A suggestion to improve navigational safety in the Strait of İstanbul (Bosphorus): Patrol tugs

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Abstract

The Strait of İstanbul, which connects the Black Sea countries and the rest of the world, is the second busiest waterway in the world. In addition to intensive maritime traffic, the increased risk of accidents is alarming, given the environmental factors that complicate the navigation of the vessels. Historical data and literature review have shown that there is room for improvement with regard to measures taken to ensure the safe navigation in order to prevent accidents in the Strait of İstanbul. In this respect, determining the characteristics of past maritime accidents and identifying risky areas is vital to improve the level of safety. In this study, the temporal and spatial profile of maritime accidents that occurred in the Strait of İstanbul in the 2006-2015 period have been examined simultaneously with the variables of hourly wind speed and wind direction in the region. Results that were obtained indicate that accidents impending to happen can be prevented in the Strait of İstanbul if the patrol tugs take action when the ships were experiencing breakdown and/or navigational difficulties. The effectiveness, response time and response options of the proposed patrol tugboats were evaluated in two different scenarios where ship and currents are parallel and anti-parallel.

Keywords: Maritime policy, safety navigation, patrol tugs

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Introduction

Maritime transportation is the backbone of the global trade. Today, about 90% of global trade by volume is carried via sea (ICS 2020). According to the report of the United Nations Conference on Trade and Development, world maritime trade gained momentum in 2017 and recorded the fastest growth in the last five years. Moreover, it is expected to expand at an annual growth rate of 3.8% between 2018 and 2023 (UNCTAD/RMT/2018). Increase in world seaborne trade leads to intensive maritime traffic, and an inevitable consequence of this is the rising risk of maritime accidents. Historical data have shown that these accidents usually take place on the busiest routes (Butt et al. 2012). Today, both national maritime authorities and international organizations are making efforts to prevent accidents in these waterways. Therefore, various studies have been carried out in order to improve the safety level in the world busiest seaborne routes. In Eleftheria et al. (2016), the risk level of the world fleet was measured and risk factors were identified in order to evaluate the current security level of the ships. The results of the study showed that there was a general increase in the frequency of ship accidents between 2006 and 2016. Puisa et al. (2018) focused on revealing the causes of marine accidents. In this context, the sea events occurring in passenger ships in the last 10 years were examined in terms of causal factors. Kulkarni et al. (2020) presented a review of the academic literature on waterway risk management, which focuses on accident prevention-oriented work. Owing to the fact that it is the shortest shipping route from the Indian Ocean to the Pacific Ocean, the Strait of Malacca is one of the busiest waterways in the world and it has the highest traffic volume in terms of the number of ships passing through. Zaman et al. (2015) revealed that collision-type accidents are the major safety concern there. Another study has shown that exceedance of the ship speed suggested by Passage Guide is one of the main factors leading to collisions in the Malacca Strait (Qu et al. 2011).

The Strait of Istanbul is the second busiest waterway after the Malacca Strait and roughly four times busier than the Panama Canal and three times busier than the Suez Canal (Maritime Local Traffic Guide of Harbor Master of Istanbul 2011).

As it is the only waterway between the Black Sea countries and the rest of the world, the traffic density of the Strait of Istanbul is increasing day by day. In 1947, an average of 17 ships per day were passing through the Strait of Istanbul, whereas this number has increased approximately by 7 times and reached 117 in 2017 (DTGM 2018). This increase led to a significant increase in the number of accidents during this period (KEGM 2020; MSRCC 2019). Some of these accidents caused environmental disasters, hence created a worldwide concern. In 1979, 94,000 tons of crude oil was spilled into the sea as a result of Independenta accident (ITOPF 2018). In 1994, after the collision between Nassia and Shipbroker, 29,000 tons of crude oil was spilled into the sea (Küçükyıldız 2014).
Aşan et al. (2020) drew attention to the challenging features of the Strait of Istanbul in the case study related to the 1994 Nassia accident. The results of the study showed that special care is needed to prevent potential accidents and environmental pollution that may occur as a result. As a consequence of these accidents, a number of studies were carried out by the national authorities in order to address the safety concerns in the Turkish Straits, including the Istanbul and Çanakkale Straits. Because of the success of intervention in a hazard event, it is directly related to the process in which the relevant units start the rescue activities. The shorter this period of response, the higher chance of success of the rescue operation. Otherwise, the size of the loss of life/property increases (Acarer 2018). In this context, the Turkish authorities revised the regulations governing the maritime traffic through the Turkish Straits in 1994 and 1998 (Maritime Traffic Regulations for the Turkish Straits 1998). International Maritime Organization (IMO) also adopted a set of rules and recommendations (IMO Recommendations 1995). It was agreed that navigational traffic separation schemes were to be implemented in the Turkish Straits System (TSS). Finally, all those measures were supported by a Vessel Traffic Service (VTS) which was established in 2003, in order to monitor ship traffic.

Although the regulations contributed to the increase in the level of safety, they were not enough to prevent accidents. In 2018 the Vitaspirit accident exhibited a well-known vulnerability: in the case of an engine breakdown and rudder failure of the ship while passing through these narrow areas, all the measures taken may remain useless. VTS with all its services remains ineffective. A pilot onboard the ship had limited options to take. In the Vitaspirit case, there were only 7 minutes between the engine breakdown and ship crashing into an house. Options that can be initiated in order to prevent such an accident in those 7 minutes were very limited.

The improvement of the safety level in the Strait has been an essential subject since the past. In this direction, there have been serious scientific publications focusing on identifying additional measures. In Atasoy (2008), local traffic density in the Strait of Istanbul was examined and it was underlined that studies were needed to determine the blind spots that might cause navigation safety problems. Arslan and Turan (2009), marine casualties in the Strait of Istanbul were investigated with SWOT–AHP method. A maritime traffic risk analysis was performed in the area and results that were obtained showed that reducing the following distance between ships is one of the main factors increasing the accident risk (Özbaş 2010).

The effect of ship length as a factor in safe navigation in the Strait of Istanbul was investigated by analytic hierarchy process method. The study indicated that this factor has a significant impact on safe navigation over the ship lengths of 151-200 m (Keçeci 2010). An artificial neural network model was developed to estimate maritime accidents in the Strait of Istanbul. The results of the study
showed that vessels larger than 58,000 GRT caused accidents when they did not take pilots (Küçükosmanoğlu 2012).

Comprehensive scenario analysis for mitigation of risks of the maritime traffic in the Strait of Istanbul has been made (Özbaş et al. 2013). In the report prepared by (DNV 2013) the risk factors that threaten navigation safety in the Strait were highlighted and it was revealed that these factors varied by accident types.

The number of ships passing through the Strait of Istanbul was examined by trend analysis, according to the year and the gross tonnage of the ships. The results of the study showed that despite the decrease in the number of ships passing, the ships’ gross tonnage increased (Arslan 2014). In Musaoğlu et al. (2015), remote sensing and geographic information systems for determination of high-risk areas regarding marine traffic in the Istanbul Strait have been used. In Altan (2017), a maritime traffic modelling based on automatic vessel tracking system was conducted in the Strait and collision-type accidents were analyzed. In Şirin (2018) the probability of collision and grounding in the Strait of Istanbul has been calculated with the help of mathematical models and it was shown that these accidents were commonly performed by general cargo ships. The results of the model has indicated that grounding and collision type accidents tend to increase especially at night and the grounding type accidents increase in parallel with the traffic density.

The factors affecting passage times of ships in the Strait were investigated by Taşan (2019). Özdemir (2019) examined maritime accidents in the region spatially using the GIS method 2003 and 2013. The results of the study indicated that accidents were intensified inside the Strait and waiting areas. İstikbal (2020) examined major accidents in the Strait of Istanbul in terms of abolishment of left-hand side navigation. (Korçağ and Balas 2020) examined the reducing the probability for the collision of ships by changing the passage schedule in Istanbul Strait. In a review study (Kodak and Acarer 2021) the effect of maritime traffic regulations on the accident rate in the Strait of Istanbul was examined. In this study, accidents that took place in the Strait were examined temporally and spatially under the environmental factor variables, aiming to present a suggestion for the prevention of accidents. It was proposed to place patrol tugs on certain areas in the Strait to monitor the ships passing through the risky areas and to take action in case of any wrong-going.

**Materials and Methods**

In this study, database on ship accidents was created based on the records of the maritime accidents in the Strait of Istanbul in the 2006 - 2015 period and the accidents were analyzed as temporal and spatial. The data were gathered from Republic of Turkey, Ministry of Transportation and Infrastructure, Main Search and Rescue Coordination Center. The data set contained time and location information pertaining to 250 merchant ships that had a marine accident while passing through the Strait of Istanbul.
The Strait of Istanbul consists of three VTS sectors, which are named from North to South as Sector Türkeli, Sector Kandilli and Sector Kadıköy, and each sectoral region has its own distinguishing decisive features, which play a role in the accidents. Thus, maritime accidents ratios vary significantly in the Strait of Istanbul, from one VTS Sector to the other. In this study, accident area was defined as the domain between the northern border of Sector Türkeli and the southern border of Sector Kadıköy. The data used in this study consist of the record of the accidents that took place within these boundaries. Mentioned boundaries are presented in Figure 1.

Wind dynamics has been one of the most important factors to be considered in the occurrence of accidents in the Strait and in determining the solution options. Therefore, environmental factors in the strait were also taken into account when examining accidents within the sectoral boundaries. For this purpose, meteorological data were obtained from Sarıyer and Atatürk Meteorology Stations located in the sectoral areas of Kandilli and Kadıköy. The data consist of hourly wind direction and hourly wind speed information measured between January 1, 2005 and December 31, 2017.

This study aims to put forward a suggestion to prevent maritime accidents in order to contribute to safety of navigation in the Strait of Istanbul. For this purpose, regional profile of maritime accidents was examined and locations where accidents were concentrated was determined. To understand the spatial characteristics of the accidents, the Strait was examined within the framework of delimitations of three VTS sectors and number of accidents per year for each VTS sector was compared. Following temporal and spatial analysis, "Patrol Tugs" were conceived as a potential solution for the prevention of accidents. In this direction, last section has been devoted to examining of the suggested patrol tugs in detail. Firstly, the reaction times of tugs have been discussed and the second
part has been dedicated to the determination of optimum base locations for patrol
tugs. In this context, current regime and wind profile have been investigated for
determining of the patrol areas for tugs. Finally, response options of the patrol
tugs have been explained. These options have been evaluated for two scenarios
when the ship and the current proceed in the same direction and vice versa.
Mentioned studies are summarized in Figure 2.

![Figure 2. Main steps of the study](image)

**Result and Discussion**

*Temporal profile of accidents*
In order to understand the changes in maritime accidents within the study period,
the first step was to create a time series. The time series graph drawn for maritime
accidents in the Strait of Istanbul between 2006 and 2015 indicated that accidents
had a tendency to decrease, particularly after 2010, although there were fluctuations from year to year. In the 4-year period before 2010, the number of
accidents sharply increased between 2007 - 2008 and 2009 - 2010. The number
of accidents reached to the maximum in 2010 and it was observed a steadily
downward trend after this point. Especially after 2011, the number of accidents
began to fall below the mean calculated within the 10 years. There were 250
maritime accidents in the 10-year period in the Strait of Istanbul and this number
corresponds to an average of 25 accidents per year. Mentioned mean value is
expressed with red line on Figure 3.

Traffic in the Strait of Istanbul is organized according to the Maritime Traffic
Regulations for the Turkish Straits (1998). In addition, traffic separation schemes
designed in accordance with Article 10 of the International Regulations for
Preventing Collisions at Sea (COLREG 72) and adopted by the IMO have been
established (Turkish Straits Navigation Guide 2015). As of 23 July 2005, some
restrictions have been applied due to the MARMARAY PROJECT underwater
railway tunnel construction area at the southern entrance of the Strait. In this context, from 12 August 2005 onward, flow of sea traffic is being planned only one way, with the exceptional categories of vessels (passenger ships, ro-ro passenger, livestock carriers, war ships, ships with safety reasons, etc. are always allowed from the opposite traffic). In other words, it has applied controlled two-way traffic system with one-way planning with some exceptions in the Strait. The measures taken within the scope of the MARMARAY project have revealed another fact: one-way planning of traffic in the region has made a noticeable decrease in the number of accidents and has revealed the importance of one-way traffic in terms of safety of navigation. Especially after 2010, the steady downward trend in the accidents clearly revealed this effect.

![Figure 3](image_url)

**Figure 3.** Temporal representation of maritime accidents in the Strait of Istanbul.

*Spatial profile of accidents*

The Strait of Istanbul, which has perilous geographical conditions, is 18 nautical miles (~33 kilometers) in length. The narrowest part of the Strait is located between Aşiyan and Kandilli with 698 meters width (Özsoy 2016).

Due to its geographical curves, the vessels which pass through in the Strait of Istanbul have to make at least eight major course alterations. These course changes are $13^\circ$ in Fil Burnu, $73^\circ$ in Macar Burnu, $82^\circ$ in Koybaşı Burnu, $46^\circ$ in Kanhca, $39^\circ$ in Aşiyan Burnu, $21^\circ$ in Kandilli Burnu, $36^\circ$ in Defterdar Burnu and $51^\circ$ in Kiz Kulesi (Figure 4). Some of the mentioned large angular turns are “blind”, with no direct visibility of the next leg of the turn, therefore large ships which are restricted in maneuverability and steering pass through in the Strait with more dependence on the local maneuvering skills, a local pilot and the Turkish Straits Vessel Traffic Services support (DNV 2013).
Figure 4. Most dangerous large angular turns in the Strait of Istanbul (Kodak 2021)

Distribution of the maritime accidents that took place in the Strait of Istanbul in three sectoral area is presented in Figure 5. Sector Kadıköy was the most intense area in terms of the frequency of accidents with 172 accidents between 2006 and 2015. This number corresponded to 68.8% of total accidents and more than half of the total number of accidents over 10 years.

Figure 5. Distribution of the maritime accidents according to their sectoral area in the Strait of Istanbul (MSRCC 2019)

Sector Türkeli followed Sector Kadıköy in terms of accident intensity, with 43 accidents. This number corresponds to 17.2% of the total accidents. In the Sector Kandilli region, 35 maritime accidents occurred in the same period. This number corresponds to 14% of the total accidents.
In a study by Coleman (2015) box plot described that as a graphical method using to summarize a data set by visualizing the minimum value, 25th percentile, median, 75th percentile, the maximum value, and potential outliers. The line near the middle of the box represents the median and the whiskers on either side of the IQR represent the lowest and highest quartiles of the data. Furthermore, ends of the whiskers represent the maximum and minimum of the data. If there is individual dots beyond the whiskers, they indicated that outliers in the data set. Figure 6 shows that accidents concentrated in Sector Kadıköy. According to the descriptive statistics results, the annual accident averages for the Kadıköy, Kandilli and Türkeli sectors were 17.2, 3.5 and 4.3, respectively, shown as red dots in Figure 6. In the 10-year period, the number of accidents per year in Kadıköy was minimum 5 and maximum 34. Kandilli and Türkeli sectoral areas had similar mean values in terms of accident intensity. No possible outlier was observed in the distribution of accidents by sectoral area.

Mean and median values were close to each other in all sectoral areas. Herein, Kadıköy and Kandilli sectoral areas were the region where accidents were most balanced over the years, because the mean and median values almost intersected. However, the mean values were greater than the median value by a small difference. Similarly, mean value was greater than median value, which leads to right-skewed distribution in Türkeli.

A suggestion for prevention of the accidents: Patrol tugs
According to the records of the Ministry, there were 32 near misses due to rudder and engine failures which were prevented before the accident would happen.
between 2000 and 2017. These near misses were prevented by tugs and they were recorded as hazardous incidents in the MSRCC data (MSRCC 2019). This number means that about two accidents per year were prevented by the tugs and this indicates an important role of tugs in preventing accidents. In other words, if the patrol tugboats had been placed in risk areas before accidents occurred, most of accidents would not have happened.

The aim of this study is to present a proposal to contribute to the prevention of accidents and improvement of the safety level in the Strait of Istanbul. Considering their accident-reducing effect, patrol tugboats placed in risky areas were proposed to prevent accidents in the Strait of Istanbul. The points where the proposed patrol tugboats can be placed, its response time and response options are discussed in following sections.

**Response time**

“The Strait of Istanbul is about 0.5 to 1 nautical miles wide in most areas and this is a major difficulty for navigation. Typical ship speed on the ground vary between 8 to 12 knots, which means that the response window for the tug intervention could be as little as 1 minute (half the strait width) and 30 minutes the most. On the other hand, maximum speed of a typical tug at low sea conditions is about 14 knots. That is, if the tug is only at 0.25 nautical miles distance from the ship, it will take about 2 minutes to reach the ship. Of course, the correct response depends on the type of accident, the position of the tug and the environmental factors such as current speed and direction, wind speed and direction.” (DNV 2013). In this context, environmental factors, which are an important factor in selecting the location of patrol tugboats, are discussed below.

**Selection of the optimum location of patrol tugs**

The secret triggering mechanism of the majority of maritime accidents is environmental factors in the Strait of Istanbul. Geographical limitations, wind forces and currents cause accidents as a result of the restriction they pose on maneuverability of the ship. These factors increase the intensity of accidents, especially in the Sector Kandilli Region, which is the narrowest and sharpest turning area in the Strait. In the framework of geometric constraints, the most dangerous sharp turns in the Strait of Istanbul are presented in Figure 4. Considering the regional accident rate, annual accident density, the frequency of accidents per sectoral area, current regime and the wind profile in the area, the Kandilli sectoral area was selected as the location of the proposed patrol tugboats. In this context, the patrol points were selected as Büyükdere, Beykoz, İstinye, Küçüksu and Bebek (Figure 7).

Environmental factors that are effective in the selection of optimum location of patrol tugs are examined below.
Wind direction
Meteorology stations located in different sectoral areas were chosen to best represent the wind direction profile in the Strait. These are Sarıyer Meteorology Station within the borders of Sector Kandilli and Atatürk Meteorology Station in Sector Kadıköy (Figure 8). Both stations have hourly wind direction data covering the 12-year period between 2005 and 2017, shown in Figure 9. At Sarıyer and Atatürk Meteorology Stations, and the wind directions recorded in these stations between January 2005 and December 2017 are overwhelmingly NNE. Compared to Sarıyer Meteorology Station, southern winds were more frequent at Atatürk Station.

When both graphs were evaluated together, it was clearly seen that NNE and NE winds were the most dominant winds in the Strait of Istanbul. Due to the Strait is
aligned with the NE-SW axis, dominant winds contributed to the current regime in their position. As a result of the wind forces, large angular course changes for passage are inevitable. The effect of wind force makes it difficult to handle the ship, especially in the area between Macar and Koybaşı Burnu (DNV 2013).

**Wind speed**

Wind speed recorded at Sarıyer Station and Atatürk Station in the 12-year period was examined daily, monthly, seasonally and yearly (Figures 10 and 11).

![Wind Speed Graphs]

**Figure 10.** Daily, monthly, seasonally and yearly wind speed variation for Sarıyer Station (Kodak and Acarer 2021)

Daily means of the wind speed were overwhelmingly recorded below 10 m/s at the Sarıyer Station. During the 12 years, the average daily wind speed exceeded 10 m/s only 24 times. Monthly means of the wind speed were calculated below 5 m/s at the Sarıyer Station. Monthly wind speed was recorded over 5 m/s only in August 2009, August 2013 and August 2016 within 12 years. Seasonal averages of the wind speed was generally calculated below 4.5 m/s at the Sarıyer Station. Monthly averages show that the wind speed reaches its highest value in September 2016, while the lowest value calculated in December 2017. The data recorded at the Sarıyer Station showed that the average annual wind speed was generally below 3.6 m/s. According to the data, the annual average wind speed measured at the Sarıyer Station shows that the wind speed increased as of January 2011 and reached its maximum value at the end of year. The annual average wind
speed, which tended to decrease in 2016, experienced the sharpest decline in 2017.

Wind speeds recorded at Atatürk station in the 12-year period are examined in Figure 11, daily, monthly, seasonally and yearly, respectively. Daily means of the wind speed were commonly calculated below 10 m/s at the Atatürk Station. During the 12 years, the average daily wind speed exceeded 10 m/s, only 24 times. Monthly means of the wind speed were recorded overwhelmingly below 5.5 m/s at the Atatürk Station. While the lowest average wind speed occurred in January 2005, the highest average has been recorded in August 2016. Seasonal means of the wind speed were overwhelmingly recorded below 5 m/s at the Atatürk Station. Seasonal autocorrelation was not observed in the average wind speed measured over 12 years. The highest wind speed was observed in the autumn 2016. The lowest wind speed in the 12-year period has observed in the winter of 2007. The annual average wind speed measured at the Atatürk Station shows that the wind speed increased as of January 2015 and reached its maximum value at the end of 2016. The average annual wind speed was in a downward trend until the end of 2017.

![Figure 11. Daily, monthly, seasonally and yearly wind speed distribution for Atatürk Station (Kodak and Acarer 2021)](image)

In Figure 12, CDF graphs have shown that all wind speed values measured at both Sarıyer and Atatürk Meteorology Stations were less than 15 m/s. Additionally, 99% of the data at both stations was below 10 m/s. Approximately 75% of the
wind speed data recorded at Atatürk Station in the 12-year period was under 5 m/s. Similarly, approximately 75% of the wind speed data measured at the Sarıyer station was recorded below 4 m/s.

In the histograms created for wind speed (Figure 13), a right-skewed distribution was observed in the Sarıyer Station. The Atatürk Station displayed a closer distribution to the normal distribution compared to the Sarıyer Station. In the Sarıyer Station, winds frequently occurred between 1 and 2 m/s. The frequency of occurrence decreased as the wind speed increased. On the other hand, wind speed in the Atatürk Station was measured between 2 and 3 m/s most frequently.

![CDF plots for wind speed measured at Sarıyer and Atatürk Meteorology Stations](image1)

**Figure 12.** CDF plots for wind speed measured at Sarıyer and Atatürk Meteorology Stations

![Frequency distribution of wind speed measured at Sarıyer and Atatürk Meteorology Stations](image2)

**Figure 13.** Frequency distribution of wind speed measured at Sarıyer and Atatürk Meteorology Stations

*Current regime*
Strait of Istanbul has a two-layered current system formed by the surface currents flowing from north to south and the undercurrents flowing from south to north.
In addition to the surface and undercurrents, reverse currents and “Orkoz” are other components that further complicate the currents system in the Strait of Istanbul. Surface and subsurface currents at the Strait are given in Figure 14.

Surface Currents: The annual average of 40 cm water level difference between the Black Sea and the Marmara Sea forms surface currents flowing from the Black Sea to the Marmara in the Strait of Istanbul. These currents are concentrated in the central parts of the Strait of Istanbul and increase southward of Kandilli (Atasoy 2008). In this regard, the area in which the surface currents reach to a maximum speed is Beylerbeyi with 4-5 knots. Surface currents flow with a speed of about 3-4 knots in Akıntı Burnu, Kandilli and Sarayburnu areas (Topakoğlu 2004). The speed of currents increases near the coast and reverse currents are created in small-sized bays which further gives difficulty to the maneuvering of passing ships (İnan 2011).

Undercurrents: The undercurrent creating the other layer arises from the density differences between two seas, it starts 15 meters below the surface of the water and can be as effective as the depth of 45 meters (Keçeci 2010).

Reverse Currents: In many of the bays in the Strait, reverse currents are formed. Velocity of the reverse currents varies depending on the speed of the surface current. Near the southwest coast of Ortaköy, the speed of the reverse current is 0.5 nautical mile on average. The reverse current between Defterdar Burnu and Akıntı Burnu becomes stronger near points of the shore and it turns east to the south of Akıntı Burnu and mixes with the main current. Some of the other reverse currents are located in the north-east of Beylerbeyi, Anadoluhisarı, Vanikoğ, Bebek Bay and İstinye Bay. At Büyükdere Bay, the reverse current, which has a speed of 0.5 nautical mile, follows to coast in the direction of Poyraz and reaches up to Macar Burnu (Maritime Local Traffic Guide of Harbor Master of Istanbul 2011).

Orkoz Current: As seen in Figure 9, northern winds were dominant in the region and those strong winds strengthen the southerly flow. However, in addition to the strong northerly winds, the winds from south can rarely be effective and deterministic in flows (Arslan 2014). In this context, the southern winds affecting the Strait of Istanbul, in particular, can move the waters of southwestern Marmara to the north and raise the water level in the southern entrance of the Strait of Istanbul up to half a meter. This changes the current regime of the Strait of Istanbul and creates a reverse current called as “Orkoz” on the surface. The speed of these currents can reach 6 - 7 knots (Maritime Local Traffic Guide of Harbor Master of Istanbul 2011).
Figure 14. Surface and subsurface currents at the Strait of Istanbul. The box on the right shows the cross section of the Strait, indicating the surface and under currents in opposite directions. (Turkish Navy 1990; İstikbal 2020)

**Negotiating the bends**

Considering the rocky structure of the Strait of Istanbul, which requires sharp turns, currents create great hazards such as causing accidents by reducing the maneuverability of vessels. The natural desire of ship masters is to start an early turn at the bends in a strait, making a shortcut between the corners. However, this is not always possible, particularly if a TSS (Traffic Separation Scheme) exists.

Figure 15. Current pushes the fore of the ship making it difficult to alter course to the desired direction, while an escort tug is assisting to the ship’s steering system in the Strait of Istanbul (İstikbal 2006).
The IMO accepts this by Resolution A.827, recommending a solution as follows: “In order to ensure safe transit of vessels which cannot comply with the TSS, the competent authority may temporarily suspend two-way traffic and regulate one-way traffic to maintain a safe distance between vessels” (IMO Recommendations 1995).

Other than this circumstance, a ship must stay in the appropriate traffic lane. This can only be achieved if the ‘cushion effect’ of the bend is compensated for by the steering of the ship. Danger emerges when a vessel must turn around a bend and a cross current. In such a case, the current literally pushes the fore part of the vessel and makes it very difficult for her to turn in the desired direction. To be this cushion effect compensated, assistance of an escort tug may be necessary in order to guarantee the safe turn at the bend. Current effect at the narrowest part in the Strait of Istanbul is presented in Figure 15.

**Response options**

Within the scope of the study, the response options of patrol tugs were examined under two different scenarios. The first is the situation where a ship in the Strait is parallel to the surface current. The second is the situation where a ship in the Strait is anti-parallel to the surface current.

**When vessel and current are parallel**

When the vessel’s course is in parallel with the direction of the currents, the tug needs to be tethered to the stern of the vessel. Thus, the vessel could be maintained in the desired course. To achieve this, the tug’s position (Tug 1) should be at the nearer shoreline, as shown in Figure 16. If necessary, this manoeuvring can be supported by a second tug from head (Tug 2). When the ship’s heading gets under control, its momentum can be decreased both by applying braking force with the tug and by using reverse propulsion (DNV 2013).

![Figure 16. Response options when vessel proceeds with the current](image-url)

At this point there are two possible scenarios. In the first of these, the current force applied on the vessel is significant in accordance with the lateral force of the wind being efficient on the vessel’s structure. In such a case, the maintenance
of the vessel’s heading is critical and this should be done until the additional tug assistance arrives.

In the other case, the effect of the current on the vessel’s hull is marginal compared to the lateral force of the wind being effective on the ship’s superstructure. In this scenario, there are two options: first, the tug should keep the vessel aligned with the coastline, second, the vessel could drop either of her anchors or both of them in order to maintain this alignment. An alternative option could be that the tug may take the vessel in tow and move slowly up the stream (DNV 2013).

*When vessel and current are anti-parallel*
A vessel mostly navigates against the current during the northbound passage, and in this scenario, in the case of an engine and/or rudder failure, same action needs to be taken to maintain the vessel’s heading. This is, to move the tug to a position toward the nearer shoreline, as shown in Figure 17 (DNV 2013).

![Figure 17. Response options when vessel proceeds against the current](image)

**Conclusion**

Increase in the world seaborne trade increases the risk of maritime accidents by rising the number of ships passing through the Strait of Istanbul. The dense population surrounded, the cultural heritage and being the only sea route between the Black Sea and outer seas, all requires further attention in maintaining safety and eliminating risks that may pose challenge to safety through the Strait. Due to the increasing traffic volume and difficult geographical conditions, many tragic accidents have occurred in recent history. The result of temporal analysis proved that especially within the measures taken in the scope of the MARMARAY Project, a steady decrease in the number of accidents was observed with one-way planning of traffic. Obtained results revealed that accidents showed a steady downward trend since 2010. As of 2011, the number of accidents fell below the 15-year accident average. In the following years, the number of accidents remained below 12 accidents. However, further accidents which took place in the
Strait indicated that additional measures should be taken. For this purpose, taking into consideration the environmental factors in the Strait, patrol tugs are offered as a suggestion proposal.

This paper brings attention of all related parties to the placement of patrol tugs in certain areas in the Strait of Istanbul and monitor ships passing through very risky areas and take action in case of any wrong-going. Tugboats on patrol need to be dynamically patrolling instead of static berthing which requires time to get prepared for the urgent task given. Furthermore, patrol boats located in bases mentioned in Figure 7 may render the best resolution in order to eliminate the risks posed to safety by those ships which are not covered by the current tug regime in use in the Strait of Istanbul.

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