Analytical investigation of marine casualties at the Strait of Istanbul with SWOT–AHP method

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The Strait of Istanbul is one of the most dangerous and busiest sea passages, according to its narrowness, sharp turns, currents, heavy traffic and many other important factors. Despite the latest precautions, marine incidents still occur, especially in narrow seaways. This study shows that a management tool that is specifically applied for reducing marine casualties and consequently enhancement of safety and ship management performance can be used to prevent accidents and casualties in maritime transportation. In this study, factors which affect marine casualties examined and determined with SWOT (strengths, weaknesses, opportunities and threats) analysis method and weighting of the factors determined by using the AHP (analytic hierarchy process) method. With this approach, strategic action plans were developed for minimizing shipping casualties at the Strait of Istanbul, taking into account the weighting factors and previously happened accidents.

1. Introduction

The Strait of Istanbul is one of the busiest and most dangerous sea passages because of its narrowness, sharp turns, currents, heavy traffic and many other important factors. Its length is about 17 nautical miles and its average width is 8 cables (see figure 1). The shores on both sides of the strait are densely populated and also there are several buildings close by. When the increasing numbers of ships, tonnages of these ships and local traffic, together with the meteorological and oceanographically conditions, are taken into account, the strait has become even more risky for ships. In this study, factors that are affect marine casualties are examined and determined with SWOT (strengths, weaknesses, opportunities and threats) analysis method at the Strait of Istanbul and weighting of the factors is determined by using the AHP (analytic hierarchy process) method. Section 2 of this paper describes the SWOT analysis and AHP method; section 3 is the description of application; section 4 describes the strengths, weaknesses, opportunities and threats for marine casualties at the Strait of Istanbul; and section 5 illustrates the results of AHP application and the strategies that are derived for reducing marine casualties at Strait of Istanbul with a SWOT-AHP application.

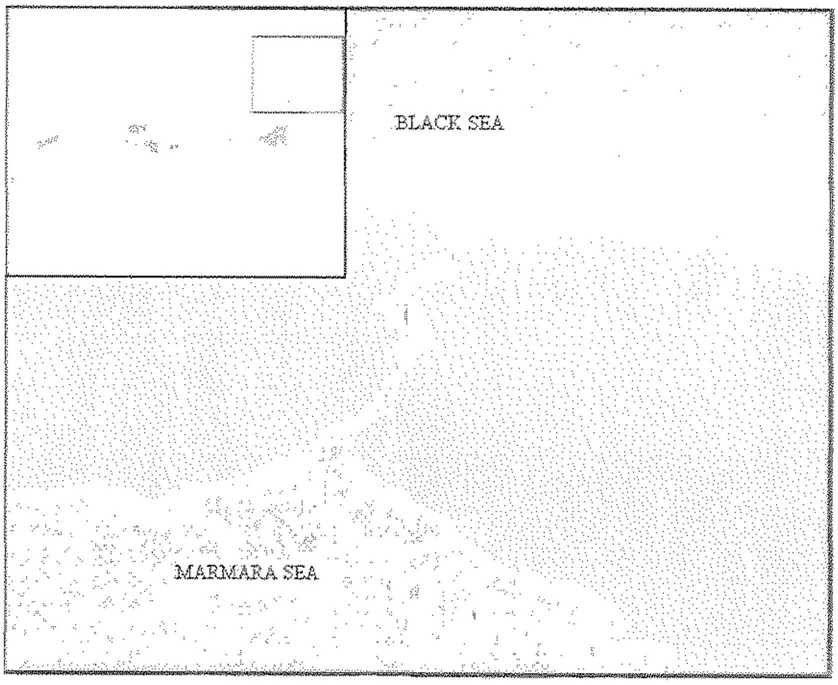

Figure 1. Strait of Istanbul.

2. Methodologies for SWOT analyses and AHP method

2.1. *SWOT analysis*

Every programme, organization, operational processes and development characteristics has its strengths and weaknesses, and opportunities and threats. Considering these strengths, weaknesses, opportunities and threats (SWOT), several strategies are derived for converting the threats into opportunities, and off-setting the weaknesses against the strengths. SWOT analysis is intended to maximize both strengths and opportunities, minimize the external threats, and transform the identified weaknesses into strengths and take advantage of opportunities along with minimizing both internal weaknesses and external threats [1]. The SWOT approach involves systematic thinking and comprehensive diagnosis of factors relating to a new product, technology, management or plan [2].

SWOT allows analysts to categorize factors into internal (strengths, weaknesses) or external (opportunities, threats) as they relate to a decision, enabling comparison of opportunities and threats with strengths and weaknesses, respectively. Activity worksheet of SWOT application is shown in Figure 2. One of the main limitations of this approach, however, is that the importance of each factor in decision making cannot be measured quantitatively, and it is difficult to assess which factor has the greatest influence on the strategic decision [3]. When used in combination with an analytic hierarchy process (AHP), however, the SWOT approach can provide a quantitative measure of the importance of each factor in decision making [4].

2.2. *Analytic hierarchy process (AHP)*

Analytic hierarchy process (AHP) is a decision analysis tool used in this study with the SWOT analysis method, it is a mathematical method for analysing complex

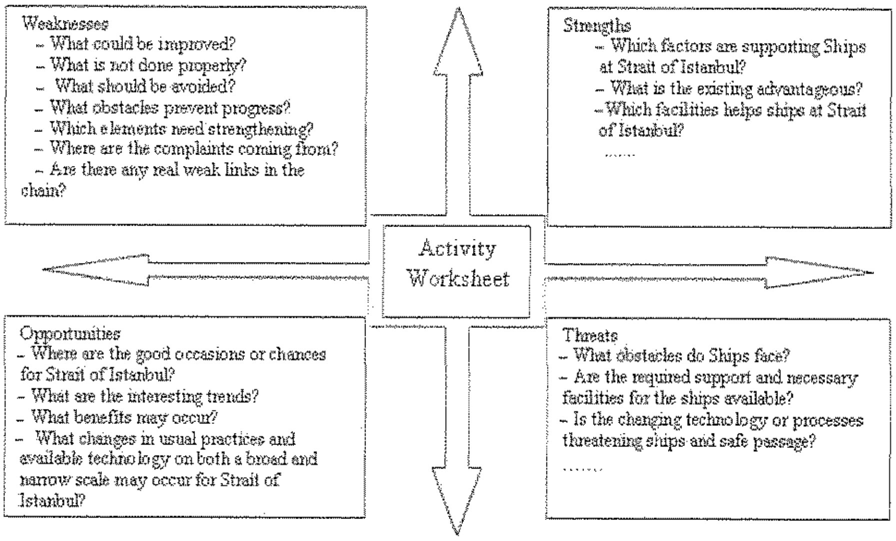

Figure 2. Activity worksheet for SWOT analysis.

decision problems with multiple criteria [5]. AHP can deal with qualitative attributes as well as quantitative ones. It has been found to be a useful decision analysis technique and has been applied in cases dealing with strategic planning. AHP enables decision makers to assign a relative priority to each factor through pair-wise comparison. As strategy planning procedures are complicated by numerous criteria and interdependencies, the utilization of conventional SWOT analysis has become insufficient because of its qualitativity. By utilizing the AHP in SWOT analysis, individual SWOT factors can be weighted and rated quantitatively. The list of SWOT factors was analysed using this method to determine the intensity or priority order of each factor. AHP is used in many fields such as planning, selecting the best alternative, resolving conflicts, optimization problems with other techniques such as linear programming, fuzzy logic, quality function deployment, etc. [6].

3. SWOT–AHP application

This study attempts to examine the strengths and weaknesses affecting marine casualties at the Strait of Istanbul, as well as the opportunities and threats that can reduce marine casualties in the external working environment for ships. The intention of this study is to develop strategy action plan for ships, ship operators, ship management companies and seafarers, through SWOT analysis and AHP with a view to making safer navigational operations at the Strait of Istanbul, in order to prevent the re-occurrence of marine casualties.

In this study, AHP in SWOT analysis is presented as an application of utilizing pair-wise comparisons. The pair-wise comparisons are carried out within SWOT factors by the pilots who have passed through the Strait of Istanbul more than 600 times, masters who have passed through the Strait more than 100 times and VTS operators who are working more than 3 years at a VTS station. Negative factors, as weaknesses and threats, positive factors, as opportunities and strengths, are observed in figure 3. Then the factors are clustered. An application utilizing pair-wise comparisons of AHP technique in SWOT analysis is presented and the weighting factors of negative parameters that are causing marine casualties and positive factors that are reducing marine casualties at the Strait of Istanbul were observed.

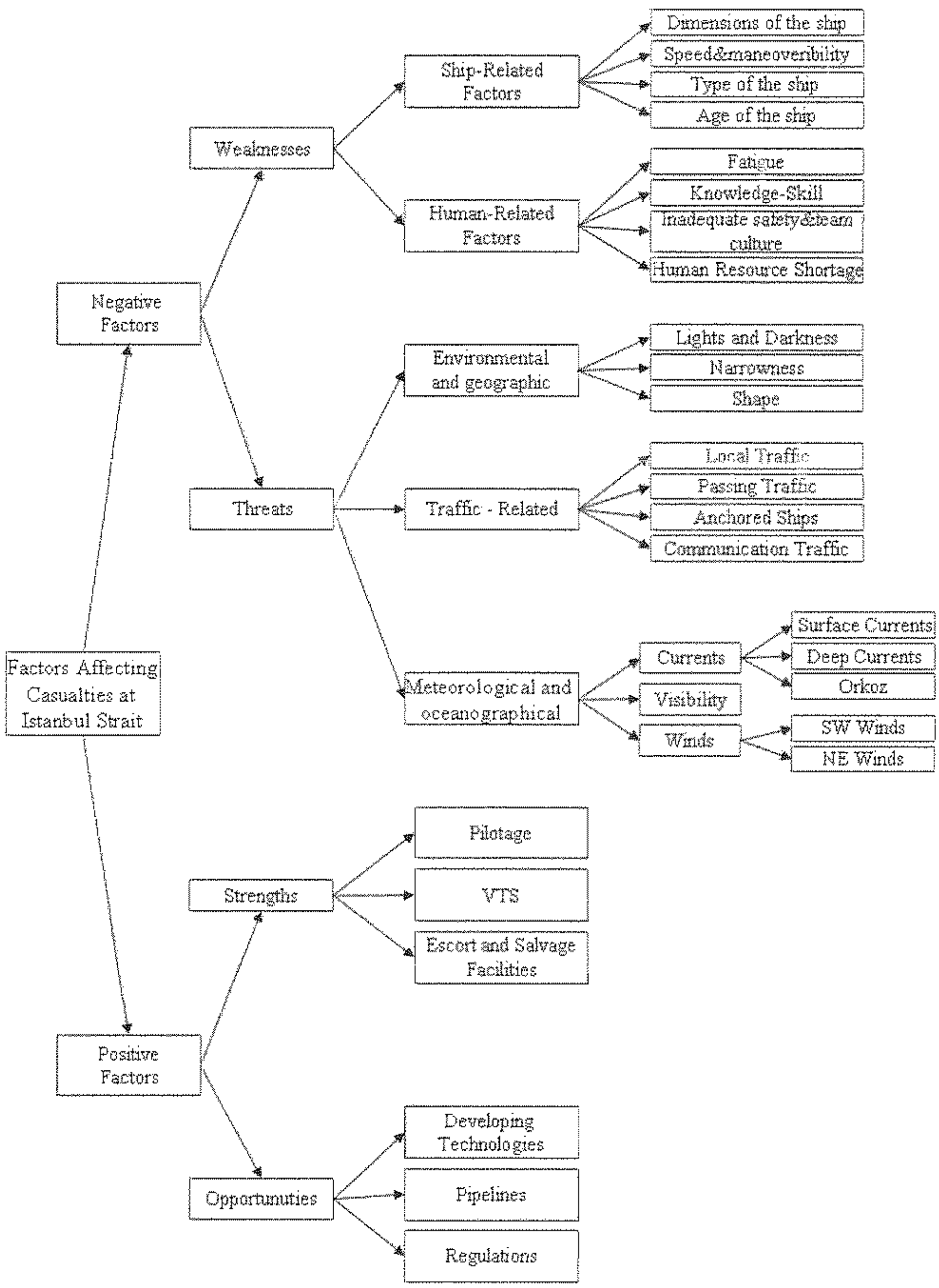

Figure 3. Classification of factors that are affecting casualties at the Strait of Istanbul.

Positive factors (strengths and opportunities) and negative factors (weaknesses and threats) are weighted by using 'Super Decisions' software (http://www.superdecisions.com).

Consequently, practical solutions are suggested for reducing marine casualties at the Strait of Istanbul. The objective of this study is to examine SWOT factors in greater detail and more systematically then producing clear and applicable strategies for safer marine operations at the Strait of Istanbul.

4. Proposed SWOT analysis application for the Strait of Istanbul

4.1. *The probable strengths about the Strait of Istanbul*

4.1.1. *Established pilotage services.* Ships can navigate safely from narrow channels by taking pilots. At the Strait of Istanbul, pilotage service is available with experienced pilots for ships that are passing from the strait.

4.1.2. *Established vessel traffic system (VTS) at the Strait of Istanbul.* Established traffic separation scheme (TSS) and vessel traffic service (VTS) Stations arrange safer navigations for ships and ships can make efficient decisions by the help of VTS centres. The Turkish Republic has recently installed VTS stations. The system was installed in 2003 and based on eight radar stations. Positions of radar stations are illustrated in figure 4. The main purposes of the Turkish Straits VTS is to improve the safety of navigation and protect the marine environment in the VTS area by proper and effective monitoring, strategic planning and good interaction with vessels, also to consider the efficiency of vessel traffic flow. There are three main services that are arranged by the VTS system: information; navigational assistance;

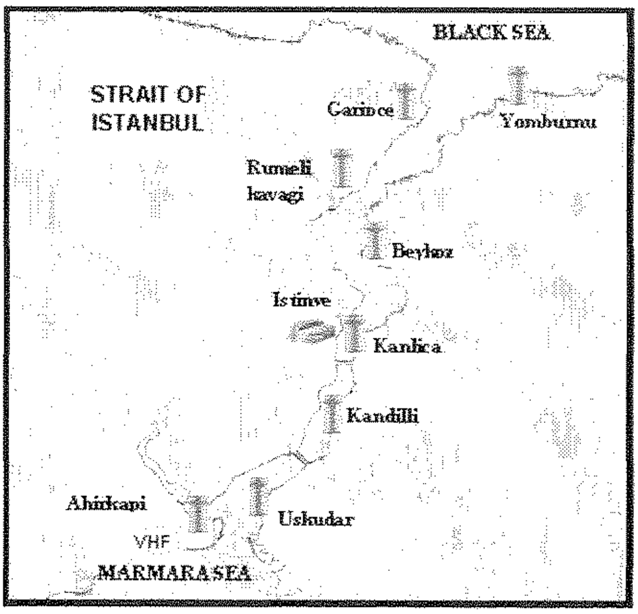

Figure 4. Location of radar stations at VTS area.
Source: http://www.dgcs.gov.tr

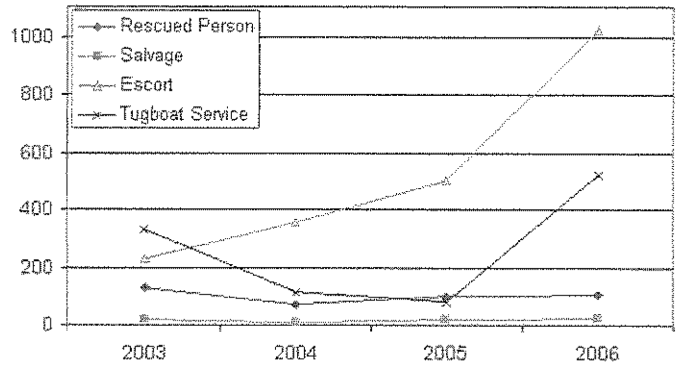

Figure 5. DGCS operations by year.
Source: http://www.dgcs.gov.tr

and traffic organization. Through this, the Strait of Istanbul became safer than before the foundation of VTS.

4.1.3. *Availability of rescue, salvage and escort facilities.* The Directorate General of Coastal Safety was established at the Turkish Straits in order to provide safe navigation of vessels, coastal safety and a salvage service; to provide all necessary equipments related with these services; to salve property, rescue and salvage; to provide assistance and towage; to remove wreck and to perform tug boat for ships, under the Ministry of Transport. A total of eight rescue boats is located and are ready 24 hours a day at different locations at the Strait of Istanbul. The numbers of rescued people, escorted vessels, salvage operations and given tugboat services, by years, are illustrated in figure 5.

4.2. *The probable weaknesses of the Strait of Istanbul*
The weaknesses of the Strait of Istanbul can be summarized in two main categories: namely with ship-related factors and human-related factors.

4.2.1. *Ship-related factors.* Dimensions of ships including length, breadth, depth and draught of ship; the speed and maneuvering characteristics of the ships; type of ship and lastly age of the ship plays an important role on marine casualties at the Strait of Istanbul.

4.2.2. *Human-related factors.* Human-related factors that affect marine casualties at the Strait of Istanbul can be summarized in four categories: fatigue of navigation officers and seafarers; inadequate knowledge and skill of navigation officers about their tasks, ship and the navigation area (Strait of Istanbul); inadequate team and safety culture of navigation officers and seafarers of ships; and, last, shortage of experienced seafarers on ships and pilots at the Strait of Istanbul. Attention failures, memory failures and human errors are directly related with fatigue. Fatigue has two main aspects: physical and psychological. Physical fatigue is related with the working hours and rest times and quality of rest times on board; and psychological fatigue is related with welfare aspects [7]. According to the latest surveys, seafarer resources are moving from traditional maritime countries towards Eastern Europe and Far East countries [8]. Seafarers who act and display care and loyalty are less likely to produce claims. Ship owners and operators can achieve a high level of crew continuity and competence by providing seafarers with secure employment and taking human factors into account, including recruitment, health, training and general awareness of shipboard best practice and by monitoring satisfaction in terms of monitoring expectation of seafarers. The master on board holds one of the most important roles within the safety management system (SMS). There is no way that the master could produce all the relevant documentary evidence to secure his position. If the SMS has been implemented and is functioning as anticipated and intended by the ISM Code, then the master should have little difficulty producing the relevant documentary evidence. Consequently this is directly related with the deployment of responsibilities and enhancing team work approach on bridge operations. Safety on board has become a critical issue in the last decades. Enhancement of shipboard operations with safety culture philosophy is directly depends on ship management company's intention and resources that is supplied to vessel [9].

4.3. *The probable opportunities at the Strait of Istanbul*

4.3.1. *Developing technologies.* New innovations or technologies such as ECDIS (electronic chart display and information system) and AIS (automatic identification system) reduce navigation officers' workloads and they have been developed to lighten considerably the navigation workload by enforcing reduced human errors. Besides, they can enable navigation officers for other important navigation-related tasks such as maintaining a safe lookout and collision avoidance. They are real-time decision aids, which provide the navigation officers with accurate and reliable information about a ship's position and its intended movements in relation to charted navigational features. World merchant fleet is renewing and new-built ships have high maneuvering capabilities when compared with the last decade of ships. Ergonomic issues have become more popular in the ship-building sector. Ergonomic bridge design allows safe look out and reduces workload of masters and navigation officers. Ergonomic design of accommodation places also increases seafarers' satisfaction and gives acceptable living conditions. New technologies about navigation or ship construction reduce navigation officers' workloads. They are assisting tools for them to enable efficient maneuvering and offering more comfortable navigation infrastructure.

4.3.2. *Establishing of pipelines at region.* The Strait of Istanbul has become a living pipeline because of the passing tanker ships. More than 10 000 tanker ships are passing from the Strait of Istanbul annually. The number of ships passing through the strait is illustrated in figure 6.

There are several pipeline projects that by-pass the Strait of Istanbul such as the BTC Pipeline. It is expected that the number of tanker ships which are passing through the Strait will be reduced in the coming years. The amount of dangerous cargoes carried by these tanker ships is illustrated in figure 7.

4.3.3. *Established national and international laws/regulations.* A left-side navigation scheme was applied in the Strait of Istanbul between 1934–1982. Vessels which were proceeding to the Black Sea from the Sea of Marmara had to

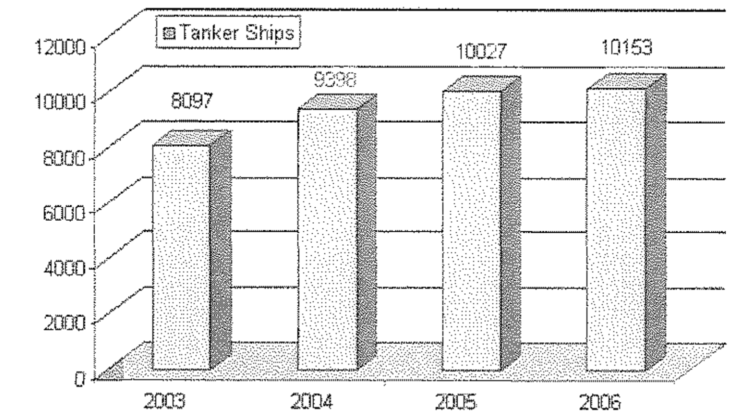

Figure 6. Number of tanker ships passing from the Strait of Istanbul.
Source: http://www.dgcs.gov.tr

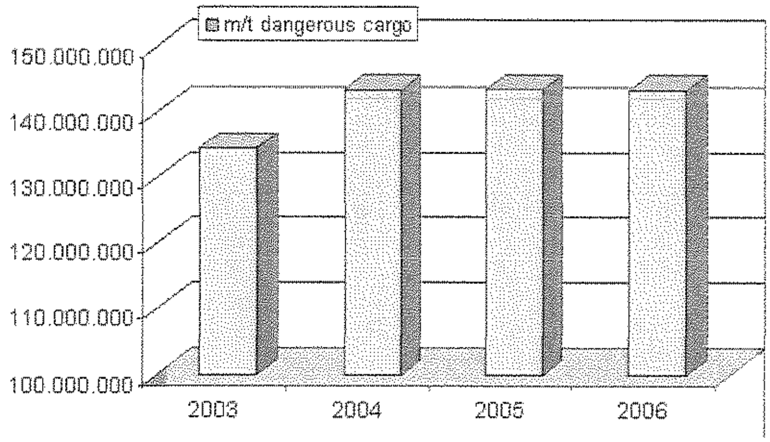

Figure 7. The amount of carried dangerous cargo from the Strait of Istanbul.
Source: http://www.dgcs.gov.tr

navigate on the west side of the Strait and as close inshore as possible to avoid collisions, according to Article 25 of the Collision Regulations, 1 May 1982. Since this date, Collision Regulations 1972 became fully applicable and right-side up scheme has been used [10]. Turkey introduced the traffic separation schemes according to Rule 10 of the COLREGS (International Regulations for Preventing Collisions at Sea, 1972) on 1 July 1994 and new traffic separation schemes have been approved by IMO and were formally adopted on 25 November 1995. According to the schemes, the transit route was divided into two traffic lanes. In the case of the passage of ships through the Strait which are larger than 200 metres in length, Turkish Administration temporarily suspends the two-way traffic and regulates one-way traffic to maintain a safe distance between vessels. The current application of the Turkish Regulations with regard to larger vessels is as follows: tankers whose length is more than 200 metres, can pass from the Strait during daytime and those whose length is between 250 to 300 metres can only pass after temporarily suspension of the two-way traffic. Vessels of 300 metres and above in length are subject to specific terms and conditions, based on the safety measures of the Turkish Administration. The same would apply for vessels under towage [10].

4.4. *The probable threats of the Strait of Istanbul*
External negative factors can be summarized in three main groups: namely, environmental and geographic; traffic-related, and meteorological and oceanographically factors.

4.4.1. *Environmental and geographic factors.* Environmental and geographic factors group is consisting from lights and darkness; narrowness and shape of Strait of Istanbul. Several sharp turns within the Strait exist in areas such as Umuryeri, Yeniköy, Kanlıca, Kandilli and Kızkulesi (45° at Kandilli, 80° at Yeniköy, 70° at Umuryeri). The narrowest point of the Strait of Istanbul is the Bebek-Kandilli, where its width is almost 0.4 nautical miles (700 m) [10]. It is 17 nautical miles in length, has numerous bends requiring 12 course alterations; some of these alterations are very sharp (more than 80 degrees) [11].

4.4.2. *Traffic–related factors.* Traffic-related factors can be summarized in four groups: local traffic at the Strait; ships passing the Strait of Istanbul; anchored or waiting ships near the entrance of the Strait; and communication traffic between all these ships. Ships are faster than in the past and marine traffic is becoming crowded. The number of ships, which are passing through the Strait of Istanbul, is increasing every year. The number of these ships is illustrated in figure 8. Ships should communicate with other ships and the VTS station for efficient and safer maneuvering. Poor maritime English obstructs reliable communication among ships. There are around 52 000 ships in service at sea, and the number of ships is increasing by 3% per annum. Increasing the number of ships and new-built faster ships causes collision risks. The density of vessel traffic causes human errors as a contributing factor for casualties, particularly in those narrow water ways and shallow waters such as straits, channels and port entrances where sea-room is insufficient [12].

4.4.3. *Meteorological and oceanographically factors.* These factors can be summarized in three groups. These factor groups are currents, visibility and winds.

Currents: two types of current are dominant in the strait: The main one is surface current and the second is the undercurrent. The main surface current is the result of the level difference between the Black Sea and the Marmara Sea. The undercurrent is the result of density difference between the Black Sea and the Marmara Sea [13]. Main surface currents can rise up to 8 knots in case of strong northerly winds and the level difference between the Marmara Sea and the Black Sea. Under the influence of strong southerly winds of prolonged duration, the water level in the Strait rises as much as almost 0.6 metre and thus gives rise to the rate of surface current to be reduced, or reversed in direction, i.e flowing towards the Black Sea [14]. Such current is locally named Orkoz. The stronger is the wind the greater is the rise in sea level, ultimately Orkoz being the strongest [15]. Orkoz can be seen between November and January in the Strait. Orkoz causes counter current in Strait and it affects the Strait

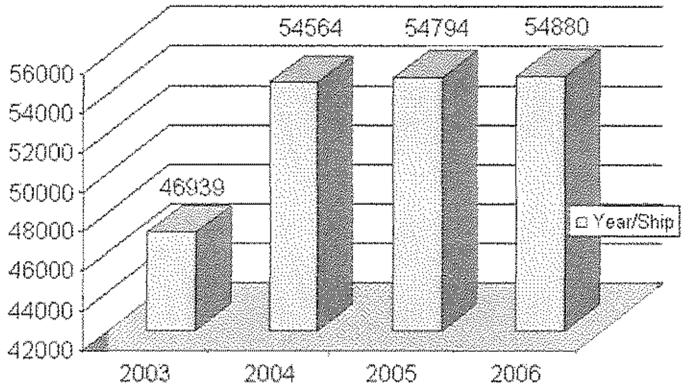

Figure 8. Number of ships passing from the Strait of Istanbul.
Source: http://www.dgcs.gov.tr

and Ships negatively. Vessels passing through Strait of Istanbul should exercise with extreme caution [15].

Visibility: decreasing visibility levels are affecting the safe navigation adversely at the Strait of Istanbul. Fog at sea, as well as coastal areas, may occasionally be encountered in winter and spring but is quite rare in summer [16].

Winds: winds from the north and north-east are most frequent. Southerly winds are usually strong and squally, and may sometimes reach to gale force, and are usually accompanied by low cloud and rain. The north-westerly winds are usually fresh. They are accompanied by clear weather.

The distrubution of January and July winds in the Strait area [11] is illustrated in figures 9 and 10. The arrows illustrates the direction of the wind and percentage of the wind's power with Beaufort Scale. The number within the direction arrows illustrates the percentage of calm days. Transient Mediterranean lows migrating northeastward across the Aegean and Black Seas bring the most hazardous winter-time weather to Istanbul. The hazards result from strong south to southwesterly winds blowing across the Sea of Marmara in advance of the low pressure systems.

5. Results of AHP application, considerations and derived strategies from SWOT–AHP application

Pair-wise comparisons have been made by utilizing AHP. Priorities and weighting factors that are causing marine casualties at the Strait of Istanbul are illustrated in Table 1. When the results are taken into account, internal negative factors (weaknesses) play a more important role on shipping casualties than external negative factors (threats). When weaknesses are examined, human-related factors are most important factors on these casualties. When external negative factors have taken into account each factor—meteorological and oceanographically; environmental and geographic; and traffic-related factors—each has nearly the

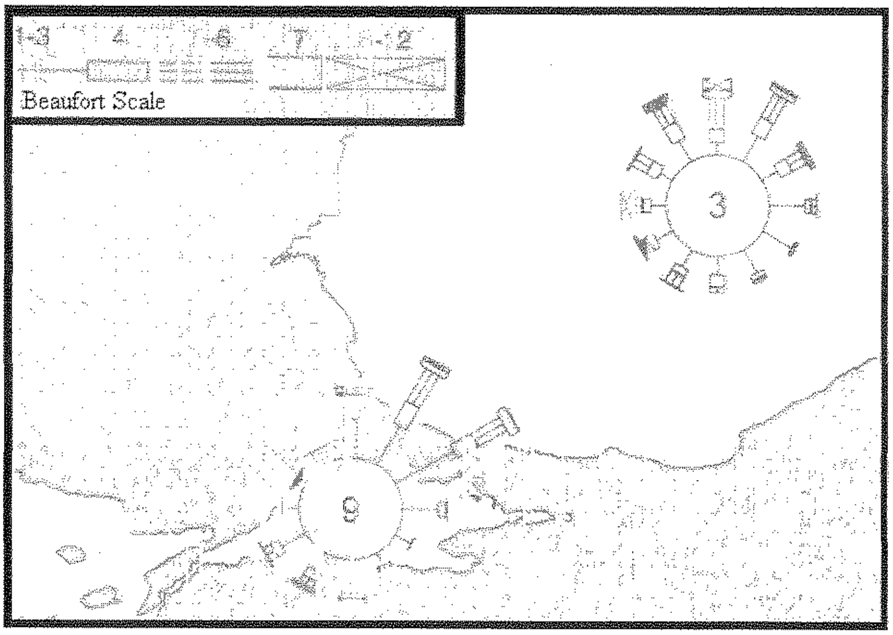

Figure 9. The distrubution of January winds at the Strait area.
Source: Admiralty Sailing Directions, NP 24

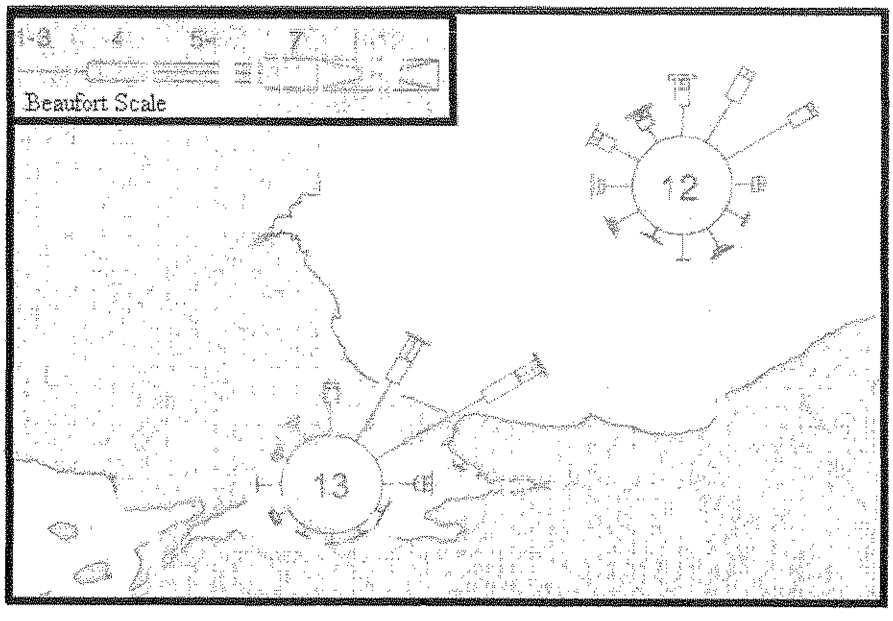

Figure 10. The distrubution of July winds at the Strait area.
Source: Admiralty Sailing Directions, NP 24

same priority. The local current (Orkoz), local traffic at the strait and darkness and back-lights are dominant threats for safe navigation.

Internal positive factors (strengths) have a more important role for reducing marine casualties at the Strait of Istanbul than external factors (opportunities). Established Turkish Vessel Traffic Management and Information System (VTMIS) and pilotage at the Strait area are two dominant factors that are reducing marine

Table 1. Priorities of factors.

Group	Swot factor	Priority
	11 Negative factors	**−0.54545**
	12 Positive factors	**0.45455**
Strengths	**121 Strengths**	**0.34091**
	1211 Pilotage	0.07991
	1212 VTS	0.23367
	1213 Escort and salvage facilities	0.02733
Weaknesses	**111 Weaknesses**	**−0.36364**
	1111 Ship-related factors	−0.09090
	11111 Dimensions of Ship	−0.01851
	11112 Speed-maneouveribility of ship	−0.05782
	11113 Type of ship	−0.00927
	11114 Age of ship	−0.00530
	1112 Human-related factors	−0.27273
	11121 Fatigue	−0.02722
	11122 Knowledge-skill	−0.11573
	11123 Inadequate safety-team culture	−0.10249
	11124 Human resource shortage	−0.02727
Opportunities	**122 Opportunities**	**0.11364**
	1221 Developing technologies	0.08149
	1222 Pipelines	0.00747
	1223 Laws and regulations	0.02468
Threats	**112 Threats**	**−0.18182**
	1121 Environmental and geographic	−0.06060
	11211 Lights and darkness	−0.04664
	11212 Narrowness	−0.01659
	11213 Shape	−0.03934
	1122 Traffic-related	−0.06061
	11221 Local traffic	−0.02946
	11222 Transit traffic	−0.01856
	11223 Waiting or anchored ships	−0.00585
	11224 Communication traffic	−0.00673
	1123 Meteorological and oceanographical	−0.06061
	11231 Currents	−0.03598
	112311 Surface currents	−0.00850
	112312 Deep currents	−0.00204
	112313 Orkoz	−0.02514
	11232 Visibility	−0.01511
	11233 Winds	−0.00952
	112331 SW winds	−0.00738
	112332 NE winds	−0.00214

casualties at the Strait of Istanbul. Development on technologies is the most important opportunity for reducing marine casualties at the Strait of Istanbul. Graphical results of pair-wise comparisons of SWOT groups and factors are shown in figure 11.

While considering the overall factors of strengths, weaknesses, opportunities and threats mentioned in section 4 of this study, the following strategies were proposed. The risk assessment of each process can easily be handled if the threats or weaknesses are identified properly. It should also be taken into account that a human factor has a great significant impact on weaknesses, as is identified in section 3 of this study.

When the overall contribution of SWOT analysis is examined, the following comments can be interpreted for reducing marine casualties at the Strait of Istanbul. Workload management should be applied on boardm, because fatigue plays an important role in human errors. Precautions which will increase seafarers' satisfactions should be taken by ship management companies. New training programmes about the new technologies should be developed. New rules and regulations should be brought into force for reducing marine casualties at the Strait of Istanbul. New technologies which will increase maneuverability of ships should be used during ship-building process. Navigation bridges and accommodation places should be designed, taking into account ergonomic aspect. Widespread use and equipping new technologies such as ECDIS and AIS should be maintained. Special training programmes about the Strait of Istanbul should be maintained for both students and seafarers at maritime education institutions. Taking Pilot at the Strait should be encouraged. The VTMIS system, pilotage system and salvage system should be maintained and developed continuously. New pipeline projects should be supported because of the physical limitations of strait.

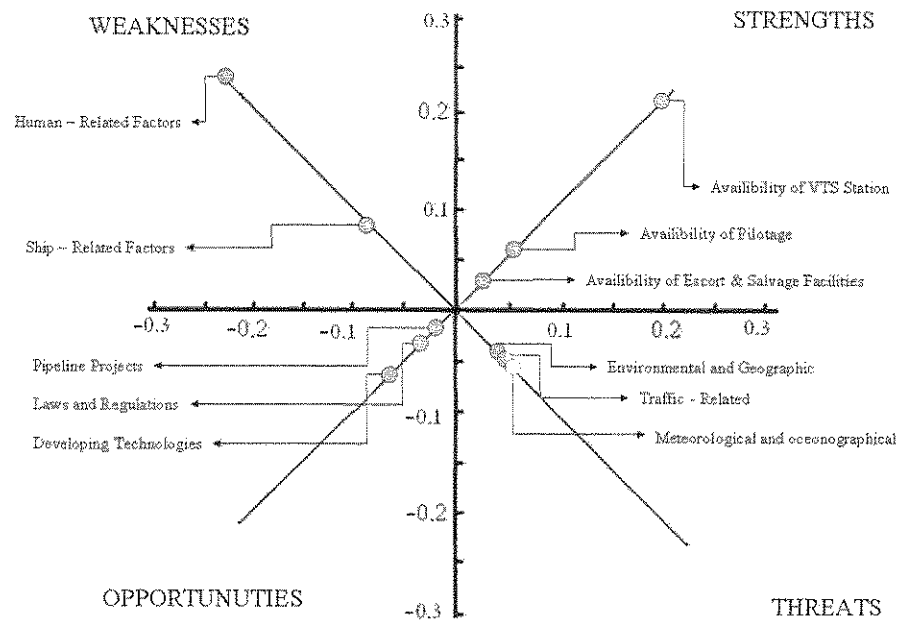

Figure 11. Graphical results of pair-wise comparisons of SWOT groups and factors.

6. Conclusion

Marine casualties are still a strong threat both for human health, marine environment and finance. Marine casualties could be reduced through the latest technologies which are being used in the shipping industry. Ships are exposed to several hazards related to both the external and internal environment. Identification of root causes and observing their priorities play an important role in understanding the present situation. The first step of the strategy is observing the present situation. At the Strait of Istanbul, groundings, strandings and collisions are main types of marine casualties [17]. The marine casualties at the Strait of Istanbul can result with catastrophic consequences such as:

- At the end of the collision between Greek tanker M/T *Evriali* and Romanian tanker M/T *Independenta* at Haydarpasa on 15 November 1979, 43 crew members died, 70 000 m/t of oil spilled to the sea and 50 000 tons of this oil was burned.
- At the end of the collision between Lebanese flag vessel *Rabunion-18* and Philippines flag vessel M/T *Madonna Lily* on 14 November 1991, close to Anadoluhisari, three crew members died and M/V *Rabunion-18* sank with 20 000 sheep.
- At the end of the collision between Greek flag M/T *Nassia* with another Greek flag vessel, M/V *Ship Broker*, on 13 March 1994, 27 crew members died, M/V *Shipbroker* completely burned, 20 000 m/t of crude oil spilled into the sea.
- Russian tanker *Volganeft-248* grounded and broke on 29 December 1999, 4000 m/t of fuel oil spilled into the sea.
- At the end of the grounding of Georgian-flagged cargo ship M/V *Svyatoy Panteleymon*, close to Anadolufeneri on 10 November 2003, 25 crew members of the ship were rescued and 220 tons of diesel and 260 tons of fuel oil spilled into the sea.
- At the end of a collision beteen Turkish Seabus *Salihreis-4* to anchored Russian ship M/V *Semyon Rudhnev* on 13 August 2007, 40 passengers were injured (see figure 12).

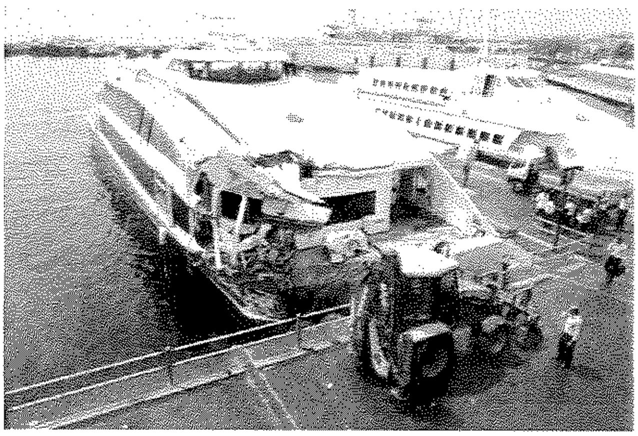

Figure 12. Collision of seabus *Salihreis-4* to anchored Russian vessel.
Source: http://www.hurriyet.com.tr

When the above-mentioned and other marine casualties at the Strait of Istanbul are investigated, it can be easily seen that the root factors of casualties are closely the same but only the weighting of factors is different because of the evolution of casualties.

At the Strait of Istanbul, several factors such as human-related and meteorological factors are still causing accidents and incidents despite latest navigational technologies and established VTS or pilotage systems. In this study, it is aimed to identify the positive and negative factors that are affecting the marine casualties at the Strait of Istanbul by applying SWOT analysis and weighting these factors by applying AHP. Taking into account the above-mentioned strengths, weaknesses, opportunities and threats and the priorities of weighting factors, several practical solutions are proposed for reducing marine casualties at the Strait of Istanbul.

This study originally proposes and determines management tool that is specifically applied for reducing marine casualties and consequently enhancement of safety and ship management performance to prevent accidents and casualties in maritime transportation.

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