Risk Analysis of Congested Areas of Istanbul Strait via Ship Handling Simulator

CEMIL YURTOREN
Department of Maritime Transportation and Management Engineering
Istanbul Technical University
Sahil Cad., No.1, 34940, Tuzla, Istanbul
TURKEY
yurtoren@itu.edu.tr

VOLKAN AYDOGDU
Department of Maritime Traffic Information
Korean Maritime University,
1-Dongsam-dong, Yeondo-gu, 606-791, Busan, South Korea
yusufvolkan18@yahoo.com

Abstract: - This paper investigates navigational risks that local traffic exposes to transit passing vessels through Istanbul Strait. Risk analysis was performed at the south entrance area of the Istanbul Strait, where the local traffic is most congested. For this purpose, the research area was created digitally and simulation studies were carried out using ship handling simulator which can imitate the effects of topographic features, vessel traffic and meteorological conditions. Furthermore, the results of the simulation were analyzed using Environmental Stress Model of Inoue (2000) which provides an opportunity to analyze vessel traffic risks quantitatively. As the result of the study, the danger that is exposed by the local traffic to the transit ships was demonstrated and the most dangerous spots in the research area were seized for further precautions.

Key-Words: - Istanbul Strait, risk analysis, local traffic, Environmental Stress Model

1 Introduction
The marine traffic density of Istanbul Strait, a connection point between Asia and Europe continents, is increasing day by day. The number, size and tonnage of vessels and the amount of dangerous cargo carried have been increased and the type of dangerous cargo that passes through Istanbul Strait has been diversified significantly in the recent years. No need to mention that the results of a possible accident in Istanbul Strait due to this high traffic density would be enormous and it could damage not only the historical and natural environment of Istanbul, but also millions of people living in it. The extent of the damage has been experienced in the cases of “Independenta” and “Nassia” accidents. [1]

Hence, the aim of this research is to point out dangerous situation of Istanbul Strait and determine empirically the amount of risk, and the places where the risk is maximum. For this purpose, the ship handling simulator installed in Istanbul Technical University Maritime Faculty (ITUMF) was utilized and confronting situations of a transit passing vessel through Istanbul Strait, with local vessels running in the research area has been simulated. Several scenarios based on actual conditions have been put into practice using ship handling simulator. Actual ship officers who have appropriate license and experience in ocean operations were asked maneuver in Istanbul Strait in the simulation environment. The data files were stored after each session and analyzed using Environmental Stress Model [2] to determine the quantitative amount of risk that occurs during navigation through the southern entrance of Istanbul Strait.

2 Theoretical Background

2.1 Istanbul Strait
The Istanbul strait is a geological strait separating the European and the Asian parts of Istanbul and it lies between the Black Sea and the Sea of Marmara. Istanbul Strait has a strategic importance since it is the
only sea route of the Black Sea states (Ukraine, Romania, Georgia, Bulgaria and Russia) and the Central Asian countries. Although the Istanbul Strait is a difficult body of water to navigate due to its treacherous currents, twists and turns, it is one of the heaviest sea traffic regions in the World. The volume of traffic in Istanbul Straits is five times heavier than the traffic in the Panama Canal [3].

Chosen research area is between the line connecting Moda and Bakırköy and Bogazici Bridge at the southern entrance of Istanbul Strait due to dense local traffic. In this area, navigational risk has increased significantly due to the increase of vessel traffic in last decades. The amount of local marine traffic, which connects the two sides of the strait, has also increased severely according to the increase in the city population. Thus the local ships confront around 136 transit vessels every day. Running vessel capacity is between 36 to 2100 passengers at the southern part of Istanbul Strait, where more than 12 million people live more than 2100 daily local marine voyages are carried out [4][5][6][7].

In the last 5 years, 158 marine accidents of different types such as collision, fire, grounding … etc. occurred in the territory of Istanbul Harbor Master. 83 of those accidents were of collision type and 57 of these collisions occurred in our research area. And also in the year of 2004, 127 vessel failures, 27 ship accidents, and 84 rule violations were reported by the General Directorate of Coastal Safety and Salvage Administration. But these figures are not exact since only vessels over than 300 grt tonnages, which Coastal Safety is responsible for, were counted [8].

Everyday close passage or near miss events happen more than 10 times in the research area between the vessel runs in the local area and those pass the strait transit. According to the regulations, the vessels in the local area must yield to the vessels passing transit. On the other hand, since the local vessels are bound to strict timelines, the inexperienced and incompetent captains often try to pass close through the bow or aft of the transit vessel. These close passages create profound danger for the surroundings. If such a collision happens between a local vessel and a transit vessel, especially one that carries dangerous cargo, the consequences would be devastating.

Despite the importance of the Istanbul Strait till now, there are only a few studies (such as [9], [10] and [11]) regarding how the Istanbul Strait is dangerous to navigate and how that dangers can be mitigated. Also there are several studies regarding accident analysis and simulation method (such as [12], [13], [14], [15], [16] and [17]) at the Istanbul Strait.

All these studies indicate that southern entrance of the Istanbul Strait has a highly congested local traffic, but none of these studies focus on the risks that local traffic exposes on the transit vessels.

2.2 Environmental Stress Model

There are several approaches for navigation safety assessment. The study of Hu et al. [18] develops a methodology for formal safety assessment (FSA) approved by IMO using fuzzy functions. This model consists of five steps, i.e. identification of hazards, assessment of risks, risk control options, cost benefit assessment and recommendations for decision-making. Some researchers offer monitoring techniques for constant control of the topographical changes in an area [19][20]. The study of Briggs et al. [21] uses physical model simulation for probability analysis in a certain area. The model uses environmental parameters such as wind, wave, current and number of ship calls. The study of Breda and Rossenier [22] focus on models for predicting the path of the surrounding vessels. Finally the study of Zhu et al. [23] proposes a model for determination of subjective radius of ship domains which is “the surrounding effective waters that the navigator of a ship wants to keep clear of other ships or fixed objects.” This model basically considers visibility and maneuverability.

When the previous studies on navigation safety are examined, most of the models used to assess navigational risks deploy only topographic and traffic related parameters. On the other hand, human factor plays a crucial role in triggering accidents [2]. Thus a new model that considers not only environmental conditions but also the stress that is perceived by the mariners, is needed.

Environmental Stress Model, proposed by Inoue [2], considers risks caused by topographic elements (such as land, ports, channels or any other fixed or floating objects) and risks caused by surrounding vessel traffic. The risk –called Environmental Stress– caused by land remarks (ESL) and surrounding ships (ESS) is calculated on the basis of subjective judgments of the mariners (SJI and SJS) with respect to time to collision (TTC) to any object.
in the frontal area of the ship, i.e. from -90° to +90° (Park et al., 2002). The formulas are given in Eq 1.

\[ SJL = \alpha \text{TTC} + \beta \] 
\[ SJS = \alpha \text{TTC} + \beta \] 
\[ ESL = \sum [SJL]_i \] 
\[ ESS = \sum [SJS]_i \]

where \( i = -90 \sim +90 \)

It also considers the human factors such as the skill or personalities of the mariners by deducting Latent Environmental Stress (L-ES) values from the ES values calculated above. L-ES values are obtained by calculating the stress value assuming that mariner’s own ship sails at a constant speed along a fixed route without making any collusion avoiding maneuvers against encountering ships [2][24]. The extent of such unacceptable real environmental stress value is considered to indicate the necessity for collision avoidance maneuvers.

In order to evaluate the amount of navigational risk at a certain region, computer based simulations are carried out using a ship handling simulator. In the model, a situation giving the same SJ value, regardless of direction, was taken as the standard situation. The relationship between each stress ranking and the acceptable level was found through the ship-handling simulator experiments. The ES model, therefore, allows us to judge how great the stress value will be when it is no longer acceptable and to point out the disadvantages of the topographical and traffic situation in a waterway. The ES model is a practical model for assessing the risk of navigation in topographically restricted and congested waterways, or in ports and harbors, because it can evaluate simultaneously or individually the difficulties of ships-handling arising from topographical restrictions and the difficulty arising from encounters with other ships and also has acceptance criteria based on a mariner’s perception of safety. Hence, Es model has chosen to emphasize risks in Istanbul Strait numerically.

3 Research Methodology

In order to perform risk analysis at congested parts of Istanbul Strait two scenarios –peak time and off peak time– were prepared using the ship handling simulator installed in Istanbul Technical University, Maritime Faculty. These two scenarios were based on real marine traffic condition of Istanbul Strait.

Environmental conditions of scenarios such as current, wind, traffic density…etc. were prepared with association and consultancy of experienced local pilots. The exact times of the scenarios were decided as 12:00 as off peak time and 18:00 as peak time, on the basis of actual traffic data (Figure 1). The simulations were run on the ship handling simulator with the supervision of experienced ship captains and the results were analyzed using Environmental Stress Model.

4 Research Results

The number of local vessels and their types, voyage durations and voyage frequencies were determined on the basis of actual timetable data. In order to design detailed routes of the local traffic vessels, the study of Yurtoren [25] was used (Figure 2). The characteristics of the transit passing ship, which is considered as own ship for simulation purposes, was determined as a tanker which is 225 meters long, also on the basis of Yurtoren [25] study.
After preparation of scenarios, simulations were run by actual ocean going officers and masters who are experienced on navigation in the research area. The scenarios were run 19 times for peak time and 19 times for off peak time and the navigational data were stored automatically by the ship handling simulator. The stored data was than analyzed to calculate ES values which represents quantitative amount of navigational risk in the research area. This model enables to evaluate whether ship maneuvering risks are acceptable or unacceptable. The acceptance criteria of ES model are given in Table 1.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Mariner's judgement</th>
<th>ES Value</th>
<th>Stress ranking</th>
<th>Acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Extremely safe</td>
<td>-1000</td>
<td>Catastrophic</td>
<td>Unacceptable</td>
</tr>
<tr>
<td>1</td>
<td>Fairly safe</td>
<td>-900</td>
<td>Critical</td>
<td>Unacceptable</td>
</tr>
<tr>
<td>2</td>
<td>Somewhat safe</td>
<td>-750</td>
<td>Marginal</td>
<td>Unacceptable</td>
</tr>
<tr>
<td>3</td>
<td>Neither safe nor dangerous</td>
<td>-500</td>
<td>Negligible</td>
<td>Acceptable</td>
</tr>
<tr>
<td>4</td>
<td>Fairly dangerous</td>
<td>0</td>
<td>Acceptable</td>
<td>Acceptable</td>
</tr>
<tr>
<td>5</td>
<td>Somewhat dangerous</td>
<td>500</td>
<td>Marginal</td>
<td>Unacceptable</td>
</tr>
<tr>
<td>6</td>
<td>Extremely dangerous</td>
<td>1000</td>
<td>Catastrophic</td>
<td>Unacceptable</td>
</tr>
</tbody>
</table>

On the basis of risk vs. distance data, the individual risk at every single location along the vessel path can be determined. For more detailed results, total voyage distance was divided into 500-meter-long sections, and average risk at each section was calculated (Figure 4). It can be easily recognized that the navigational risk is maximum between 2500 and 3500 meters, i.e. 6th and 7th sections of the vessel path for both peak and off peak time simulations.

The results of the risk assessment analysis were then converted to graphical presentation to demonstrate the places where the navigational risks are maximum. The graphs given in Figure 3 demonstrate the quantitative value of risk (ES value) with respect to distance traveled by the vessel, for peak time and off peak time simulations separately. In this study, risk vs. distance graphic was preferred rather than risk vs. time graphic, since the time of travel can vary in each simulation depending on the route, speed...etc. preferences of the navigating officer.
Fig. 4 Individual risk values of the vessel path for each section at peak times (top) and off peak times (bottom)

Finally in order to seize average risk value of the research area both in peak and off peak times, average risk values has been prepared. These results indicate what the average risk value is for a transit vessel while passing through the southern entrance area of Istanbul Strait. The results imply that the risks exposed by the local ships (ES₇) are much higher than the risks exposed by the topographic objects (ES₇). The results are given in Table 2 and Fig. 5.

<table>
<thead>
<tr>
<th></th>
<th>Risk Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ES₇</td>
</tr>
<tr>
<td><strong>Peak Time Local Traffic</strong></td>
<td>% 28.1</td>
</tr>
<tr>
<td><strong>Off Peak Time Local Traffic</strong></td>
<td>% 21.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>ES₇</th>
<th>ES₇</th>
<th>ES₇</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unacceptable Risk Value</strong></td>
<td>% 10.1</td>
<td>0</td>
<td>% 15.3</td>
</tr>
<tr>
<td><strong>Off Peak Time Local Traffic</strong></td>
<td>% 8.2</td>
<td>0.5</td>
<td>% 13.1</td>
</tr>
</tbody>
</table>

Fig. 5 Comparison of simulator experiment results, total risks (top) and unacceptable risks (bottom)

5 Conclusion

On the basis of the results, most risky area for maritime traffic at the southern entrance of Istanbul Strait is between 2500 and 3500 meters from the starting point of the simulation scenario. This part corresponds to the region between Sarayburnu and Kadikoy. When the actual characteristics of the area are considered, one can realize that this area has extremely dense local traffic, since approximately 10...
vessels depart from this area at the same time during peak time. This is the main reason of the traffic mess and danger.

On the other hand, this area is on the border of two Vessel Traffic System (VTS) sectors. Istanbul region is divided into 4 VTS sectors. Each sector is controlled by different operators. VTS system allows the operator to see other sectors but the operators should consider only their own sectors. Thus VTS sector borders cause confusion and reduce to effectiveness of VTS. Since the most risky area of the strait is on the border, the research findings strongly recommend that VTS sector line should be shifted to another location.

The results given in Table 2 and Figure 5 indicate that approximately every 1 out of 2 transit passing vessels has risk exposed by local traffic at the southern entrance of Istanbul Strait and approximately every 1 out of 7 transit passing vessels has unacceptable risk, i.e. a near miss or accident event occurs. When these factors are considered, it can be easily concluded that there is severe necessity for a local traffic management system.

References:
[1] Ozgurce O., Head of Turkish Straits VTS Department, 2005 Seminar on International, Community and Turkish law on ship’s routing, ship’s reporting and vessel traffic services ISTANBUL 28-30 JUNE


