therefore, it is of vital importance for the world economy. Moreover, this volume level makes it sensitive to developments in the world economy. In this respect, it has a close relationship with regional and global economic activities (Stopford, 2009, p. 136).

A variety of tools can measure economic activities in the world. The most widely used and most important is Gross Domestic Product (GDP). GDP is an essential indicator of the market value of all final products and services produced in a country in a given time. Moreover, while GDP is also an indicator of income, it is also an indicator of expenditure because every expenditure in the country generates income for someone else. By measuring the value of all goods and services produced in a country, it can be determined whether the government has grown compared to the previous period or its position compared to other countries (Mankiw, 2021, p. 91). Therefore, GDP is a valuable tool for measuring the output of all factories, offices, shops and any other enterprise in the country (Baumol, Blinder, and Solowet, 2020, p. 87). Economic growth refers to the increase in GDP per capita in an economy (Acemoglu, Laibson, List, 2022, p. 175). In other words, the change that occurs in a country's output can be expressed as the country's economic growth. Economic growth rates are related to how much the economy has grown compared to the previous period. These rates can vary from country to country. In some countries, they have higher rates, and in others, they have lower rates.

Furthermore, suppose that the GDP per capita of one of the two countries is low, but the country with the higher growth rate can catch up with or even surpass the other country with a lower growth rate in the long run. This is because relatively poorer countries benefit from the technologies and knowledge of rich countries. Since they allocate less budget to R&D investments, their growth rates are high, converging to rich countries. Such situations are also called catch-up growth. The growth rate experienced by the more prosperous country with a slower pace is called sustained growth since the growth is positive and at a relatively steady rate (Acemoglu et al., 2022, p. 181).

Whatever the source of economic growth, it will indirectly increase the demand for maritime transport as it indicates an increase in the final goods and services produced. Therefore, it can be said that there is an essential interaction between maritime transport and economic growth. In this direction, an empirical study examining the relationship between dry bulk freight rates and world GDP was conducted by Başer and Açık (2019). Based on the assumption that economic growth will increase the demand for maritime transport and freight rates will increase after increasing demand, it has been determined that there is a significant positive relationship between world GDP and dry bulk freight. In a similar study by Tarı and İnce (2019), dry bulk freight rate changes were analyzed when the world raw material demand was at an average level and above the average. In the research with the Markow Regime Change model, it has been determined that raw material demand plays a decisive role in dry bulk freight rates.

The relationships between the sub-factors affecting GDP and maritime transport were also examined in the literature, and significant results were obtained. Ports are the intersection points of marine and road transport, so the traffic there constitutes the decisive indicators of maritime transport. In this direction, although we cannot examine all studies in detail due to limitations, the effects of exchange rates (e.g. Lättilä and Hilmola, 2012; Chi and Cheng, 2016; Tsai and Huang, 2017; Kim, 2017), industrial production (e.g. Chou, Chu, and Liang, 2008; Lättilä and Hilmola, 2012; Tsai and Huang, 2017; Gosasang, Yip, and Chandraprakaikul, 2018) and GDPs (e.g. Chou et al., 2008; Lättilä and Hilmola, 2012; Akar and Esmer, 2015; Tsai and Huang, 2017) of countries on port throughputs have been examined in the literature, and significant results have been obtained. All these studies have used time series analysis to determine relationships. These variables are the factors that directly affect and determine the GDP, and they are effective on the maritime transportation demands of the countries. Apart from these variables, freight rates are also the determinants of the need for maritime transport. Therefore, increasing transportation costs can increase the prices of final products, reducing the demand for products and hence the demand for maritime transportation. In the literature, studies have been conducted by Kim (2016) and Açık (2019) in this direction, and the adverse effects of increasing transportation costs on maritime trade volume have been revealed.

As can be seen from the literature framework, the impact of GDP and the factors that form and affect it on maritime transport are noticeable theoretically and empirically. That's why we decided to use GDP and trade volume when estimating vessel traffic through the strait. Thus, we contributed to the literature on maritime transportation demand and the Istanbul Strait vessel traffic. Because we could not come across a study that dealt with the issue with an economic approach in the strait literature, we could not find a study that dealt with cargo passing through the strait in the maritime transport demand literature. Our inclusion of trade volume variable to the model is that GDP also includes local and in-country resources. On the other hand, international trade volume may be more closely related to maritime transport as it requires a mode of transportation to perform export and import activities. By estimating both models, possible differences between the effects of the two variables are also revealed.

Data and methodology

In this study, we aimed to determine the relationship between the economic and commercial volumes of the countries with a coast to the Black Sea and the number of ships passing through the Istanbul Strait and to determine the possible tonnage of vessels that will pass in the future by using the coefficient we obtained. First, we found it more appropriate to measure the amount of ships by tonnage rather than the number of ships. Because of the changing technological factors over time, the average ship sizes have grown. This situation can be seen in Table 3. Therefore, while the number of ships passing through the strait decreases, the total tonnage and average ship tonnage increase. For this reason, measuring traffic by capacity is a more objective approach.

To measure the economic volumes of the countries, we selected the GDP (constant 2010 US$) variable obtained from the World Bank (2021a) web source. Since the data of the study were compiled from public statistical websites, it does not require ethics committee approval. Considering that the ships crossing the Black Sea are related to the economic situation of the countries with a coast to the Black Sea, we calculated the economic size in the region by summing the GDP values of the relevant countries. Bulgaria, Georgia, Romania, Russia, Turkey, and Ukraine are selected countries. Descriptive statistics of the variables are presented in Table 4. The tonnage unit is a million Gros Tons, and the unit of GDPs are million US dollars. When we examine the table in terms of mean values, it is seen that the country with the highest GDP value is Russia ($1,373.9 billion). It has sizeable natural resource reserves can be considered the main reason for this high share. The lowest GDP value is seen in Georgia ($11.54 billion). The Russian economy is approximately 119 times larger than the Georgian economy on average. However, when we calculate the coefficient of variation values (standard deviation/mean) for GDPs, it is seen that Ukraine is the most stable country (18.1%), and Georgia is the most variable country (36.2%). When the growth rates are considered, Georgia has the highest growth rate (1.0485) on geometric average. The country with the lowest average growth rate in Ukraine (1.0160). In other words, although the variability may seem like instability, it may also indicate a high average growth rate. Finally, according to the skewness and kurtosis values in the table, all of our variables have normal distribution characteristics, which may indicate that there are no extreme tail values in the dataset and that linear analysis can be performed without any structural problems.

Table 4: Descriptive Statistics of Variables in GDP Model

	TONNAGE	BULGARIA	GEORGIA	ROMANIA	RUSSIA	TURKEY	UKRAINE	GDP
Mean	465.3146	46771.37	11539.61	161652.0	1373913.	801712.3	121893.2	2517481.
Median	505.6159	50101.53	11677.53	167570.4	1504470.	746831.2	129940.5	2629635.
Maximum	638.8921	63191.57	18517.15	234000.7	1779170.	1284114.	153669.9	3492347.
Minimum	156.1000	31069.64	5579.186	107310.9	813030.6	459411.6	84420.72	1551676.
Std. Dev.	129.7935	10174.34	4178.871	40522.53	338850.5	280755.2	22072.89	675996.7
Skewness	-0.688272	-0.115584	0.102124	0.152144	-0.460621	0.434877	-0.556771	-0.122707
Kurtosis	2.499360	1.708711	1.654653	1.870786	1.641583	1.799300	1.987896	1.603585
JB.	2.234907	1.792569	1.928829	1.424703	2.806232	2.289741	2.358677	2.093960
Probability	0.327112	0.408083	0.381206	0.490490	0.245830	0.318265	0.307482	0.350996
Obs.	25	25	25	25	25	25	25	25

Source: Akten (2003); Egemen (2004); UAB (2021); World Bank (2021a)

The visual of the data we used in our GDP model is presented in Figure 3. Stacked columns show GDP values, and the tonnage of ships passing through the strait is shown with a line. The close relationship between the total GDP and tonnage variables can be easily seen from the graph. When the correlation between them is analyzed with the Pearson method, a value of 0.92 (t-stat: 11.39, p-value: 0.000) is obtained, which indicates that the relationship is significant. In 1997, there was a massive leap in cargo compared to the previous year. While the increase in the number of ships is 2%, the increase in ship tonnage is approximately 80%. There has been a significant increase in the average ship sizes this year.

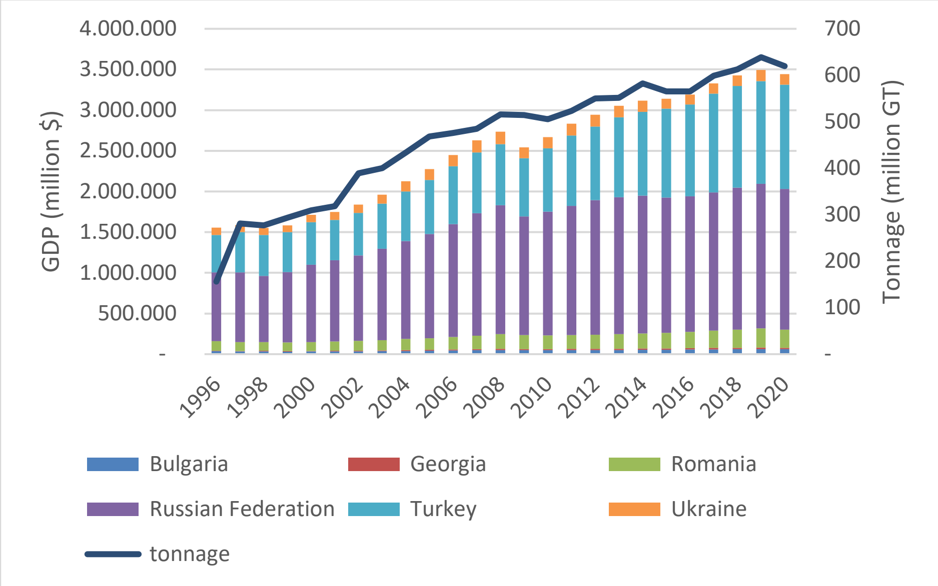

Figure 3: Graphical Display of the Variables in GDP Model

Source: Akten (2003); Egemen (2004); UAB (2021); World Bank (2021a)

We also presented the intensities of the economic activities considering the GDPs and trade volumes of the countries in the region for 2020 in Figure 4. As can be seen, Russia's economic dominance is high. Among the remaining countries, Turkey stands more. This situation can be easily determined from the data in Table 4.

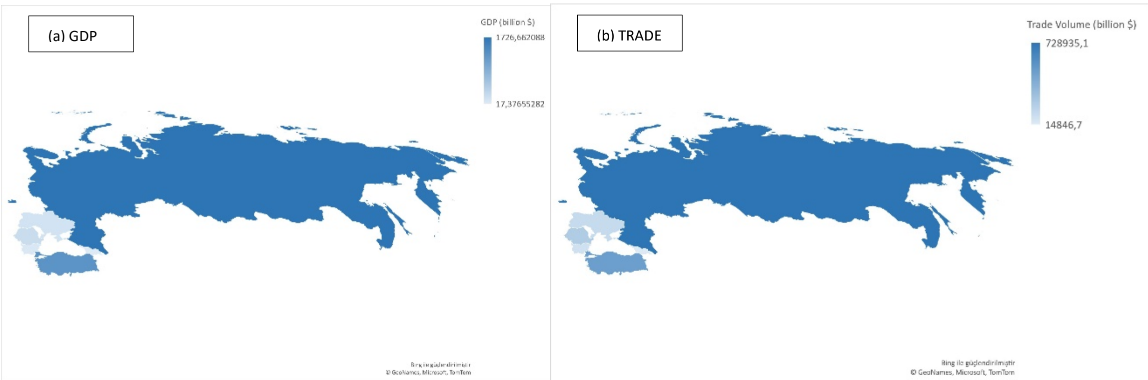

Figure 4: Density of GDPs and Trade Volumes in the Region in 2020

Source: World Bank (2021a; 2021b; 2021c)

To measure the commercial volumes of the countries, we selected exports and import values of goods and services (constant 2015 US$) obtained from World Bank (2021b; 2021c) web sources. Considering that the trade volumes of countries in the region are determinant in the vessel traffic in the strait, similar to the GDP variable, we examined the possible relationship with ship traffic by collecting the export and import values of the countries in the region. Descriptive statistics of the variables are presented in Table 5. The tonnage unit is million Gros Tons, and a trade volume team is million US dollars. The dataset of trade volumes for Georgia has been available in the source since 2010. However, it is not a problem as we are using the sum of the trading volumes of the countries in the region. When we examine the mean values, it is seen that the country with the highest trade volume is Russia ($548.46 billion) in parallel with GDP.

The country with the tiniest trade volume stands out as Georgia ($14.5 billion). However, according to average GDP values, while Romania has a higher value than Ukraine, Ukraine is ahead of Romania in average trade volume values. This situation may indicate the differentiation in the economic structures of the countries. However, the difference between the highest and lowest countries in average values is only 37.8 times (119 in GDP), and the gap between countries relative to GDP appears to be narrower. When the coefficient of variation values is analyzed, it is seen that the most stable country is Ukraine (20.7%) again, but the country with the highest variability in Romania this time (63.3%). When the geometric averages of growth rates in trade are analyzed, it is seen that the lowest value is in Ukraine

(1.0034) and the highest value is in Romania (1.0852). Despite having a relatively low volume on average, this situation can be interpreted as Romania implementing effective policies to increase its trade volume. However, Ukraine may be experiencing a commercial and economic recession due to the political instability in the region. Finally, when our trade volume variables' skewness and kurtosis values are examined, they have normal distribution characteristics. The absence of the tail effect makes linear analyzes more applicable.

Table 5: Descriptive Statistics of the Variables in Trade Model

	TONNAGE	BULGARIA	GEORGIA	ROMANIA	RUSSIA	TURKEY	UKRAINE	TRADE
Mean	465.3146	47445.49	14502.38	98196.40	548469.9	313819.3	126291.9	1140604.
Median	505.6159	47357.75	14769.84	92762.55	639444.5	317668.8	118826.8	1265526.
Maximum	638.8921	79422.19	20229.39	214732.8	788644.1	500104.5	188852.1	1721485.
Minimum	156.1000	21747.42	9128.101	27959.37	237392.0	123868.2	89354.44	532709.9
Std. Dev.	129.7935	18595.58	3348.113	62169.90	203418.0	126237.3	26131.99	415121.5
Skewness	-0.688272	0.153371	0.119021	0.491161	-0.401541	0.048598	0.599053	-0.250079
Kurtosis	2.499360	1.721897	2.239470	1.958289	1.565720	1.642954	2.488976	1.572868
JB.	2.234907	1.799622	0.291074	2.135539	2.814687	1.928148	1.767296	2.382149
Probability	0.327112	0.406647	0.864558	0.343775	0.244793	0.381336	0.413273	0.303895
Obs.	25	25	11	25	25	25	25	25

Source: Akten (2003); Egemen (2004); UAB (2021); World Bank (2021b; 2021c)

The visual of the data we used in our TRADE model is presented in Figure 5. Stacked columns show trade volume values, and the tonnage of ships passing through the strait is shown with a line. It can be seen from the chart that there is a close positive relationship between the total trade volume and tonnage of ships, as well as the close relationship between the GDP variable and capacity in the previous figüre. When the correlation between them is analyzed with the Pearson method, a value of 0.96 (t-stat: 17.093, p-value: 0.000) is obtained, which indicates that the relationship is compelling. This value is even more significant than the correlation coefficient with GDP, emphasizing the decisive role of trade for maritime transportation demand.

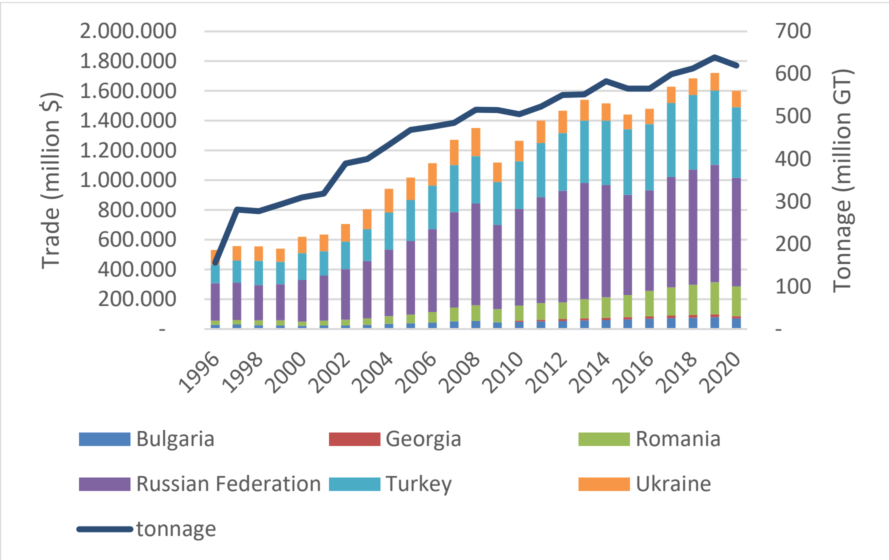

Figure 5: Graphical Display of the Variables in Trade Model

Source: Akten (2003); Egemen (2004); UAB (2021); World Bank (2021b; 2021c)

Our research found it appropriate to apply time series analysis to determine the factors affecting the vessel traffic flow by considering the ships passing through the strait in a certain period, and how much traffic these factors affect. The main reasons for this decision are the lack of data and the economic analysis of the subject. Thousands of ships pass through each year, and we do not have the technical capacity to access data such as waiting time, transit time, delay, collision, physical size for each ship. Additionally, time series analysis is widely used in the literature to examine the effect of an economic variable on other variables. Thus, different characteristics of different times are also discussed, and with only 25 observations, the interaction over a countless period can be detected.

Since maritime transport has a derived demand structure, we chose GDP and trade volume variables from the macroeconomic variables representing this demand. This is because maritime transport is used to transport approximately 90% of the world's cargo in terms of weight. Since GDP covers all goods and services produced within the country, maritime transport is used extensively to sell needed raw materials and excess demand products. Therefore, we preferred to analyze GDP and trade volumes with two different models as independent variables to estimate vessel traffic. The main reason for this distinction is that these two variables are interrelated, and import and export activities are the main requirements for the GDP development of the countries. Net exports are also included as an item in GDP calculations. This interrelationship leads to a high correlation between the two variables. Therefore, a multicollinearity problem will arise if both GDP and trade volume are included in the regression analysis. In the preliminary studies we conducted, the variance inflation factor value, which indicates the multicollinearity status, was too high in the model that includes two independent variables.

Our analysis determined how much changes in GDP and trade volume variables affect vessel traffic in the strait and estimated the possible future traffic flow based on obtained coefficient value. For this target, we preferred to apply linear regression analysis. Regression analysis is a standard method used to detect functional and theoretical relationships between variables (Chatterjee and Hadi, 2015, p. 1). A simple regression model consists of a dependent variable Y and an independent variable X. Models that include only one independent variable are called simple regression models (Gaurav, 2011, p. 3). If there is more than one independent variable, such models are called multiple regression models (Allen, 2004, p. 4).

The simple regression model can be expressed as in Equation 1. Y is the independent variable in this equation, X is the dependent variable, and ε is the error term. The parts of the dependent variable that the independent variable cannot explain are included in the error term. So, the smaller this value, the better for the model. The most important output of the regression models can be indicated as β coefficients of independent variables (Esquerdo and Welc, 2018, p. 2). Thanks to this coefficient, it can be determined 1-unit change in the independent variable causes how much change in the dependent variable (Archdeacon, 1994, p. 148). Moreover, it can be determined whether the effects of independent variables are positive or negative.

$$Y = \beta_0 + \beta_1 X_1 + \varepsilon \quad (1)$$

In our research, we applied analysis by taking the logarithms of the series because, in this way, the distribution characteristics of the data are improved, and the discrete data become continuous. In the interpretation of log-log regression analyzes, a 1 unit change in the independent variable is considered a 1% change. Additionally, the change in the dependent variable is interpreted as a percentage change (Gujarati, 2004, p. 176).

The regression model we estimated for GDP is presented in Equation 2, and the regression model we estimated for trade volume is shown in Equation 3. After the regression models are evaluated, the residuals are expected to satisfy some assumptions. These are homoscedasticity, no autocorrelation and normal distribution assumptions (Pagan and Hall, 1983). If one or more of them cannot be satisfied, the standard errors are recalculated by changing the covariance method. If there is heteroscedasticity in the residuals, Huber-White (White, 1980), and if there is heteroscedasticity and/or autocorrelation, the HAC (Newey and West, 1987) method can be preferred.

$$lnStrait\_Traffic_t = ln\beta_1 + \beta_2 lnRegion\_GDP_t + \varepsilon_t \quad (2)$$

$$lnStrait\_Traffic_t = ln\beta_1 + \beta_2 lnRegion\_TRADE_t + \varepsilon_t \quad (3)$$

One of the most critical factors affecting the validity of the results in time series analysis is that the series contains unit roots. Variables with a unit root carry the shocks they receive, and results obtained with such data may be inconsistent and biased. On the other hand, stationary series tend to return to the mean in the long run, and the series can be stationary or trend stationary. To determine the persistence of the shocks, we applied ADF (Dickey and Fuller, 1969) and KPSS (Kwiatkowski, Phillips, Schmidt, and Shin, 1992) tests to all variables before applying the regression analysis. Suppose a series is nonstationary and contains a unit root. In that case, it is indicated as I (1), and the series is made stationary by applying the difference taking operation (de Bruyn, 2000, p. 129).

Results

First, we applied ADF and KPSS tests to the tonnage of ships passing through the strait, the GDPs and trade volumes of the countries in the region and presented the results in Table 6. The null hypothesis of the ADF test is that the series contains a unit root. According to the results, while the cargo is stationary at a level, the GDPs and trade volumes become stationary when their first differences are taken. The null hypothesis of the KPSS test is that the series is stationary. According to the results, all variables are stationary at the level. Considering both the length of the dataset and the results of the KPSS test, we decided that the series were stationary at the level and applied our analysis.

Table 6: Unit Root Test Results

	Level		First Difference		
	Intercept	**Intercept & Trend**	**Intercept**	**Intercept & Trend**	**Decision**
	Augmented Dickey-Fuller (1969)				
GDP	-1.114	-0.821	-3.485**	-3.583*	I (1)
TRADE	-1.471	-0.836	-4.027	-4.236**	I (1)
TONNAGE	-2.976*	-1.314	-13.026***	-14.373***	I (0)
	Kwiatkowski et al. (1992)				
GDP	0.704***	0.155***	0.235*	0.097*	I (0)
TRADE	0.679***	0.167***	0.246*	0.098*	I (0)
TONNAGE	0.689***	0.194***	0.479***	0.132**	I (0)

Note: ADF CVs -3.737*** for 1%, -2.991** for 5%, -2.635* for 10% at Intercept, -4.394*** for 1%, -3.612** for 5%, -3.243* for 10% at Intercept & Trend, Schwarz Information Criterion is used. KPSS CVs 0.739*** for 1%, 0.463** for 5%, 0.347* for 10% at Intercept, 0.216*** for 1%, 0.146** for 5%, 0.119* for 10% at Intercept & Trend, Bartlett Kernel and Newey West are used.

The regression estimation results for GDP and TRADE models are presented in Table 6. According to the F statistic, the GDP model is significant, and according to the t statistic of the independent variable, the variable is significant. The R square value indicates that changes in the independent variable explain approximately 84% of the changes in the dependent variable. The coefficient of GDP shows that a 1% change in GDP causes a 1.1% change in the tonnage of ships passing through the strait. Additionally, according to the Ljung (Ljung and Box, 1979) and ARCH (Engle, 1982) tests applied, there is no autocorrelation and heteroscedasticity in the model's residuals. Here, the model is a valid usable model. However, when the graph showing actual, fitted and residual values based on the regression estimation is examined, it is seen that the deviation in the 1996 estimation is high. This difference is that the cargo is very low compared to the number of ships, as seen in Table 2. Based on this situation, we re-estimated the model by adding a dummy variable in that year, assuming it was an extreme case in 1996. According to the results of the new estimation, the explanatory power of the model increased to 97%. The coefficient of the independent variable decreased to 0.95. Since autocorrelation and heteroscedasticity were detected in the model's residuals, HAC (Newey and West, 1987) correction was applied to the regression model. The results revealed that the model and the independent variable are significant. A 1% change in GDP causes a 0.95% change in tonnage passing through the Istanbul Strait. According to the coefficient of the dummy variable, it was determined that the ship tonnage was 47.5% $(100 \times (e^{\beta_2} - 1))$ less in 1996, regardless of the GDP value.

The values of the TRADE model are also presented in Table 7. According to the F statistic, the model as a whole is significant. Additionally, the t statistic of the independent variable shows that changes in trade significantly affect vessel traffic in the strait. Adjusted R-squared value indicates that changes in business explain 86% of the changes in ship traffic. The trade coefficient reveals that a 1% change in trade causes a 0.76% change in vessel traffic. However, as in the GDP model, vessel traffic in 1996 significantly deviates from the estimated values. Therefore, a dummy variable is added to this year, and the model is re-estimated. In the new model, the trade coefficient has decreased to 0.66, and the dummy variable has a coefficient of 0.645. This result shows that a 1% increase in trade causes a 0.66% increase in vessel traffic. Additionally, according to the coefficient of the dummy variable, ship traffic decreased by 45.9% $(100 \times (e^{\beta_2} - 1))$ in 1996, regardless of the changes in trade. Finally, the autocorrelation and heteroscedasticity tests are applied to the model's residuals and show that the model provides the assumptions of the linear regression analysis.

Table 7: Regression Estimation Results

Model	GDP Model Tonnage	GDP Model Tonnage with Dummy	GDP Model Tonnage with Dummy Robust	TRADE Model Tonnage	TRADE Model Tonnage with Dummy
GDP	1.10 [0.000]	0.95 [0.000]	0.95 [0.000]	-	-
TRADE	-	-	-	0.76 [0.000]	0.66 [0.000]
Constant	-11.48 [0.000]	-7.27 [0.000]	-7.27 [0.000]	-1.23 [0.480]	1.59 [0.028]
Dummy	-	-0.645 [0.000]	-0.645 [0.000]	-	-0.614 [0.000]
F Stat.	129.9 [0.000]	481 [0.000]	481 [0.000]	151.0 [0.000]	615 [0.000]
R-Squared	0.849	0.977	0.977	0.867	0.982
Adj. R-Squared	0.843	0.975	0.975	0.862	0.980
Durbin-Watson	0.881	0.85	0.85	1.05	1.48
Autocorrelation	No	Yes	-	No	No
Heterosc.	No	Yes	-	No	No
Normality (JB)	153 [0.000]	2.03 [0.361]	-	156 [0.000]	1.81 [0.403]
Wald F Stat.	-	-	5600 [0.000]	-	-

Note: Probabilities are shown in [ ].

Using the coefficients we obtained in GDP and TRADE models, we estimated the future ship traffic in the strait. To use the coefficient of the GDP model, we use the GDP growth values calculated by the IMF (Knoema, 2021) to predict future strait traffic. These estimated growth values are presented in Table 8 and include projections up to 2026. This dataset obtained from April 2021 World Economic Outlook (WEO) Database (Knoema, 2021). Using these values, we calculated the Black Sea countries' GDP values from 2020 to 2026. Then, we calculated that the total economic size in the region will be 4.16 trillion dollars in 2026 and will increase by 21.08% compared to 2020.

Table 8: Forecasted GDP Growth Rates by IMF (%)

Country	2021	2022	2023	2024	2025	2026
Bulgaria	4.4	4.4	3.9	3.2	3.04	2.8
Georgia	3.5	5.8	5.501	5.2	5.2	5.2
Romania	6	4.801	3.8	3.7	3.5	3.498
Russia	3.763	3.75	2.1	1.8	1.8	1.8
Turkey	6.042	3.499	3.5	3.545	3.523	3.505
Ukraine	4.04	3.396	3.405	3.799	4	4

Source: Knoema (2021)

According to the calculation we made using the coefficient we obtained from the regression estimation for the GDP model, the tonnage of ships passing through the Istanbul strait will increase by 20.02% to 743 million gross tons in 2026. The estimated values according to the results obtained from the regression model are presented in Figure 6. As can be seen, in the calculation based on IMF economic growth rate estimates, an increasing trend is expected in the tonnage of ships in the strait traffic.

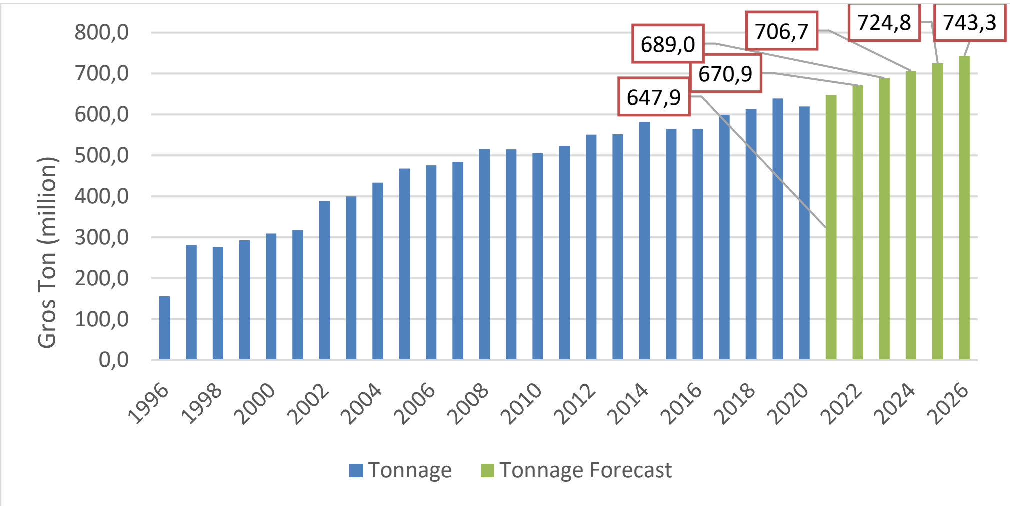

Figure 6: Estimated Ship Tonnage in the Strait by GDP Model

To use the coefficient of the TRADE model, we use the trade growth values estimated by the IMF (IMF, 2021) to predict future strait traffic. These estimated growth rates for import and export volumes of the regional countries are presented in Table 9. This dataset was obtained from October 2021 World Economic Outlook (WEO) Database (IMF, 2021) and includes forecasts up to 2026, as in the GDP forecast dataset. Using the forecast values in this table, we have estimated the trade volume in the region until 2026. $2.296 trillion and will increase 43.5% compared to 2020.

Table 9: Forecasted Import and Export Growth Rates by IMF (%)

Country	Type	2021	2022	2023	2024	2025	2026
Bulgaria	Import	5.2	5.986	7.363	4.601	3.333	3.457
	Export	5.099	5.994	5.765	4.189	3.957	3.902
Georgia	Import	-8.176	9.995	14.701	12.265	6.987	-0.228
	Export	21.602	15.704	18.113	11.97	5.598	5.644
Romania	Import	14.126	10.363	6.914	6.518	6.638	6.613
	Export	13.252	10.992	7.44	7.202	6.903	6.748
Russia	Import	17.315	6.821	1.595	1.536	1.591	1.738
	Export	3.175	5.574	1.979	1.674	1.585	1.644
Turkey	Import	3.448	10.401	10.483	9.851	9.31	9.9
	Export	21.37	6.979	4.761	4.291	4.071	3.746
Ukraine	Import	9.545	10.19	10.743	9.286	9.553	8.812
	Export	11.767	7.629	7.64	8.386	8.446	8.333

Source: IMF (2021)

According to the results we obtained using the TRADE model coefficient, it is estimated that the number of ships passing through the strait in 2026 will reach around 789 million gross tons, as shown in Figure 7. This increase suggests growth of 28.8% in 2026 considering the ship traffic in 2020. Therefore, estimates from this model are higher because estimates of trade growth are probably higher.

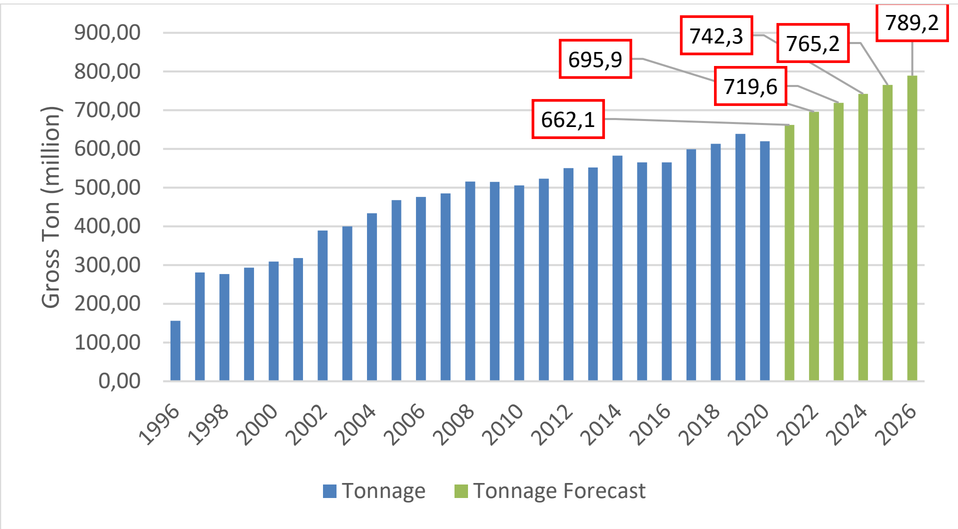

Figure 7: Estimated Ship Tonnage in the Strait by TRADE Model

Conclusion

Above 10 million people living in Istanbul may face huge dangers caused by Maritime Traffic at any moment. According to UAB 2020 data, 8435 tankers passed through the Istanbul Strait. Since tanker ships are pretty dangerous due to their cargo, the heavy traffic poses a high risk for Istanbul Strait safety (UAB, 2020). Our results show that the ship traffic passing through the Istanbul Strait will increase by 20.02% in terms of tonnage to 743 million gross tons in 2026 according to the GDP model, and traffic will increase by 28.8% in terms of capacity to 789.2 million gross tons in 2026 according to Trade Volume model. Our research also determined that the trade volume model is more successful. The main reason for this outcome may be that GDP represents production more comprehensively locally.

On the other hand, international trade can be more decisive in the demands of countries for foreign trade transportation modes. In our study, a positive relationship was found between ship traffic and economic activities, as in the study by Başer and Açık (2019), where GDP is examined as an indicator for the demand for maritime transport. In line with the trade needs of the Black Sea countries, their demands for maritime transport are changing. Additionally, in parallel with the effect of factors on ports such as exchange rates (e.g. Lättilä and Hilmola, 2012; Chi and Cheng, 2016; Tsai and Huang, 2017; Kim, 2017) and industrial production (e.g. Chou et al., 2008; Lättilä and Hilmola, 2012; Tsai and Huang, 2017; Gosasang et al. 2018), which are the most fundamental factors affecting international trade, we determined in our study that increases in trade volumes of countries increase vessel traffic. Since all these factors inevitably affect the entire supply chain, they will also affect maritime transport.

Additionally, as can be understood from both the channel passage statistics and the theoretical information, the average ship sizes are increasing. Navigation opportunities, which are already partially difficult in the canal, will thus become even riskier. Ships with higher physical characteristics in length, width and depth may endanger city and environmental safety. As can be seen from the statistics in Table 1, the number of bulk carriers and chemical tankers passing through the strait is increasing every year. The average dimensions of these ships are also growing in line with the general trend. In this respect, there is a need to develop and plan projects to regulate the already heavy traffic and reduce risks. The Canal Istanbul project can come to the fore as a vital structure to reduce this danger and risk.

We also have a few suggestions for further studies. Our study used the growth forecast data published by the IMF (Knoema, 2021) and updated it periodically. Instead of getting the ready data, the growth data of the countries can be estimated within the study with econometric methods. Thus, the originality and inclusiveness of the studies can be increased. Additionally, nonlinear models can estimate the number of ships passing the strait using different methods. Counting numbers with linear models may be inaccurate, as the increase in the average size of vessels is not linear because too many non-quantifiable factors affect the average ship size trend. Additionally, similar to simulation studies examining the current density in the strait traffic, the future situation can be simulated with the estimated tonnage. The traffic situation in the strait can be discussed.

As a limitation of the study, it can be shown that the data on the ship statistics are annual because economic factors can follow fluctuating and volatile movements throughout the year and may fluctuate seasonally. If ship statistics could be obtained quarterly or monthly, more dynamic models could be formed with economic variables. Additionally, if there were representative freight indices for each ship type and if the cargo demands of the Black Sea countries were known in the covered period, the sensitivity of ship traffic to other factors could also be examined.

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