



INVESTIGATION INTO MARINE TRAFFIC AND A RISKY AREA IN THE TURKISH STRAITS SYSTEM: CANAKKALE STRAIT

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Abstract. The Turkish Straits comprising the Strait of Canakkale, the Strait of Istanbul and the Sea of Marmara are unique in many respects. All dangers and obstacles characteristic of narrow waterways are present and acute in this critical sea lane. This research reveals the simulation of Canakkale (Dardanelle) Strait under different traffic conditions and identifies risky areas. The results of this simulation show that an increase of 25% in the existing traffic grows 43 times in the number of waiting ships (from 1.663 to 73.73), whereas waiting time increases 29 times (from 24.267 to 737.07). As a result of simulations and risk analysis, it is found that Nara turning point is the bottleneck point of the strait due to its topographic structure and the current system.

Keywords: AWESIM, marine traffic, Canakkale Strait, Dardanelle, risk, simulation, narrow waterway, the Turkish Straits.

1. Introduction

The Turkish Straits System (TSS), consisting of the Marmara Sea, the Strait of Istanbul (Bosporus) and the Strait of Canakkale (Dardanelles), are very complicated and narrow waterways connecting the Black Sea to the Mediterranean Sea (see Fig. 1). It is an established fact that the Turkish Straits are one of the most hazardous, crowded, difficult and potentially dangerous waterways for mariners in the world. The Turkish Straits located between the Black and Mediterranean Seas are 164 nautical miles (nm) in length and have unique physical, geographical, hydrological and oceanographic characteristics and complicated navigational conditions prevailing in the area.

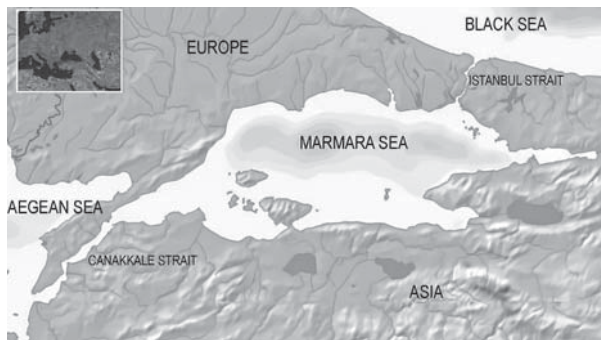


Fig. 1. The Turkish Straits System

The Turkish Straits form a waterway of strategic and economic importance since being comprised of Istanbul and Canakkale Straits and the Sea of Marmara. As the only water route between the Black Sea and the Mediterranean Sea, the Turkish Straits both geographically and metaphorically connect Europe to Asia. The TSS are the most unique amongst other straits due to different physical, hydrological and oceanographic characteristics as well as because of complicated navigational conditions.

The length of the Strait of Canakkale is about 37.8 nm with a general width ranging from 0.7 nm to 1.08 nm (see Fig. 2). A very sharp course alteration is needed at the narrowest point at Nara turning (approximately 90 degrees), the westernmost section of the waterway that divides Europe from Asia and connects the Mediterranean and Black Seas. The strait, through the Sea of Marmara, is a narrow, winding passage flanked on the north by the Gallipoli peninsula. Due to the geography and an increasing volume of traffic of the straits, the existence of harbours is of real danger for the safety of passage and navigation, life, property and the environment. Big ships and especially tankers face serious difficulties when navigating the sharp turns because of geographical structure, strong surface and undercurrents of the strait.

Despite unpredictable weather and swift surface currents, the Dardanelles has been a strategic water route and an object of conquest throughout history.

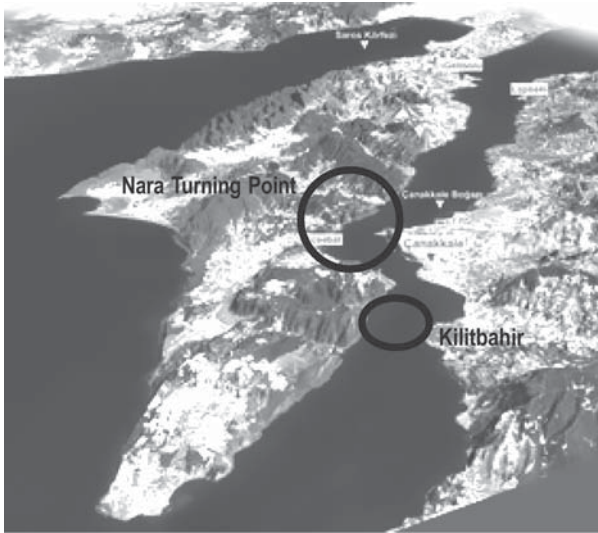


Fig. 2. Canakkale Strait

The aim of this paper is to investigate marine traffic at Canakkale Strait and to identify the risky areas of the place. The paper has been divided into two main sections. First, a description of traffic at Canakkale Strait and second, simulations of marine traffic at the strait are provided.

1.1. The Current System of Canakkale Strait

The current system consists of two parts. The upper part runs from Marmara to the Aegean Sea, and below, Aegean salty waters run with the speed of 50 cm/s. The upper current sometimes reverses due to the shape of the coast and meteorological conditions. These reverse currents are more visible in the middle and south part of the strait. Surface currents up to Nara are about 1.5–2 knots, whereas at Nara and Kilitbahir they reach about 4 knots (Black Sea Pilot 1990).

Ors and Yilmaz (2004) modelled the current system at Canakkale Strait (see Fig. 3). The Fig. 3 shows that the current change at Nara turning point is obvious which would also negatively affect navigation at this point.

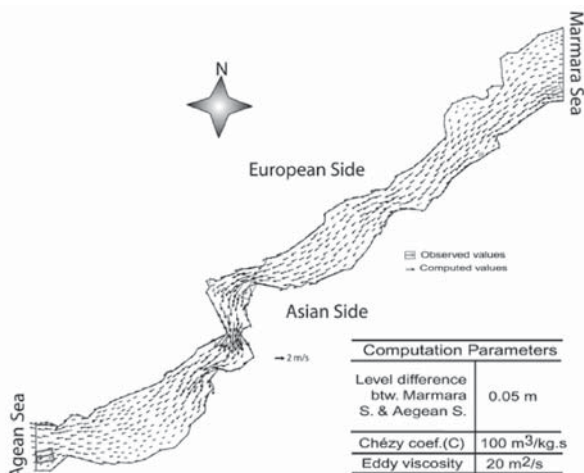


Fig. 3. The current systems at Canakkale Strait (Ors and Yilmaz 2004)

1.2. Maritime Traffic in the Strait

Maritime traffic in the Turkish Straits is exceptionally dense due to merchant traffic, coasters, fishing vessels and local traffic crossing the strait and causing difficulties in the navigation of the transit passage. Such dense traffic includes the transport of noxious, dangerous and hazardous cargo (oil, LNG, LPG, chemicals and other explosive and environmentally hazardous substances).

The volume of traffic is expected to increase by 40–50% with additional traffic coming from the Main-Danube, Volga–Baltic and Don waterways. Traffic congestion will further increase in oil supply and the volume of foreign trade from the Black Sea states and neighbouring countries.

1.3. Maritime Traffic Regulations in the Turkish Straits

Along with the introduction of the Regulations, the Turkish authorities have also established ‘Traffic Separation Schemes’ (TSSc) in the Straits, in accordance with the provisions of ‘International Regulation for Prevention of Collusion at Sea’ (COLREG). TSSc was approved by the International Maritime Organization (IMO) General Assembly in November 1995, in association with ‘Rules and recommendations on navigation through the Strait of Istanbul, The Strait of Canakkale and the Marmara Sea’ (IMO 1995; The Strait of Istanbul ... 1995). The sectors at Vessel Traffic System (VTS) and traffic separation at Canakkale Strait are shown in Fig. 4 (IMO 1995) indicating that the strait consists of 3 sectors including Gelibolu, Nara, and Kumkale. Nara is the narrowest sector and has a sharp turning point.

Slowing Down (Turkish Straits Vessel ... 2008):

- An immediate notice should be given to the TSVTS Centre when a vessel is forced to slow down in either Istanbul or Canakkale Strait. The TSVTS Centre shall assess the traffic situation and provide information, recommendations and instructions regarding the situation.

Overtaking (Turkish Straits Vessel ... 2008):

- Vessels shall not overtake another vessel unless there is an absolute necessity. In case of such necessity, a vessel intending to overtake another shall inform the TSVTS Centre prior to commencing the overtaking. The TSVTS Centre shall

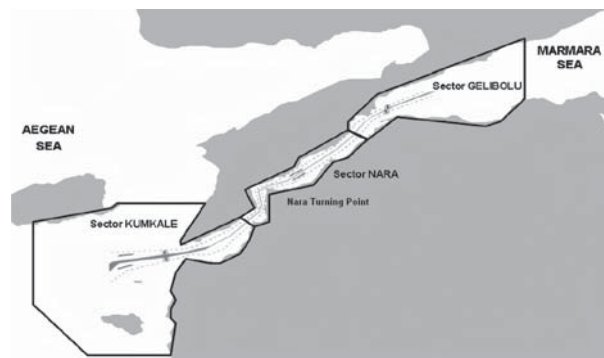


Fig. 4. The traffic separation system at Canakkale Strait

assess the traffic situation and provide information, recommendations and instructions regarding the situation.

- Efforts shall be made to overtake the vessel in a single manoeuvre. However, overtaking shall not take place between Nara and Kilitbahir in Canakkale Strait.

Visibility (Maritime Traffic Regulations ... 1994):

- Whenever visibility is 2 NM or less in any part of the Strait, the vessels passing through the Strait will keep their radar turned on constantly to provide radar readings. On the vessels with two radars, one of those will be assigned to the pilot's usage.
- When visibility is 1.5 NM or less in any part of the Strait, the vessels the radar of which does not provide complete display ability shall not enter the Strait.
- When visibility in the Strait is 1 NM or less, the vessels carrying hazardous cargo and large vessels shall not enter into the Straits.
- When visibility in any part of the Strait is 0.5 NM, maritime traffic shall be open in the appropriate direction and closed in the opposite. In such situations, only vessels less than 100 meters in length and carrying no hazardous cargo can navigate in the direction open to traffic.
- When visibility in any part of the Strait is less than 0.5 NM, the traffic flow in the Strait shall be closed in both directions.
- When visibility in the Strait is suitable for navigation, the arrangement and order of entering the Strait shall be determined and notified to the waiting vessels and persons concerned by the Traffic Control Centre.
- When a large vessel with hazardous cargo enters the Strait, a similar vessel approaching from the

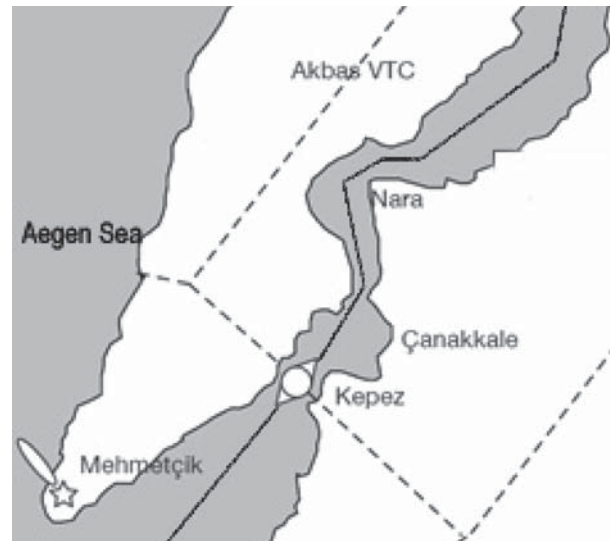


Fig. 5. The manoeuvring scheme of VLCC tanker

opposite direction may not enter the Strait until the previous vessel has exited. There shall be a distance of at least 20 NM between two such vessels proceeding in the same direction.

- The competent authorities may temporarily suspend two-way traffic and regulate one-way traffic to maintain a safe distance between vessels. As can be seen from Fig. 5, a large vessel during manoeuvring can violate the traffic separation lane due to the sharp turning point at Nara and Kilitbahir.

1.4. Statistics on Canakkale Strait

The passage through Canakkale Strait is given in Table 1, (UMA 2006). In 2006, 48915 vessels in total passed the Strait of Canakkale. The total numbers of tanker passages are 9567 from which LPG and LNG carriers make

Table 1. Statistics on passages through the strait in 2006 (UMA 2006)

Months	Vessels Passed	# of Tanker carrying dangerous goods	Length 250–300 m	Length 200–250 m	Length 150–200 m	Length 100–150 m	Length <100 m
January	3456	714	72	110	236	156	140
February	3371	768	64	128	249	174	153
March	4018	831	74	142	215	205	195
April	4156	770	63	139	208	165	195
May	4385	861	76	151	229	191	214
June	4320	826	68	139	208	180	231
July	4323	841	71	152	206	185	227
August	4426	852	81	146	200	207	218
September	4234	750	74	131	189	192	164
October	4045	776	70	137	202	186	181
November	3999	801	65	132	210	190	204
December	4182	777	65	112	213	184	203
Total	48915	9567	843	1619	2565	2215	2325

798 passages and chemical tankers – 1447 passages. 7204 oil tankers are also included in this number.

Table 1 discloses that 843 vessels between the length of 250–300 m, 1619 vessels between the length of 200–250 m and 7105 vessels between the length less than 200 m passed through the strait in 2006.

2. Material and Methods

A simulation model can be used for determining the effects of changes (scenarios). For example, Hayuth *et al.* (1994) used a simulation model to evaluate the future of the port and ensure optimum investment strategies. In this study, the simulation language AWESIM was used as primary modelling tools (AweSim! User’s Guide 1997). Thiers and Janssens (1998) made detailed models of traffic on the rivers, including navigation logic, tides and lock planning. Köse *et al.* (2003) investigated marine traffic at Istanbul Strait. They found the bottleneck points at the strait. Demirci (2003) investigated port and new investments using AWESIM. Somanathan *et al.* (2009) simulated passage traffic at the North of Canada.

3. Simulation of the System

The model was developed to simulate traffic at Canakkale Strait. This model investigates the behaviour of traffic according to different scenarios and different ship arrival and waiting times. Namely, the model simulates traffic at Canakkale Strait and gives information about future traffic under different scenarios.

The developed model includes only national and international transpassing ships. Therefore, inputs to the model such as the number of ships at both ways were taken from Table 1. Weather conditions were obtained from the Turkish State Meteorological Service (2006).

Three sub-systems were used to simulate the system:

- traffic flow in direction 1 (from Marmara to the Aegean Sea);
- traffic flow in direction 2 (from Aegean to the Marmara Sea);
- two information systems representing big ships and the simulation of bad weather conditions.

Each of these processes is modelled considering the movement of the entity through a sub network. Big ships (ship length $L > 200$ m) are modelled by gates open representing no big ship through. To ensure that only one ship enters the strait from one side, a resource, where only one ship is allowed to pass, is employed in conjunction with the gate. These resources are named Marmara and Aegean corresponding to m1 and a1 and represent the starting location before each direction (the Marmara and Aegean Sea entrance). The starting location is seized by each ship entity before passing through and then freed immediately after it passes. FIFO rule is applied at the entrances.

The network model is depicted in Fig. 6. Although, the decision logic of traffic flow at both directions is the same, arrival time and time in the system are different. Therefore, two networks are used to model both traffic flows with the attributes employed to specify the

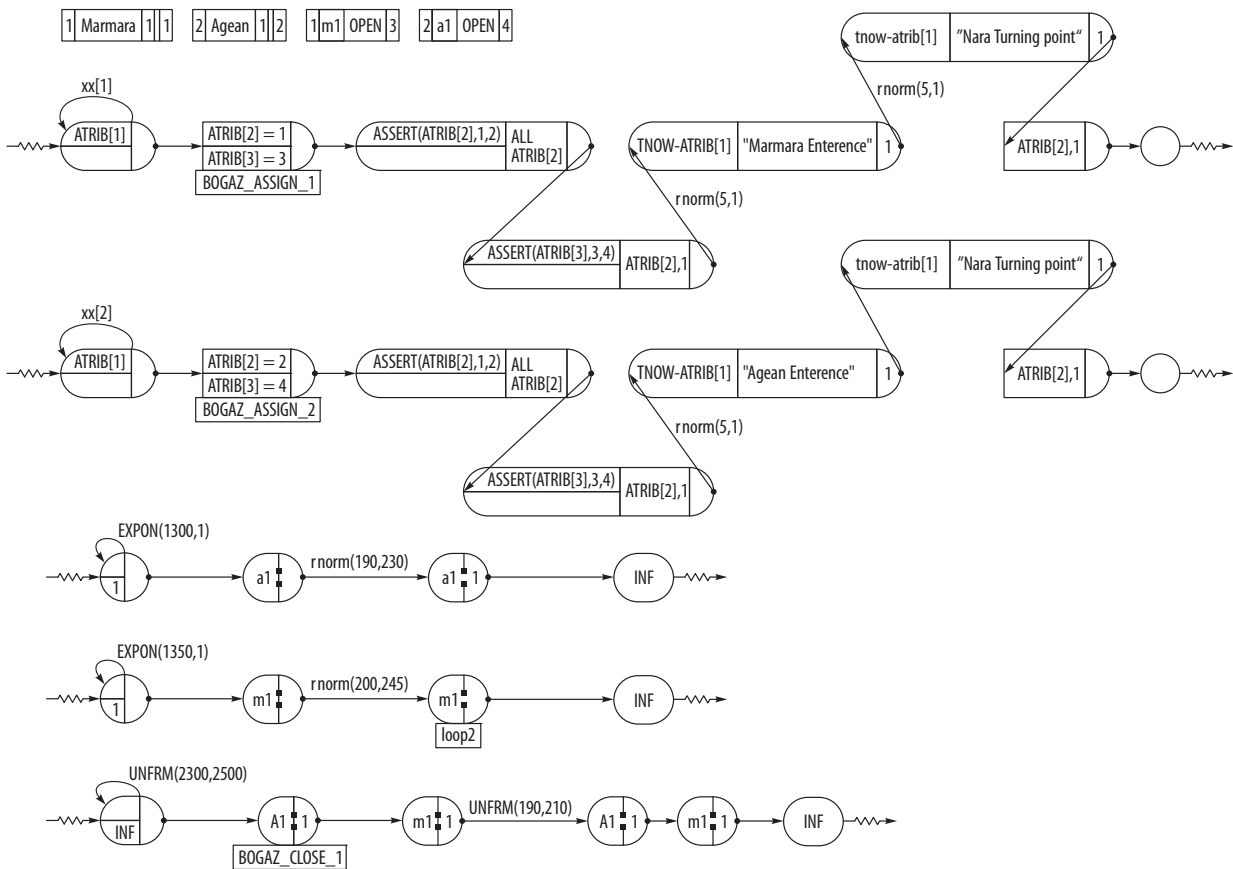


Fig. 6. The network for Canakkale Strait

resources and the gates required. ATRIB (2) is used to maintain the resource number and file number associated with the first location. If ATRIB (2) equals 1, the ship entity requires the resource *m1*. If ATRIB (2) equals 2, then resource *a1* is required.

The entities representing ships are created at two CREATE nodes, one for each direction. Time between ship arrivals is uniformly distributed. Following the creation of the entities, ATRIB is called ATRIB (2) =1 for direction 1 and ATRIB (2) =2 for direction 2. The ships waiting for entering will be put in files 3 or 4 and ATRIB (3) is used to indicate these numbers. Thus, entities are assigned and ATRIB (3) =3 for direction 1 and ATRIB (3) =4 for direction 2. Once the entity is allocated for the starting location, it proceeds to the next AWAIT node waiting for the gate is defined by ATRIB (2) which is either *a1* or *m1*. If an appropriate line is closed (which means a big ship goes through the line), then, the entity will wait in files 3 or 4 in accordance with the value given by ATRIB (3). The COLCT node is used to record the values of the waiting time of the ship at the entrance.

Two other segments of the model control the entrance of a big ship or dangerous cargo vessels in any direction and consist of a series of OPEN and CLOSE nodes. In this segment of the model, resources and gates are referred to the label given them in the RESOURCE and GATE blocks. GATE 1 refers to the line from the Black Sea to the Marmara Sea and GATE 2 is vice versa. If a gate is open, the ship can proceed, otherwise, they have to wait until the gate is open. The system closes the gate according to uniform distribution between 190 and 230 minutes and duration of 200–245 minutes which corresponds to approximately 1325 hours per year which means that one line is closed about 1325 hours. The last segment of the model is simulating dangerous passages and bad weather conditions to close two lines.

To simulate the system, the following assumptions are made:

- vessels do not overtake each other;
- vessels enter the strait one at a time from each entrance;
- all vessels are trans-passing (not stopping for loading and unloading within the strait);
- local crossing traffic does not interfere with transit traffic.

Ship arrivals were simulated with 5 different uniform distributions and the intervals of those are given in Table 2.

Table 2. Distribution of ship arrivals (a – the Aegean Sea entrance, m – the Marmara Sea entrance)

Scenarios	Low		High	
	m	a	m	a
1	20	21	23	23
2	16	17	18	19
3	14	14	16	17
4	12	11	14	13
5	10	10	9	11

a1 direction was assumed to be closed with the uniform distribution between 190 and 230 minutes which corresponds to closure once every 1300 hours. *m1* direction was closed once every 1350 hours and close time varied between 200–245 minutes. The closure of two directions was modelled also with uniform distribution between 2300–2500 minutes which corresponds to about 219 hours of closure a year.

The model was running for 43200 minutes (1 month) for six different arrival times. The results of six scenarios are given in Table 2.

4. Results

The third scenario simulates the existing situation modelled by uniform distribution between UNFRM (14, 16) for Marmara entrance and UNFRM (14, 17) for the Aegean Sea entrance. The average arrival times for Marmara and Aegean entrances are 15 and 15.5 minutes and the average waiting times make 24 and 18 minutes respectively. When arrival time reduces to the average, 10 minutes waiting time and the number of waiting ships increase rapidly (see Figs 7, 8 and Table 3).

Fig. 7 shows that an increase of 25% in ship number grows 43 times taking into account the number of waiting ships at Marmara entrance (from 1.663 to 73.73) and 76 times at the Aegean Sea entrance (from 1.094 to 84.81).

Fig. 8 shows that only 25% increment in ship arrivals caused ship waiting time to increase from 24.267 to 737.73 minutes for Aegean entrance. Similar results were also found for Marmara entrance (from 18.386 to 883.73 minutes).

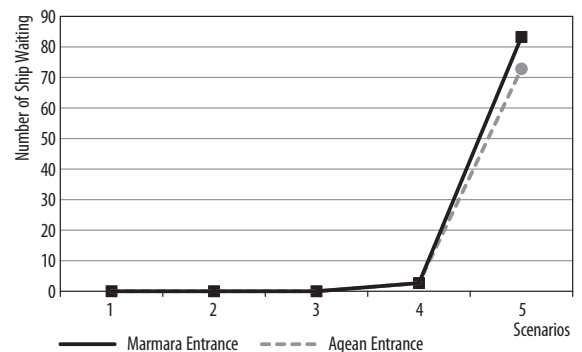


Fig. 7. The average number of waiting ships

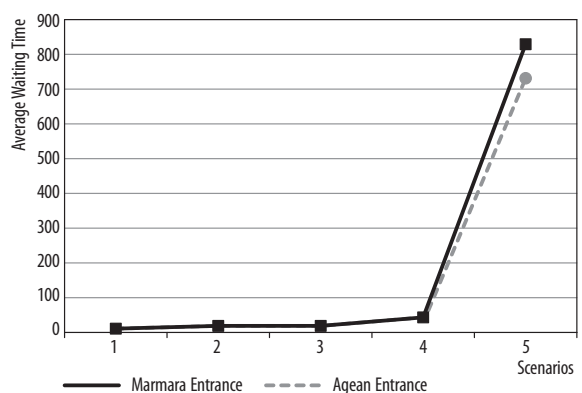


Fig. 8. The average number of waiting time

Table 3. The results of 5 scenarios (a – the Aegean Sea entrance, m – the Marmara Sea entrance)

Scenarios		1	2	3	4	5
# of observation	m	2160	2514	2953	3559	3976
	a	2057	2492	2563	3568	3984
Average Length	m	0.705	0.989	1.663	3.397	73.735
	a	0.622	0.999	1.094	3.491	84.816
Std. Dev.	m	1.973	2.491	3.436	4.913	37.506
	a	1.795	2.503	2.646	4.933	46.532
Waiting Max. length	m	10	12	14	17	133
	a	10	12	12	17	160
Current Length	m	0	0	7	6	133
	a	0	0	6	6	160
Average waiting Time (min)	m	14.091	16.999	24.267	41.157	737.073
	a	13.062	17.313	18.386	42.186	832.72
Average Utilization	m	0.917	0.916	0.920	0.918	0.913
Average Utilization	a	0.632	0.688	0.785	0.815	1.00

5. Conclusions

1. Everyone recognizes that given the nature of Canakkale Strait and the existing grave situation created dense traffic congestion. In this case, the strait cannot bear additional oil shipments without putting into danger the safety of Canakkale, the lives of its population and its unique historical and precarious environment.
2. The third simulation is the current level of maritime traffic. The obtained results of this simulation show that waiting time at Marmara entrance is about 24 minutes.
3. As seen from Table 3, if maritime traffic at Marmara entrance increases in 25%, the average waiting time changes from 24 to 737.
4. Table 3 also indicates that an increase of 25% in traffic at Aegean entrance would result an increase in waiting time from 18 to 883.
5. As simulations showed, there would be congestion at the entrances of the strait in case of the increased number of ships which would put pressure on either vessels to increase their speed or the owners to carry goods using large ships.
6. The current systems and approximately 90 degrees turning make ship manoeuvring difficult at Nara Turning point. Large ships and speed increase would regularly make manoeuvring difficult. Thus, Nara point can be considered as a risky area. Therefore, necessary actions like keeping emergency staff and equipment should be taken.

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