Dissertation for Doctor of Engineering

A Study on Local Marine Traffic Management to Promote Marine Traffic Safety in the Istanbul Strait

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Abstract

Istanbul, with its natural, cultural and historical wealth, is not only one of Turkey's most beautiful cities, but it is also one of the most exciting cities in the world. In fact, while linking the two continents geographically, Istanbul has been the original and striking meeting point of Europe with Asia and the East with the West. Istanbul Strait is what makes Istanbul such a special city.

However, there are enormous challenges for navigation in the Istanbul Strait due to its geographical, geopolitical and oceanographic structure. One of the challenges is the local marine traffic which crosses from one side to other of the strait. Daily, more than 2,100 scheduled and unscheduled crossings take place by passenger and car ferries, passenger boats and sea buses in the southern entrance of the Istanbul Strait where local traffic mostly effects navigation safety.

In this dissertation, the aim is to improve navigation safety by investigating and proposing counter measures for local marine traffic in the southern entrance of the Istanbul Strait which is the chosen geographical area of research. More specifically, the

research area is the zone between the line connecting the Moda Cape and Bakirkőy and the Istanbul Strait Bridge, where the local marine traffic is more congested and poses a threat to navigation safety. In order to devise these counter measures, local marine traffic parameters such as local traffic volume, traffic flow and probability of collision are analyzed by utilizing various statistics.

Then, previously conducted expert surveys, real time simulation studies and marine traffic fast time simulation studies are used to examine the various changes of marine traffic parameters. At the end of the dissertation, a few local traffic separation schemes are proposed to promote navigation safety in the Istanbul Strait.

Chapter 1 of the dissertation describes its scope, gives a review of the literature and presents the research layout.

Chapter 2 gives a general introduction to marine traffic and environment in the Istanbul Strait.

Chapter 3 reviews and investigates marine traffic risks in the Istanbul Strait in 3 sections. In the first section of chapter 3, marine traffic safety assessment parameters, which are local traffic volume, traffic flow, potential number of local traffic vessel encounters and possibility of collision, are investigated in order to determine the degree of danger at the southern entrance of the Istanbul Strait. Finally, by utilizing these parameters, the high-risk zones are identified in the research area. On the basis of information collected in section 1 of chapter 3, an expert survey is discussed in order to assess danger perceptions of experts, determine risks in the research area and then propose a basis for further studies in section 2 of chapter 3. Stakeholders such as pilots, Vessel Traffic Services Operators (VTS-O), skippers of local traffic vessels and master marines who had experience passing through the Istanbul Strait were surveyed. Based on the expert survey study, the most dangerous vessel type and ship length, the effect of external factors (i.e. current, wind, visibility) and the effectiveness level of the potential counter measures are determined.

Section 3 of chapter 3 investigates the navigational stress that local traffic imposes on transit vessels passing through the Istanbul Strait. For this purpose, the research area is created digitally and simulation studies are carried out using a ship handling simulator which can imitate the effects of topographic features, vessel traffic and meteorological conditions.

Furthermore, the results of the simulation studies are analyzed using Environmental Stress Model of Inoue (2000) which provides an opportunity to measure the stress level of a mariner quantitatively due to ship handling difficulty. Thus, the danger that is imposed by the local traffic on transit ships is demonstrated and the most dangerous spots in the research area are revealed.

Safety is a human perceived quality that determines to what extent the management, engineering and operation of a system is free of danger to life, property and the environment (Chengi, 2007). The ultimate aim of this dissertation is the improvement of navigation safety in the Istanbul Strait.

In the chapter 3, dangers in the research area are presented by collision probability, expert survey and real time ship handling simulator studies and outcomes of those studies show the necessity of risk reduction.

Risk reduction is the term used to describe the moving of a hazard from one location higher on the risk scale to a lower location (Chengi, 2007). Based on this concept, current marine traffic situations during peak and off-peak times are simulated by marine traffic fast time simulation studies.

The studies were then analyzed by the Latent ES Model which was introduced to exclude influence of the individual skill differences and navigator personality and to guarantee the universality of the results in evaluating shiphandling difficulty (Inoue et al 1999) in Chapter 4.

Afterwards, marine traffic parameters such as changing the vessel size, traffic flow, and traffic direction are investigated; and various traffic separation schemes for local marine traffic (LTSS) are proposed in order to lower scaled stress due to ship handling difficulty in the research area.

Chapter 5 summarizes the findings and recommends LTSS and one-way traffic implementations in order to improve marine traffic safety in the Istanbul Strait.

Last but not least findings of the study are listed briefly below;

a) When compared collision probability of the Istanbul Strait with various Korean waterways, it is found almost two times higher than Korean waterways.

b) According to result of the real time simulation study, most risky area for maritime traffic in the research area is the region between Sarayburnu and Kadikoy. The results indicate that there is strong necessity for improvement of navigation safety in the research area.

c) Results of marine traffic fast time simulation studies according to current traffic situation are shown that 29% unacceptable stress occurs during peak and 22% during off-peak time in the research area.

d) Results of marine traffic fast time simulation studies are also shown that recommended local marine traffic routes by Istanbul Harbor Master Local marine Traffic Guideline (RLMTR) promotes navigation safety in the research area. However, it is not effective as proposed LTSS or one way traffic implementations.

e) Results of marine traffic fast time simulation studies are shown that proposed LTSS' s improve marine traffic safety in the research area. According to results, proposed LTSS 1 is most effective measure to improve navigation safety in Sector A1 and proposed LTSS 3 is most effective measure to improve navigation safety in Sector A2 and Sector A3 among proposed LTSS. Finally, local traffic separation scheme implementation is strongly recommended for the improvement of marine traffic safety in the southern entrance of Istanbul Strait.

f) Results of marine traffic fast time simulation studies are shown that one way traffic implementation is highly effective to reduce stresses in the research area which is in compliance with result of expert survey. Therefore, continuity of one way traffic implementation is also strongly recommended.

Keywords: Local Marine Traffic, Istanbul Strait, Local Traffic Separation Scheme (LTSS), Marine Traffic, Simulation

이스탄불해협에서의 항행안전을 증진시키기 위한 Local Traffic Management에 관한 연구

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요 약 문

이스탄불은 터키에서 자연, 문화, 역사적 가치를 가지고 있는 가장 아름다운 도시 중 하나일 뿐만이 아니라, 전 세계에서도 가장 흥미로운 도시 중의 하나이다. 사실 이스탄불은 지리학적으로 두 대륙을 연결시키는 곳이기도 하지만, 유럽이 아시아와 만날 뿐만 아니라 동양이 서양과 만나는 인상적인 곳이기도 하다. 이스탄불 해협이 바로 이스탄불을 그와 같이 특별한 도시로 만든다. 그러나 지리학적, 지정학적 그리고 해양학적 구조 때문에 이스탄불 해협을 항행하는 데는 많은 어려움들이 존재한다. 그러한 어려움 중의 하나가 해협을 횡단하는 수많은 local marine traffic이다. 이들 교통량이 항행안전에 가장 많은 영향을 주는 이스탄불 해협의 남측입구에서는 매일 약 2,100회의 횡단이 이루어지는데, 이들 교통량을 구성하는 선박들은 여객 및 카페리, 여객선 및 바다버스(sea bus) 등이다. 이 연구에서는 이스탄불 해협의 남측 입구 해역을 연구대상으로 삼아, local marine traffic에 대한 대안을 조사하고 제시하여 이 해역에서의 항행안전을 증진시키고자 한다.

좀 더 구체적으로 연구대상해역을 설명하자면, Moda Cape과 Bak ı rk□y 및 Istanbul Strait Bridge를 연결하는 선내의 해역으로, local marine traffic이 집중되어 항해에 위협이 되고 있는 수역이다. 개선안을 도출하기 위해서 각종

통계자료를 이용하여 해당 지역의 교통량, 교통 흐름과 충돌의 개연성을 분석하였다. 다음으로는 전문가 설문조사, 실시간 시뮬레이션 및 속성 시뮬레이션을 실시하여, 이들 해상교통요소들의 변화들을 조사 분석하였다. 이 논문의 마지막 부분에는 이스탄불 해협의 항행안전을 증진시키기 위한 대안으로서 몇 가지 Local TSS를 제안하였다.

이 논문의 제1장에는 연구의 범위를 비롯하여 선행연구에 대한 검토 및 논문의 레이아웃을 기술한다.

제2장은 이스탄불 해협의 교통량 및 해상교통환경에 대한 전반적인 소개 내용을 담고 있다.

제3장은 3개의 절로 나누어 이스탄불 해협의 해상교통 위험요소를 검토하고 조사한다. 제3장의 제1절에서는 이스탄불 해협 남측 입구 수역의 위험도를 결정하기 위하여 local traffic volume, 교통흐름, local traffic의 잠재적인 조우회수 및 충돌의 개연성 등과 같은 해상교통안전평가요소들을 조사한다. 종국에는 이들 요소들을 이용하여 연구 대상 해역에서 위험도가 높은 지역을 식별해낸다.

제3장 제1절에서 수집된 정보를 기반으로 전문가 면담 및 조사를 통하여, 전문가들이 인식하는 위험의 정도와 연구 대상 해역의 위험요소들을 결정하고, 나아가 다음 연구 방향을 제안하는 내용이 제2절에 기술되어 있다. 이 연구에 참여한 전문가들은 도선사, 해상교통관제사, 이스탄불 해협의 통항 경험이 풍부한 선장 및 항해사들이다. 전문가 면담 및 조사를 기반으로 가장 위험한 선종(type of vessel), 길이, 외부요인 (조류, 바람, 시정 등)의 영향 및 개선 방안에 대한 유효수준 등이 결정된다.

제3절에서는 local traffic이 이스탄불 해협을 통과하는 선박들에게 주는 항행상의 스트레스를 조사한다. 이 목적을 위하여 연구 대상 해역을 디지털화하고, 지형적인 특성이나 통항상황 및 기상 특성을 그대로 나타낼 수 있는 선박조종 시뮬레이터를 이용하여 시뮬레이션을 실시하게 된다. 게다가, 시뮬레이션 결과는 이노우에 교수의 환경스트레스모델(2000)을 사용하여 분석함으로써, 선박조종 상의 어려움으로 인하여 항해자가 겪는 스트레스의 정도를 정량적으로 나타낼 수 있게 된다. 그 결과로서 local traffic이 해협을 통과선박에게 미치는 위험이 입증되어 지고, 연구 대상 해역에서 가장 위험한 장소가 들어나게 된다.

안전이란 시스템을 관리하고 운영함에 있어 사람과 재산 및 환경에 대한 위험으로부터 자유로워지는 정도를 결정하는데 인간이 인지하는 질이라고 정의한다(Chengi, 2007). 이 논문의 궁극적인 목표는 이스탄불 해협의 항해안전을 증진시키고자 하는 것이다. 제3장에서 연구대상해역의 위험도는 충돌의 개연성, 전문가 면담조사 및 실시간 선박조종시뮬레이션을 통해 밝혀졌고, 이러한 연구의 결과를 보면 대상 해역에 대한 위험감소의 필요가 있음을 보여주고 있다. 위험 감소란 위험의 정도가 높은 곳에서 더 낮은 곳으로 이동하는 것이라고 설명하고 있다(Chengi, 2007).

제4장에서는 이 개념을 기본으로 하여, 교통량이 밀집되는 시간대(peak time) 및 한가한 시간대 (off-peak time)의 현재 교통상황을 속성 시뮬레이션 기법을 이용하여 시뮬레이션 한 후에, Latent ES Model을 이용하여 분석하게 되는데, Latent ES Model은 개인의 숙련도의 차이나 항해자의 개인특성을 제외시켜 조선곤란도의 평가 결과의 보편타당성을 보증하고자 한 모델이다(Inoue *etal*1999).그 다음으로는 선박 크기, 교통의 흐름 및 교통의 방향 등과 같은 해상교통요소들을 바꾸어 주는데 따른 결과를 조사하고, 연구대상해역에서의 조선곤란도의 정도를 낮추기 위하여 local marine traffic을 대상으로 한 다양한 항로지정방식을 제안하였다.

제5장에서는 이스탄불 해협에서의 해상교통 안전을 향상시키기 위한 Local TSS와 편도 통항방식을 권고한다.

다음으로는 이 연구의 결과들을 간략하게 정리하여 제시한다.

a) 해협의 충돌 개연성을 한국의 해역과 비교했을 때, 이스탄불의 위험성이 거의 2배 정도임을 발견하였다.

b) 실시간 시뮬레이션 연구 결과, 연구 대상 해역에서 가장 위험한 해상교통을 보이는 지역은 Sarayburnu와 Kadikoy 사이인 것으로 확인되었다. 따라서 이 연구결과를 보면 해당지역에 대해 항행 안전을 증진시키기 위한 모종의 개선 방안이 도입되어야 함을 알 수 있다.

c) 현재의 교통 상황을 가지고 속성 시뮬레이션을 실시한 결과, 연구 대상 해역에서 교통량이 정점에 이르는 시간대에는 29%, 그 이외의 시간대에는 22%의 받아 들일 수 없는 스트레스가 발생했다.

d) 속성 시뮬레이션을 수행해 본 결과 Istanbul Harbor Master Local marine Traffic Guideline (RLMTR)에 의해 추천된 Local marine traffic용 항로들이 해당 해역의 통항 안전성을 증진시키는 것으로 밝혀졌다.

그러나 이 연구에서 제안하는 LTSS나 일방통행방식 보다는 그 효과가 크지 않은 것으로 조사되었다.

e) 속성 시뮬레이션 결과, 제안된 LTSS 방안들이 연구 대상 해역의 통항 안전을 개선시키고 있음을 알 수 있다.

시뮬레이션 결과, 제안하고 있는 LTSS 1은 Sector A1에서 운항 안전을 개선하는데 가장 효과적인 방안으로 밝혀졌고, 제안된 LTSS 중 LTSS 3은 Sector A2와 Sector A3에서 운항 안전을 하는데 가장 효과적인 방안으로 밝혀졌다.

결과적으로, 이스탄불 해협 남측 입구 부근 해역의 해상교통 안전을 증진시키기 위해서는 Local marine traffic을 위한 통항분리 방안이 도입되어야 함을 강력히 추천하지 않을 수 없다.

f) 속성 시뮬레이션 연구 결과, 일방통항 방안 역시 연구 대상 해역에서 항해자들의 스트레스를 감소시키는 아주 효과적인 방안으로 밝혀졌는데, 이 결과는 전문가 면담조사 결과와 일치하고 있다. 따라서 일방통항 제도의 지속적인 시행을 적극적으로 권고한다.

핵심 용어: Local Marine Traffic, 이스탄불 해협, Local Traffic Separation Scheme (LTSS)

Chapter 1 Introduction

1.1 Scope of Research

This study investigates the risk level of marine traffic and risks in the southern entrance of Istanbul Strait in order to improve marine traffic safety. In this study, local marine traffic parameters such as local traffic volume, traffic flow and probability of collision are investigated by utilizing various statistics. Afterwards, an expert survey, real time simulation studies and marine traffic fast time simulation studies are conducted to investigate several marine traffic parameters. At the end, Local Traffic Separation Schemes (LTSS) are proposed to promote navigation safety in the Istanbul Strait. According to Inoue (2000), there is a linear correlation between risk and stress which is imposed on navigators due to ship handling difficulty in a waterway. In this study, ES Model (Inoue, 1999) is utilized to demonstrate risks in the southern entrance of the Istanbul Strait and validate the effectiveness of proposed countermeasure by marine traffic fast time simulation studies. The ES Model is a practical model for assessing ship handling difficulty in topographically restricted and congested waterways, or in ports and harbors, because it can evaluate simultaneously or individually the difficulties of shiphandling arising from topographical restrictions and the difficulty arising from encounters with other ships. It also has acceptance criteria based on mariner's perception of safety. The ES model originally is designed to evaluate ship handling difficulties during real and marine traffic fast time simulation studies. Hence, ES model has chosen to emphasize risks in Istanbul Strait numerically and the term of "stress level" is used to imply risk.

Traffic density in Istanbul is rising each passing day. While 4,500 ships on average passed through in the year 1936 when Montreux Treaty was signed, nowadays, the number of passage has reached 56 thousand ships in a year. Especially in the Istanbul Strait, daily 2,100, scheduled or unscheduled local traffic ships run from one side to the other of the Istanbul Strait which adds up to more than 700 thousand passages a year (Undersecretariat for Maritime Affairs, UMA-2005).

With the technological developments in the field of ship building and with arrival of Caspian petrol in the international market, there have been important rises on the dimensions and number of ships passing through Turkish Straits, on tonnages and the variety and abundance of the dangerous cargo. While the rate of the ships carrying dangerous cargo was 10% before the year 2000, by the end of 2003 it rose up to 19% and has remained at around 18% since then. Serious increases have been observed in the transportation of dangerous cargo through the Istanbul Strait in recent years. The quantity of petrol and petrol products carried through the Istanbul Strait was 65 million tons a year. This reached to 82 million tons in 1999, 91 million tons in 2000, and 101 million tons in 2001. By the end of 2009, it reached up to 144.5 million tons. Still, on a daily basis an average of 150 ships pass through the Istanbul Strait and 132 ships pass through the Canakkale Strait (UMA, 2010). In addition, the intensive tanker traffic has reached a daily average of 25 tankers, and it is expected to reach up to 30 big tankers (UMA, 2005). According to the “Maritime Traffic Regulations for the Turkish Straits”, large vessels are described as having a length overall (LOA) of 200 meters or more, and these vessels have difficulty to keep their course in the Traffic Separation Schemes (MTRTS, 1998). The first maritime traffic regulations adopted by IMO Maritime Safety Committee (MSC) for the Turkish Straits came into force on 1st of July, 1994. Certain precautions for safety passage in the Turkish Strait, such as, establishment of TSS, only day time passage for ships 200 meters in length or more was part of it. In 1998, these regulations were revised after 4 years of practice and experience. IMO adopted the 1998 Guidelines in MSC 71 and circulated IMO Rules and Recommendations as "Rules and Regulations on Navigation through the Strait of Istanbul, the Strait of Canakkale and the Marmara Sea" (IMO Resolution A.857 (20) and A.827 (19), IMO NAV 44/14).

The rules for navigating and passing trough the Istanbul Strait are inspected by Directorate General of Coastal Safety, Ministry of Transport according to 1998 Guidelines (DGCS). As designated by the Guidelines-Article 14, "within the Straits the vessels may not overtake vessels except in necessary cases" and "no overtaking may take place between the Vanikoy and Kanlica points". Ships longer than 200 meters are not allowed to enter the Strait in opposite directions and for ships longer than 300 meters, all other traffic in the Strait is suspended to ensure safe passage. In the last 10 years, nearly 350 marine accidents have occurred in Turkey, especially in the Istanbul Strait. Incidents are classified according to the nature of their occurrences as follows: 57% of accidents are collisions, 22% of accidents are grounding, 16% of accidents are stranding, and the rest are due to fire and other (Yurtoren, 2004).

The zone chosen as research area spans from the line between Moda and Bakirkoy in the south entrance of the Istanbul Strait to the 1st suspension bridge "Bogazici Koprusu" in the Istanbul Strait. Recently marine traffic density has increased and consequently the navigation risks are greater than before in the Istanbul Strait. The local traffic density rises in correlation with the rising city population. 95% of the scheduled and unscheduled local traffic vessels, which can reach up to 2,500 vessels, transport passengers in the South entrance of the Istanbul Strait.

In addition, a big part of the population in Istanbul, which has exceeded 12 million people, lives in this district or thinks of this district as a transition hub to both sides.

In light of the factors mentioned above, there is a requirement to regulate the dense regional traffic in an effective way in order to promote safe navigation and to protect the historical structures of Istanbul. Thus, the objective of this study is to investigate marine traffic features and marine risks generated from local traffic vessels and to promote marine traffic safety in the southern entrance of the Istanbul Strait.

1.2 Literature Review

Sarioz and Narli (2003) investigate the maneuvering performance of the large tanker ships for the Istanbul Strait by using a real time ship maneuvering simulation method. The study was conducted based on all combination of environmental factors such as wind, current and wave drift forces, with a simulator capable of subjecting a given hull form. The results indicate that, when realistic environmental conditions are taken into account, the size of ships that can navigate safely in compliance with the traffic separation lanes is limited.

Or and Kahraman (2002) analyse possible factors contributing to accidents in the Istanbul Strait by using the Bayesian method and simulation modeling. The conditional maritime accident probabilities in the Istanbul Strait are obtained by applied the Bayesian method. The simulation model takes into account the characteristics and the critical traffic rules and behavior of the Istanbul Strait, and uses the conditional accident probabilities determined via the Bayesian method. Simulation results indicate significant increases in number of accidents in maritime conditions involving higher transit traffic rates, denser local traffic conditions, higher percentage of longer ships and/or adverse weather conditions.

In the study of Arslan and Turan (2009), the SWOT analyse method is suggested to determine factors that cause the shipping accident in the Istanbul Strait. After describing the factors by using the SWOT analyse method, they applied Analytic Hierarchy process (AHP) method to find weights of each factor. As a result of the study, several strategic precautions are proposed.

Akten (2004) investigates marine casualties' in-depth relation to casualty types, numbers of ships, the localities where most incidents occur, and external factors such as currents and darkness that contribute to marine casualties in the Strait. The study revealed the major factors in order to suggest possible solutions.

Atasoy (2008) determines the local traffic intensity and some risks-related parameters in the Istanbul Strait. The risks were defined based on environmental stress factors via Environmental

Stress (ES) model.

In her doctoral thesis, Nur (2005) studies geographical, meteorological, hydrological, oceanographic, economical and strategic characteristics of the Istanbul Strait. She also investigates the shipping traffic, marine casualties and circumstances of innocent passage based on present safety precautions. In addition, she generates a casualty chart for the Istanbul Strait by using the statistical analyse method. In the conclusion, two different results are revealed: (i) the relation ship between the number of marine casualties and the passage of ships without pilot, and (ii) influence of meteorological factors on ship accidents such as current, wind, fog and the tonnage of ships in the Istanbul Strait.

Yazici and Otay (2009) developed a real time maritime traffic support model for safe navigation in the Istanbul Strait. A new MATLAB code for the simulation and the Marine GNC Toolbox is applied to analyse the vessel hydrodynamic and the auto-pilot model. The casualty probabilities of each trajectory are found after computing the trajectory tree of the vessel by forward-mapping its position distribution with respect to the initial position vector. Within certain restrictions on vessel geometry, the proposed model predicts the safest possible intended course for the transit vessels based on the navigational parameters including position, speed, and course of the vessel. The model is tested in the Istanbul Strait for validation.

Kum (2008) investigates the risk profile of maritime accidents in the Istanbul Strait, and then develops a methodology to minimize human error. He exposes the potential threats and defines the risk profile based on the geographical and physical specifications of the Istanbul Strait.

1.3 Research Review

Chapter 1 of the dissertation describes its scope, gives a review of the literature and presents the research layout. Chapter 2 gives a general introduction to marine traffic and environment in the Istanbul Strait. Chapter 3 reviews and investigates marine traffic risks in the Istanbul Strait in 3 sections. In the first section of chapter 3, marine traffic safety assessment parameters, which are local traffic volume, traffic flow, potential number of local traffic vessel encounters and possibility of collision, are investigated in order to determine the degree of danger at the southern entrance of the Istanbul Strait. Finally, by utilizing these parameters, the high-risk zones are identified in the research area. On the basis of information collected in section 1 of chapter 3, an expert survey is discussed in order to assess danger perceptions of experts, determine risks in the research area and then propose a basis for further studies in section 2 of chapter 3. Stake holders such as pilots, Vessel Traffic Services Operators

(VTS-O), skippers of local traffic vessels and master marines who had experience passing through the Istanbul Strait were surveyed. Based on the expert survey study, the most dangerous vessel type and ship length, the effect of external factors (i.e. current, wind, visibility) and the effectiveness level of the potential counter measures are determined. Section 3 of chapter 3 investigates the navigational stress that local traffic imposes on transit vessels passing through the Istanbul Strait. For this purpose, the research area is created digitally and simulation studies are carried out using a ship handling simulator which can imitate the effects of topographic features, vessel traffic and meteorological conditions. Furthermore, the results of the simulation studies are analysed using Environmental Stress Model of Inoue (2000) which provides an opportunity to measure the stress level of a mariner quantitatively due to ship handling difficulty. Thus, the danger that is imposed by the local traffic on transit ships is demonstrated and the most dangerous spots in the research area are revealed.

Safety is a human perceived quality that determines to what extent the management, engineering and operation of a system is free of danger to life, property and the environment (Chengi, 2007). The ultimate aim of this dissertation is the improvement of navigation safety in the Istanbul Strait. In the chapter 3, dangers in the research area are presented by collision probability, expert survey and real time ship handling simulator studies and outcomes of those studies show the necessity of risk reduction. Risk reduction is the term used to describe the moving of a hazard from one location higher on the risk scale to a lower location (Chengi, 2007). Based on this concept, current marine traffic situations during peak and off-peak times are simulated by marine traffic fast time simulation studies. The studies were then analysed by the Latent ES Model which was introduced to exclude influence of the individual skill differences and navigator personality and to guarantee the universality of the results in evaluating shiphandling difficulty (Inoue et al. 1999) in chapter 4. Afterwards, change of marine traffic parameters such as the vessel size, traffic flow, and traffic direction are investigated; and various traffic separation schemes for local marine traffic (LTSS) are proposed in order to lower scaled stress due to ship handling difficulty in the research area. In chapter 5, LTSS and one-way traffic implementations are recommended to improve marine traffic safety in the Istanbul Strait.

1.4 Research Layout

Research flow chart is given in Figure 1.1.

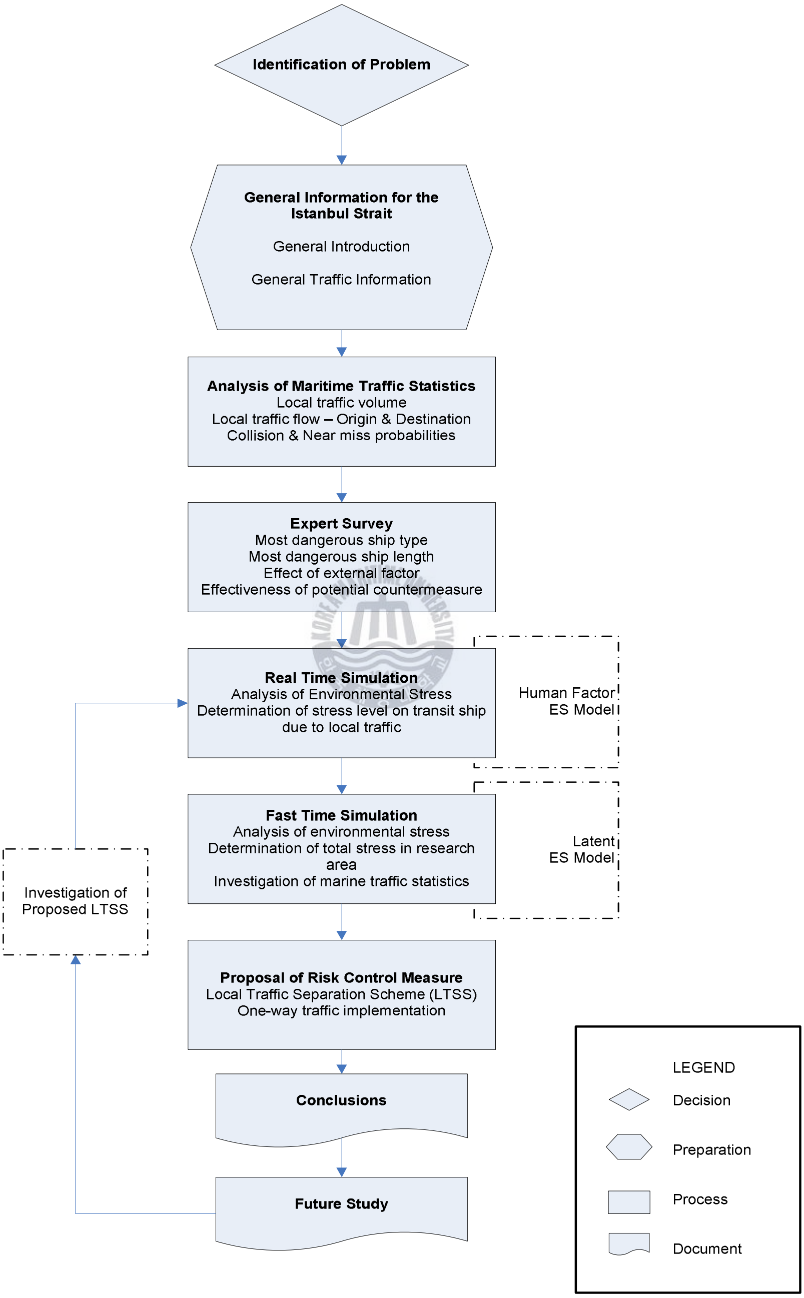


Figure 1.1 Research Flow Chart

Chapter 2 Marine Traffic and Environment in the Istanbul Strait

2.1. General Introduction of the Istanbul Strait and Dangers

The region which is known as Turkish Straits, including the Istanbul Strait, the Canakkale Strait and Marmara Sea, poses dangers to life, property and environment due to busy national and international marine traffic. It is also risky because of its challenging geographic, morphologic and oceanographic structure.

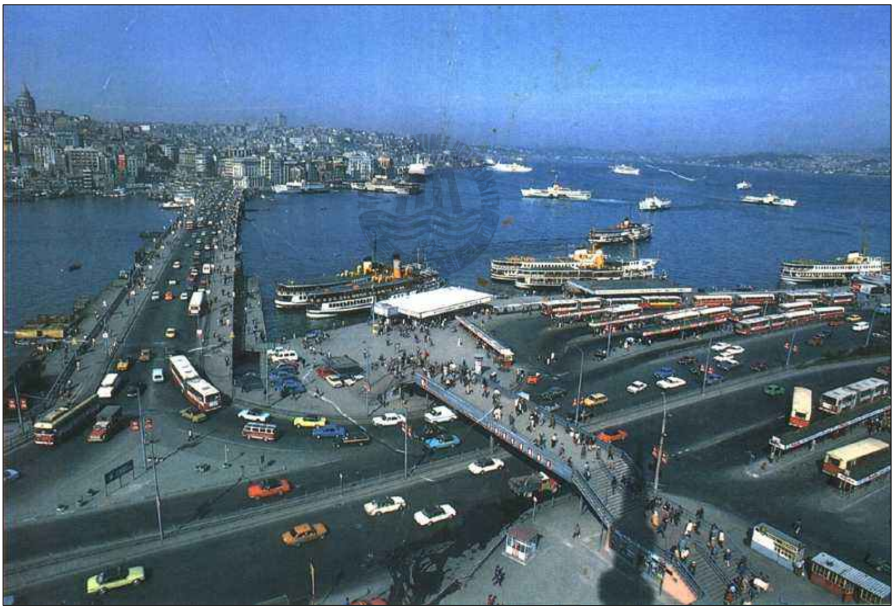


Figure 2.1 A scene from local traffic area in the Istanbul

Of the 164 miles comprising the Turkish Straits, 17 miles of this is the Istanbul Strait, 110 miles is the Marmara Sea, and 37 miles is the Canakkale Strait. There are difficult elements in the Istanbul Strait include current which can reach a speed of up to

6-7 miles per hour, wind, bars and small islands that require forced maneuvers and hinder safe navigation (UMA, 2005).

Traffic density in Istanbul is rising with each passing day. While an average of 4,500 ships passed through in the year 1936 when the still valid Montreux Treaty was signed, today the number of passages has reached 56 thousand. Especially in the Istanbul Strait, everyday 2,100 scheduled or unscheduled local traffic ships, which make up more than 700 thousand ships per year, make the voyage between the two sides of the city, and on a daily basis about 1 million passengers are transported (Atasoy, 2008).

With the technological developments in the field of ship building and with the arrival of Caspian petrol in the international market, there have been important increases in the dimensions and number of ships passing through Turkish Straits, on tonnages and the variety and abundance of dangerous cargo. While the rate of the ships carrying dangerous cargo was 10% before the year 2000, by the end of 2003 it rose up to 19% and has remained at around 18% since then. Serious increases have been observed in the transportation of dangerous cargo through the Istanbul Strait in recent years. The quantity of petrol and petrol products carried through the Istanbul Strait was 65 million tons a year. This reached to 82 million tons in 1999, 91 million tons in 2000, and 101 million tons in 2001. By the end of 2009, it reached up to

144.5 million tons. Still, on a daily basis an average of 150 ships pass through the Istanbul Strait, and 132 ships pass through the Canakkale Strait (UMA, 2010). In addition, the intensive tanker traffic has reached a daily average of 25 tankers, and it is expected to reach up to 30 big tankers, (UMA, 2005). According to the “Maritime Traffic Regulations for the Turkish Straits”, big vessels are described as having a length overall (LOA) of 200 meters or more, and these vessels have difficulty to keep their course in the Traffic Separation Schemes (MTRTS, 1998). The first maritime traffic regulations adopted by the IMO Maritime Safety Committee (MSC) for the Turkish Straits came in to force on 1st of July, 1994. Certain precautions for safety passage in the Turkish Strait, such as, the establishment of Traffic Separation Scheme (TSS), only day time passage for ships 200 meters in length and over was part of it. In 1998, these regulations were revised after 4 years of practice and experience. IMO adopted the 1998 Guidelines in MSC 71 and circulated IMO Rules and Recommendations as "Rules and Regulations on Navigation through the Strait of Istanbul, the Strait of Canakkale and the Marmara Sea" (IMO Resolution A.857(20) and A.827(19), IMO NAV 44/14).

The rules for navigating and passing through the Istanbul Strait are inspected by the Directorate General of Coastal Safety, Ministry of Transport according to 1998 Guidelines (DGCS). As designated by the Guidelines-Article14, “within the Straits the vessels may not overtake vessels except in necessary cases” and “no over taking may take place between the Vanikoy and Kanlıca points”. Ships longer than 200 meters are not allowed to enter the Strait in opposite directions and for ships longer than 300 meters, all other traffic in the Strait is suspended to ensure safe passage. In the last 10 years, nearly 350 marine accidents have occurred in Turkey, especially in the Istanbul Strait. Incidents are classified according to the nature of their occurrences as follows: 57% of accidents are collisions, 22% of accidents are grounding, 16% of accidents are stranding, and the rest are due to fire and other (Yurtoren, 2004).

It is very clear that in case of an accident resulting from dense tanker traffic, the damage to historical structures and the natural environment of Turkish Straits could be similar to the damage of a potential earthquake in Istanbul. This can be exemplified by the catastrophic Independenta and Nassia accidents that happened in the Istanbul Strait in November 1979. M/T Independenta (Romanian) and M/V Evriyali (Greek) collided and as a result 43 sailors lost their lives. The explosion caused heavy damage and windows of thousands of houses in Kadikoy were broken. Nearly 100 thousand tons of petrol spilled into the sea, burned for days and resulted in environmental pollution. In March 1994, a collision between M/T Nassia (South Cyprus) and M/V Shipbroker (South

Cyprus) resulted in air, sea and environmental pollution due to 13,500 out of 98,600 tons of petrol spilling in to the sea. 29 sailors lost their lives, sea traffic stopped for a long time, hundreds of ships accumulated at the entrance of the Istanbul Strait, and city transportation and life were highly affected (Ozgurce, 2005).


Figure 2.2 Scenes from Nassia (left) and Independa (right) accidents

2.2 Natural structure

Structurally, the Istanbul Strait is a strong and steamy waterway that lies by twisting. Due to its basic physical characteristic, it is one of the narrowest waterways in the world. When measured by the middle line, its average length is 17 miles and its cost line is 19 miles on the Anatolian Side and 30 miles in European because of its twisting structure. The widest parts are in the North, 3,600 meters between the Anatolian Lighthouse and Turkeli Lighthouse and 3,220 meters between the Ahirkapi Lighthouse and Inciburnu Lighthouse in the South (Ustaoglu, 1995).

Figure 2.3 Satellite View of the Istanbul Strait

The ships passing the Istanbul Strait in the direction of North-South and vice versa must alter course at least 12 times. Especially Yenikoy (Koybasi) which requires a 45 degrees turn, is the narrowest and one of the riskiest zones in the Istanbul Strait. The width between Kandilli and Asiyan is 700 meters and requires an 80 degree turn, another highly risky zone due to both sharp turns and current. Secure passing depth in the Istanbul Strait is nearly 30-60 meters and the deepest point reaches to 110 meters in Kandilli. For this reason, depth is not an important factor of risk in terms of navigation.

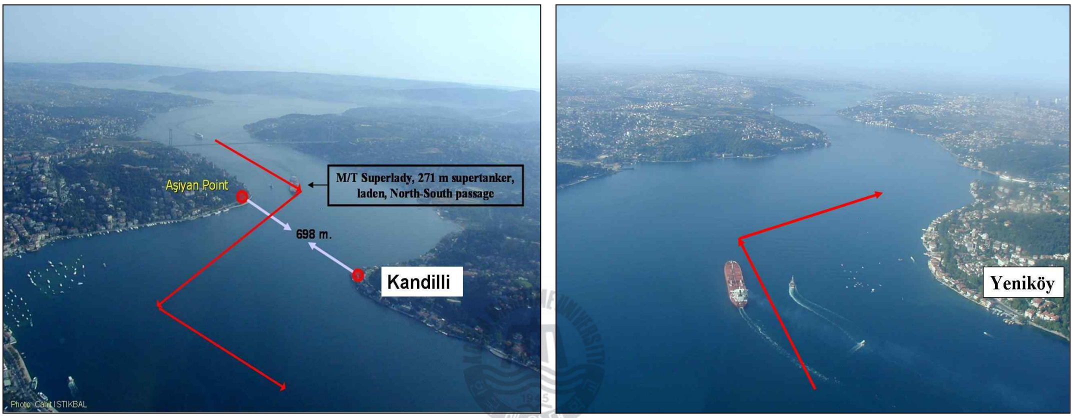


Figure 2.4 Passing at Kandilli and Yeniköy in the Istanbul Strait (Photos: Cahit Istikbal)

Factors affecting navigation negatively in the Istanbul Strait are;

Shallow waters at Sarayburnu, Kız Kulesi, Umuryeri, Yenikoy, Buyukliman, the capes of Salacak, Kandilli, Arnavutkoy, Akinti, Kanlica and Yenikoy, and the bays of Bebek, Istinye, Beykoz, Tarabya and, in addition, Kiz Kulesi (Maiden Tower) and, Kurucesme, Bebek and Dikilitas piers complicate navigation and require much attention (Yurtoren, 2004 and Atasoy, 2008). Two suspension bridges that blend naturally into the city landscape are also factors that partly affect navigation. The heights of these bridges are 58 and 64 meters. Moreover, high voltage lines and the Haydarpasa break water are two more factors that affect navigation (Atasoy, 2008).

2.2.1 Current

In the Istanbul Strait, there are four different types of currents caused by water level and density differences between the Black Sea and the Marmara Sea, namely, the surface and undertow currents. Between the Black Sea and the Marmara Sea, there is a 25 cm waters level difference, the Black Sea being higher (Inceli, 1968). While the surface current flows from the Black Sea to the Marmara side, the undertow flows towards to the Black Sea from the Marmara Sea due to salinity difference. In normal conditions, the speed of the current flowing from the Black Sea to the Marmara Sea changes between 0.4 knots and 4.8 knots at varying points in the Istanbul Strait. However, the change of meteorological conditions, notably the direction and severity of wind affect the current significantly (Ece, 2005). If the wind blows stronger than the North wind and the Borealis, the surface current in the Istanbul Strait might rise to 7~8 knots, rising 2~3 times in the parts where it is normally 3~4 miles. The undertow is generally 25~60 meters deep and flows in the opposite direction. The speed of these currents changes between 1.0 and 3.0 knots. With the strong storms of southwest wind, the surface current turns to the opposite creating the Orkos current. When the Orkos occurs, water levels rise up between the surface current and undertow at the mouth of the strait. As the depth of the surface current decreases, depth of the undertow rises and the deep water begins to affect the deep draught ships (Inceli, 1968). Also, there are gulfs, or in other words, mirrors, in the strait which occur when the waters flow into the bays or capes and are deflected by the shore and move in the opposite direction. These currents cause dangerous situations for ships altering course where sharp turns have to be made. The Istanbul Strait current chart is shown on the Figure 2.5 (Istikbal, 2005).

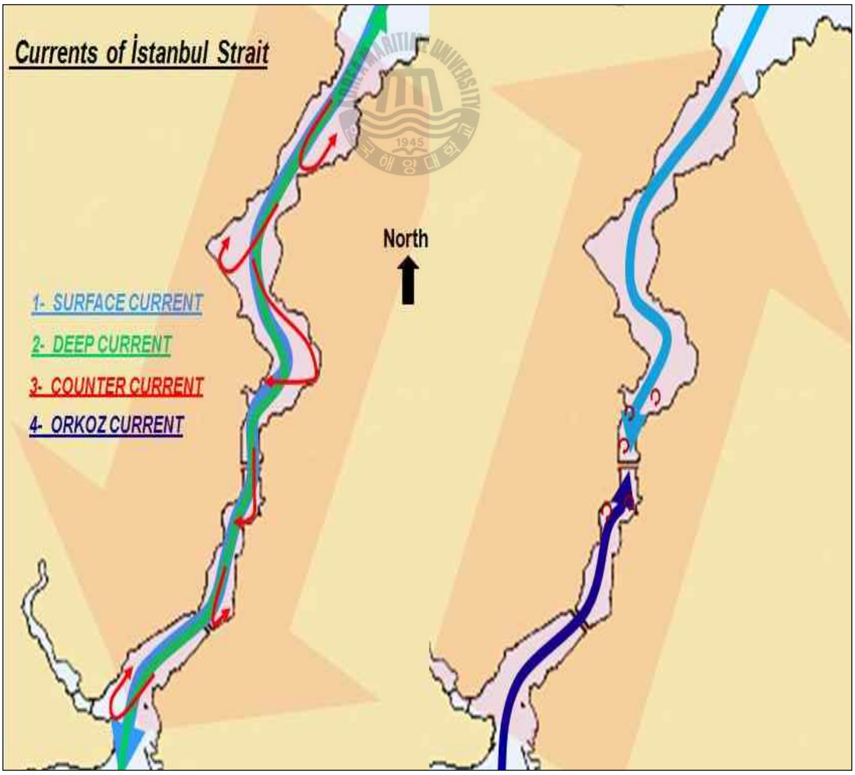


Figure 2.5 The Istanbul Strait current' chart

2.2.2 Visibility

Another factor affecting ship accidents in the Istanbul Strait is the low visibility caused by fog, snow and rain. The occurrence rate of accidents is high when the visibility decreases down to 0.5 miles. The heaviest rain fall is in December with an average 106 mm of rain fall which affects safe navigation. Visibility may decrease to 20~30 meters in the strait due to fog. However, the best visibility in the strait is during nightfall in December and January and at noon in other months. As shown in the Figure 2.7, March continues to be the worst month for visibility with an average of 4.8 days in which visibility is less than 1,000 meters. Notably, low visibility of 6~10 meters due to fog is common in early morning (Yurtoren, 2004).

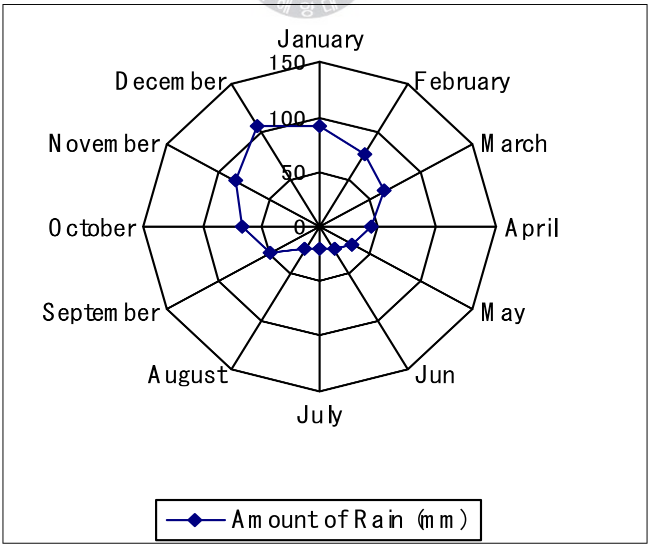


Figure 2.6 Average rain fall distribution

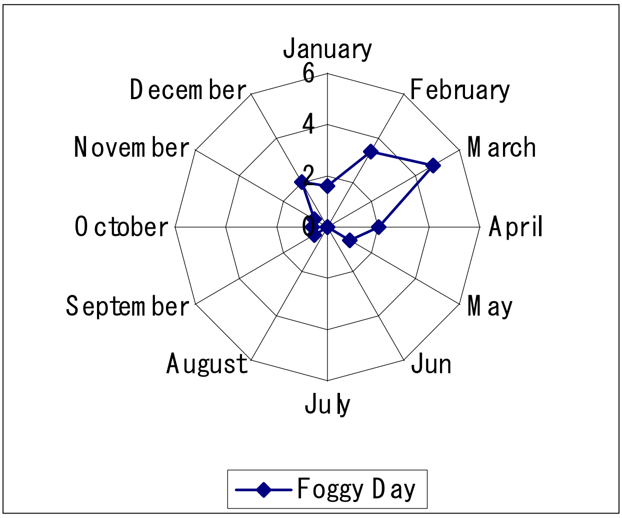


Figure 2.7 Distribution of day's visibility less than 1000m

2.3 Marine Traffic Environment in the Research Area

The chosen research area is the zone between the line connecting Moda Cape to Bakirkoy and the Istanbul Strait Bridge. It is 7.5 miles long and has two turning points. There are two big cargo and passenger ports in the research area. The ships using these ports are also factors that affect marine traffic safety.

One of the elements affecting safe navigation in the research area is the current which effects the entire strait. The zone between Defterdar and Cengelkoy is where the current is in the center of the strait and flows with the most speed. The speed of the current near Beylerbeyi Palace reaches up to 4~5 knots, and after touching Uskudar shores, flows to Sarayburnu. The speed of the main current in this zone is approximately 3~4 knots from

Vanikoy to Kiz Kulesi. In the South of Kiz Kulesi, it decreases to 2~3 knots as it crashes into Sarayburnu cape. Its speed is therefore reduced and some of the waters bend towards Tophane and Golden Horn forming mirrors (UMA, 2000).

The intensity of the mirrors changes in correlation with daily main current intensity. For example, the countercurrent between Galata and Defterdar Cape flows stronger in the afternoon, but the speed of it lessens at late hours in the night. The speed of the counter current near the south west shore of Ortakoy is over 0.5 knots (Ece, 2008). The counter current sometimes gets stronger at parts that are close to the shore between Defterdar Cape and Akinti Cape. It blends with the main current turning to the east in the South of Akinti Cape. Direction and strength of current is closely related to the changes of weather conditions. With the South and south west winds, the width of the gulf current tightens to little more than 1 cable. When the winds of the south are too strong, the main current in the Strait makes its way to the North there by affecting the entire strait.

The countercurrent in the north bay of Uskudar flows north-east in a narrow line. This current is moved by south west winds in to the middle part of the Strait. A short counter current circulation exists in the north-east bays of Beylerbeyi, Anadolu Fortress, Vanikoy, Bebek and Istinye (Yurtoren, 2004).

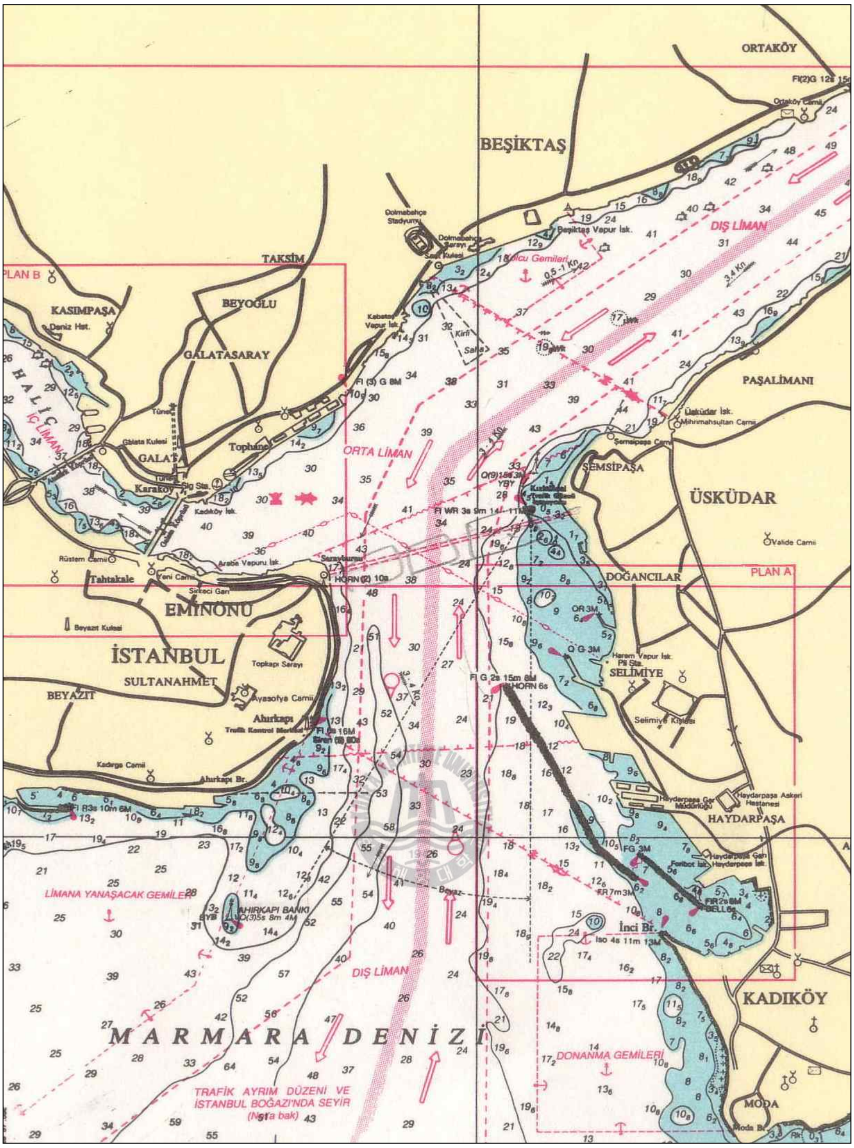


Figure 2.8 Chart view of the research area

2.4 Marine Traffic in the Research Area

In the Southern entrance of Istanbul Strait, four directional traffics is formed consisting of transit traffic that passes through the strait (with or without stop-over) in North-South or South-

North bound and local traffic in the directions of East-West and West-East bound.

2.4.1 Transit Ships vs Stop-over Ships

Figure 2.9 compares number of transit and stop over ships that pass through the Istanbul Strait between the years 1997 and 2009. An important increase is observed in the numbers of transit ships in the recent years. Most of the transit ships that do not stop over are those with foreign flags, and the ones that do stop-over are generally Turkish ships. “Stop-over” means the ship visits ports in the Marmara Sea or the Port of Istanbul (UMA- 2010).

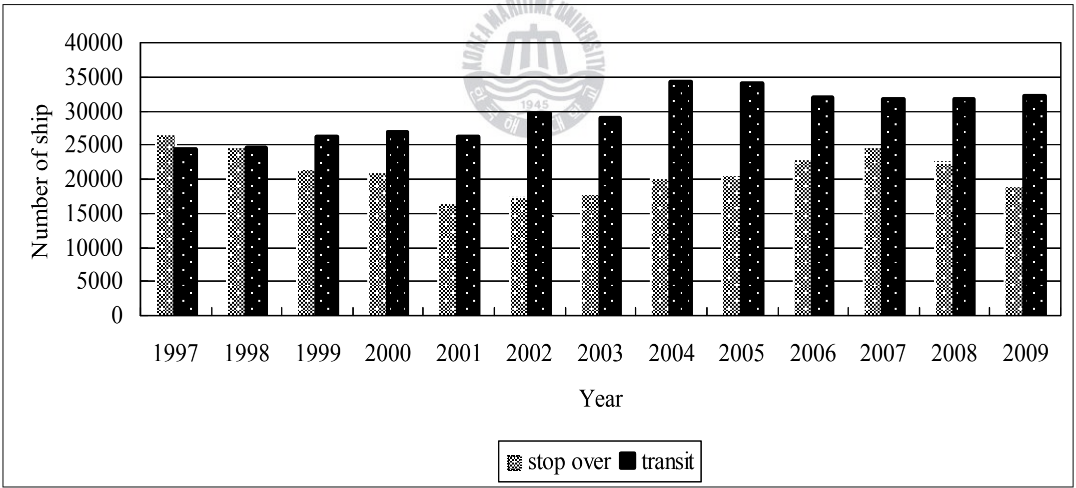


Figure 2.9 Transit - stop over passage statistics

In the Figure 2.10 shows the main flag states whose ships pass through the Istanbul Strait. By 2009, the country making with the most transit was Turkey with 22%, followed by Malta, Panama and Russia (UMA-2010).

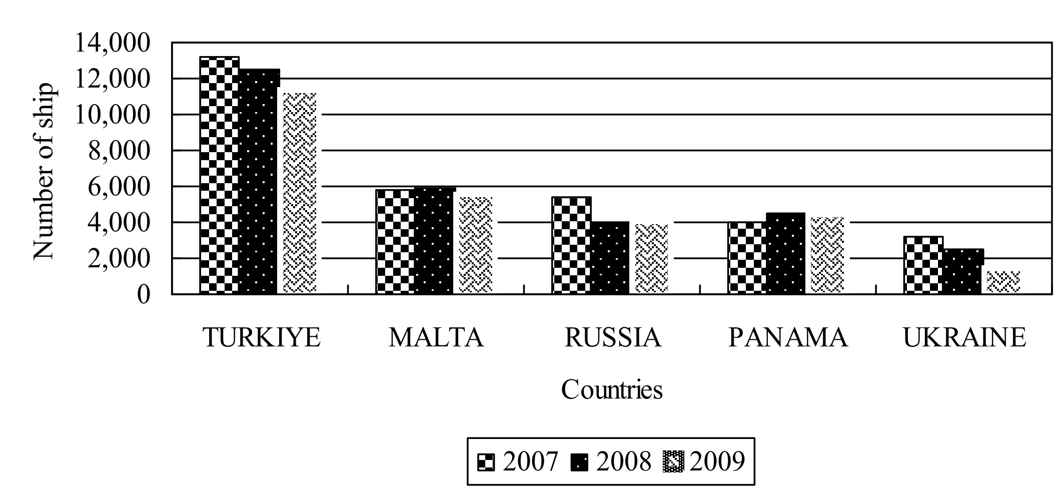


Figure 2.10 Flag States of Ships which pass through Istanbul Strait

The large transit or stop over ships bound for the Aegean Sea or Black Sea, substandard ships and ships carrying dangerous cargo are the main factors for marine traffic risks in the strait. Studies to improve safe navigation in the strait are focused on these ships. The elements that threaten these ships include local traffic and oceanographic and topographic structure. Encounter situations of local traffic ship with substandard ships forms the most dangerous situations. It is a common for ships making local passage to come closer and/ or pass closer to transit ships.

Istanbul Strait traffic has increased since the Black Sea countries declared their in dependence and have formed their own fleets. River ships from East European countries which sail to the Black Sea by using the Tuna-Ren seaway also contribute and affect the traffic density in the Istanbul Strait. For the safety of

Istanbul and its strait, the tendencies to use the Turkish Straits for transporting Caspian oil to western markets have to be limited. At present, the traffic of the Turkish Straits is over the safety limit in terms of navigation, life, property and environment (Yurtoren, 2004).

In Figure 2.11, Length over All (LOA) distribution of the ships that have pass through the Istanbul Strait in recent years is presented. The graphs show an increase in the number of ships passage during the last years. With the exact LOA starting from 150 meters to 300 meters and higher, with gaps of 50 meters, 4 different LOA graphics are given. A clear increase can be observed in the numbers of the ships with an LOA less than 300 meters between the years 1990 and 2002. However, the numbers of ships with an LOA of 300 meters and over noticeably decreased after 1999. According to Turkish Straits Regulations, ships having a LOA of 200 meters and over are considered as big size ships. Yurtoren, in his doctorate, stated the LOA of big ships as 226 meters (Yurtoren, 2004). For these reasons, a ship with a 225 meters LOA was chosen to be used in the simulator during the real time simulation study.

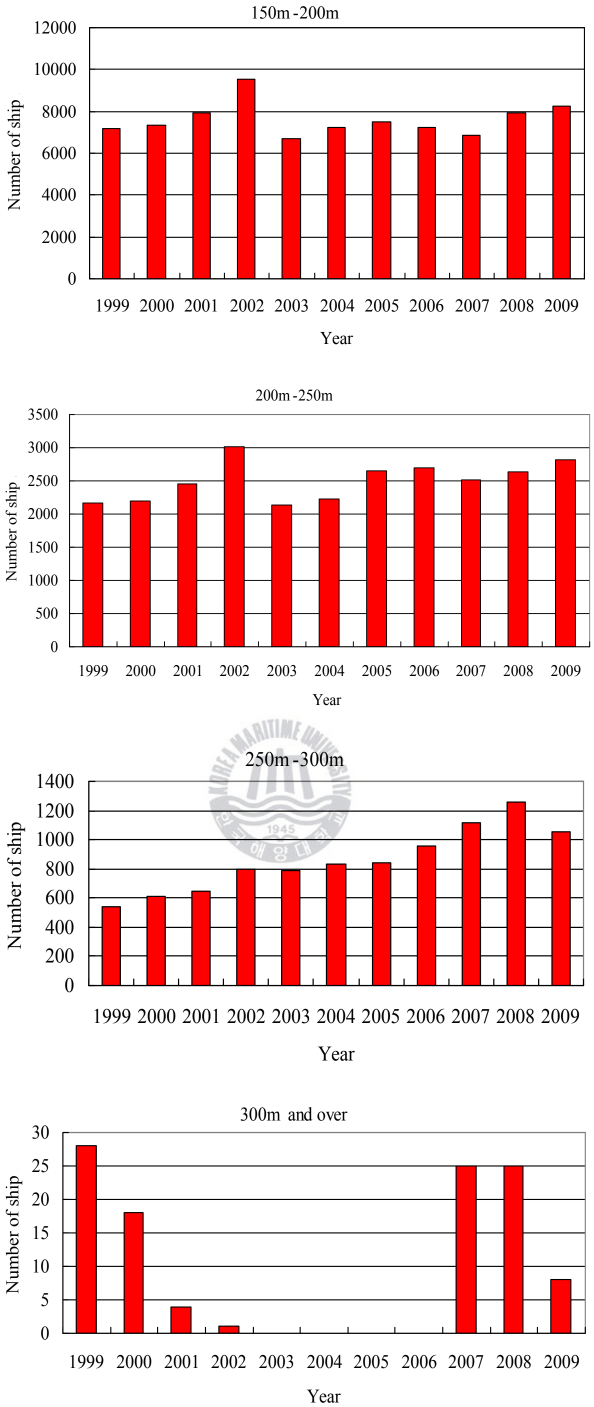


Figure 2.11 LOA distribution of the ships pass through the Istanbul Strait in recent years

2.4.2 Density of Local Marine Traffic

An important element that influences navigation safety in a negative way in the Istanbul Strait is the local marine traffic which mainly crosses from one side to other of the strait. Local marine traffic in the Istanbul Strait consists of City Lines Transportation, Sea Busses, Special Passenger Motors Line, Fishing Boats, Excursion and Sports Boats, and Military Boats (Atasoy, 2008). In the table 2.1, scheduled local traffic lines in the Istanbul Strait are sorted according to departure-arrival ports, voyage duration and quantity.

Table 2.1 Scheduled local traffic lines in the Istanbul Strait

Origin-Destination	Voyage Duration	Voyage Number
Passenger Boat and Vehicle Ferry		
Karakoy-Kadikoy	20 min	312
Eminonu-Kadikoy	20 min	184
Kadikoy-Besiktas	25 min	144
Eminonu-Uskudar	20 min	248
Eminonu-Bogaz	90 min	240
Sirkeci-Harem	15min	132
Sirkeci-Adalar	45 min	34
Kabatas-Cinarcik	90 min	24
Uskudar-Kabatas/Besiktas	15 min	92
Sea Bus		
Eminonu-Kadikoy	10 min	26
Kabatas-Karakoy	10 min	14
Kabatas-Yalova	25 min	14
Kadikoy-Eminonu	10 min	18
Eminonu-Beykoz	20 min	4
Passenger Boat		
Uskudar-Besiktas/Kabatas	15 min	550
Beykoz-Yenikoy	10 min	95
Total		2131

When scheduled and unscheduled local marine traffic lines are investigated, it is revealed that, except for the Beykoz-Yenikoy line, almost 95% of local marine traffic in the Istanbul Strait, run and/ or navigates in the determined research area (Yurtoren, 2004).

2.4.2.1 Transportation with City Lines Ferries

The City Lines Ferries belonged to TDI Sehir Hatlari Isletmesi until 2004, when it was handed over to Istanbul Sea Buses Corporation (IDO) with a fleet of 61 passenger and car ferries, a total 54 piers, 17 of which are in the research area. IDO conducts over than 800 voyages in the research area on a daily basis (IDO, 2008).

2.4.2.2 Transportation with Sea Busses

Another major company which transports passengers in the Istanbul Strait is the Istanbul Sea Busses Corporation (IDO). This line blends with the ships that make international cruises within the Karakoy-Eminonu-Kadikoy area. Daily, 125 local voyages are made by IDO vessels in the research area. Sea busses are the fastest ships in the Straits with speed of 25-30 knots. Ships run between 06:00 and 21:00, and traffic density is highest during the day time (Atasoy, 2008).

2.4.2.3 Trip Aimed and Passenger Carrying Motorboats

Passenger transportation in the Istanbul Strait is also conducted by Passenger Carrying Motorboats which belong to private owners and are operated under two separate cooperatives. These cooperatives, Dentur Avrasya and Turyol, operate registered vessels in different locations in the strait. A total of 60 boats run on the Uskudar-Eminonu-Karakoy, Kadıkoy-Haydarpasa-Eminonu, and the Eminonu-Adalar and Karakoy-Adalar lines in the summer time. In addition, there are 4-5 dolmush motors work between Bebek and Anatolian Fortress. 39 vessels of 4 different types are registered to Dentur Avrasya (Dentur, 2008) and 62 vessels of 5 different types are registered to Turyol (Turyol, 2008). The length (LOA), speed and passenger capacity of local vessels in Istanbul are given in Table 2.2 (highlighted vessels are not working in the research area).

Table 2.2 Ships particular of local traffic vessel

	Type	Number	LOA	Speed	Passenger Capacity
Conventional Passenger Boats	YA1	5	78 m	8 knt - 12 knt	2100 passenger
	YA2	3	67 m	8 knt - 12 knt	2000 passenger
	YB	18	58 m	8 knt - 12 knt	1500 passenger
	YB	6	49 m	8 knt - 12 knt	750 passenger
Conventional Vehicle Ferries	ND	2	73 m	12.5 knt	600 passenger
					80 vehicle
	FA	8	73 m- 81 m	11 knt	1400 passenger
					114 vehicle
	FB	7	53 m- 67 m	11 knt	738 passenger
					66 vehicle
Sea Buses	Catamaran F.	5	42.9 m	30.9 knt	449 passenger
	Catamaran	10	38.8 m	32 knt	449 passenger
	Catamaran	8	35 m	32 knt	400-350 passenger
	Catamaran	2	35 m	33.5 knt	450 passenger
Fast Ferries	Catamaran	2	88 m	37.4 knt	1200 passenger
					225 vehicle
	Fast Ferry Catamaran	2	86 m	37 knt	800 passenger
					200 vehicle
	Fast Ferry Catamaran	2	59.9 m	34.5 knt	490 passenger
					94 vehicle
	Double-Ended Fast Ferry	2	80.8 m	22 knt	588 passenger
					112 vehicle
Dentur Passenger Boats	A plus	13	37 m - 42 m	13 knt - 18 knt	650-430 passenger
	A Class	17	23 m - 27 m	11 knt - 17knt	330-150passenger
	B Class	7	18m	10 knt - 18 knt	200-125 passenger
	C Class	2	16m	9 knt - 11 knt	106-94 passenger
Turyol Passenger Boats	A-1	32	42 m - 39 m	14 knt - 17 knt	850-380 passenger
	A-2	19	34 m - 39 m	12 knt - 14 knt	600-450 passenger
	B-1	4	29 m - 33 m	11 knt - 13 knt	450-325 passenger
	B-2	4	24 m - 28 m	9 knt - 10 knt	200-150 passenger
	C-1	3	21 m - 25 m	8 knt - 11 knt	200-100 passenger
Total		183 ships			

Yurtoren (2004) analyses the time tables of local marine traffic lines, which include city lines ferries, sea busses and passenger carrying motorboats, and presents the fluctuations of local traffic density, as shown in the Figure 2.12. The fluctuations in traffic density can be observed hourly in the daytime, the busiest time frame being 07:00-09:00 am in the morning and 17:00-19:00 pm in the evening. A 100% business annotation rate was given to these time frames in each of the peak periods. According to the graphic in the Figure 2.11, traffic density decrease nearly 1/2 during noon time, 1/3 in the afternoon and 1/4 during night hours when compare with peak hours. There are no registered voyage from midnight until 6 o'clock in the morning (Yurtoren, 2004).

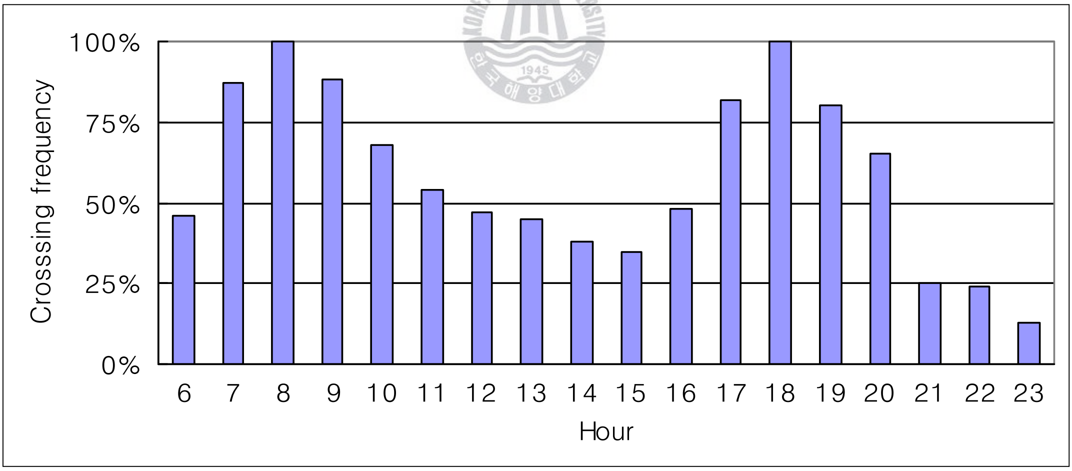


Figure 2.12 Local marine traffic crossing frequency and time table

2.5 Marine Traffic Management

2.5.1 Examination of Vessel Traffic Services (VTS)

There has been always a need for ships to navigate accurately, safely and fast and to assist in this, many authorities have provided aids to navigation in and around their coastal waters. Over recent decades Vessel Traffic Service (VTS) has develop from a shore-based radar system with the aim of enhancing navigation in bad visibility conditions to a modern system using multiple devices with the objective enhancing safety, improving the efficiency of maritime traffic and protecting the marine environment (Marine Safety, 2008). It is acknowledged by IMO that vessel traffic services have been provided in various areas and have made a valuable contribution to safety of navigation, improved efficiency of traffic flow and the protection of the marine environment. (IALA, 2008)

According to the IMO Resolution A.857(20), VTS is defined as a service implemented by a competent authority, designed to improve the safety and efficiency of vessel traffic and protect the environment. The service should have the capability to interact with the traffic and to respond to traffic situations developing in the VTS area.

The benefits of implementing a VTS are that it allows identification and monitoring of vessels, strategic planning of vessel movements and provision of navigational information and assistance. It can also assist in prevention of pollution and co-ordination of pollution response.

The government or fully authorized organization shall be provided with sufficient staff, appropriately qualified, suitably trained and capable of performing the tasks required, taking into consideration the type and level of services to be provided in conformity with the current IMO guidelines on the subject.

The VTS authority is responsible for its own management, operation and coordination. It should communicate with vessels and ensure services are carried out in a safe and effective way. This authority can be a corporation of the state, a harbor organization, a guiding corporation or a combination of those (DGCS, 2006 and Ozgurce, 2005).

According to the IMO Resolution number 857, VTS provides 3 kinds of services:

i. Information Services (INS)

The information service is provided by broadcasting information at fixed times and intervals or when deemed necessary by the VTS or at the request of a vessel and may include for example reports on the position, identity and intentions of other traffic, waterway conditions, weather, hazards, or any other factors that may influence the vessel's transit.

ii. Navigational Assistance Service (NAS)

This service is especially important in difficult navigation and/ or meteorological conditions or in the case defects or deficiencies. This sevice is normally rendered at the request of a vessel or by the VTS when deemed necessary.

iii. Traffic Organization Service (TOS)

The traffic organization service concerns the operational management of traffic and the forward planning of vessel movements to prevent congestion and dangerous situations, and is particularly relevant in times of high traffic density or when the movement of special transports may affect the flow of other traffic. The service may also include establishing and operating a system of traffic clearances or VTS sailing plans or both in relation to priority of movements, allocation of space, mandatory reporting of movements in the VTS area, routes to be followed, speed limits to be observed or other appropriate measures which are considered necessary by the VTS authority.

2.5.2 The Istanbul Strait Vessel Traffic Service

The Istanbul Strait, the Marmara Sea and the Canakkale Strait, together comprise the Turkish Straits. The length of the Istanbul Strait is 17 nautical miles (nm) long, the Marmara Sea, 110 nm, and the Canakkale Strait, 37 nm, which means the Turkish Straits include a total of 164 nm for the passage of vessels.

Transportation of dangerous cargo, high traffic density, rising ship length, complex traffic structure, complex current and environmental conditions, and the resulting marine accidents in the Turkish Strait have lead to the compulsory establishment of Vessel Traffic Services.

Vessel Traffic Services (VTS) in Turkey operates in the entire area of the Turkish Straits VTS (TSVTS) as shown in Figure 2.13. The total length of the TSVTS area is 243 nm. TSVTS has been operating since December 30, 2003. Authorized organization for traffic control is VTS Authority under the Directorate General of Coastal Safety on behalf of the Undersecretariat for Maritime Affairs (Competent Authority) (UMA-web and DGCS web). The TSVTS Authority have taken into account the IMO Resolution A-857 (20): Guidelines for VTS, STCW-95 Resolution 10, SOLAS Chapter V Regulation 12, IMO MSC Circular 952, IALA Recommendations and Guidelines (IALA VTS Manual and IALA V-103/1/2/3/4), and EU Directive 2002/59 for planning and operating of VTS.

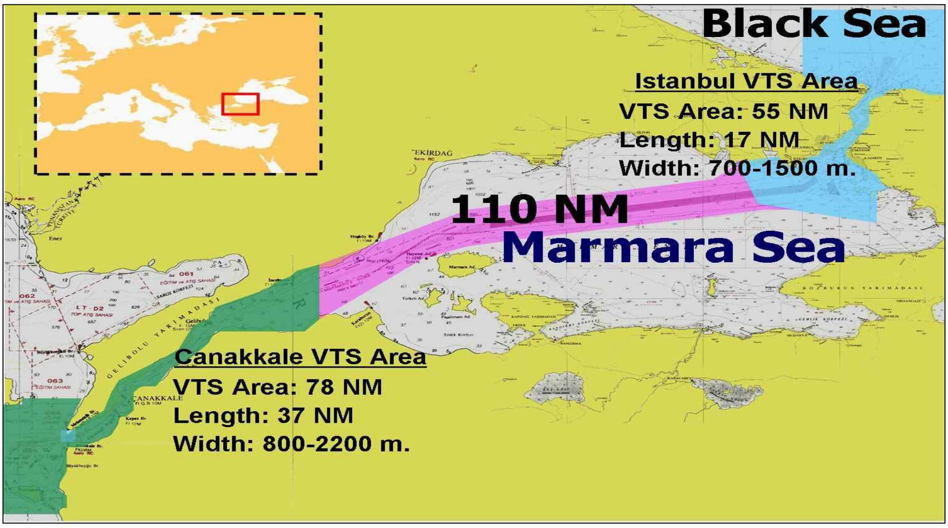


Figure 2.13 Turkish Straits Region and TSVTS Area

Marine traffic in the TSVTS area is monitored by using Radar, ENC, AIS, CCTV and VHF equipment such as VHF R/T, DSC and DF. The TSVTS also receives information from various sources on anticipated vessel movements, hazards to navigation, aids to navigation and any other information of interests to the TSVTS participants. The risks of close passing, near misses, collision and grounding are perceived by the system and the necessary cautions are made and all these activities are kept under record. The sole target of radar scanners which could turn 360°, are ships and with the so called process of "sector closing", electron transmission towards shore is not allowed. Hence, the radar devices in question do not give off radiation in the amount to affect people.

Contributions of the system to the marine traffic in the Istanbul

Strait;

① Providing organized and secured vessel traffic in the channels.

② Ensure safe navigation by considering the responsibility of the captain in an effective way.

③ Giving the necessary cautions and advices in emergencies situations.

④ Ensuring and keeping "the vision of traffic" of the ship traffic in responsible area and giving this information to demanding ships, by considering sensitivity of information and keeping records.

⑤ Recording all audios, videos and information about ship traffic and showing them again when it is required.

⑥ Ensuring obedience of the international and national marine traffic rules and legislations in the strait.

⑦ Minimizing the risks of marine accidents such as collision, grounding and stranding.

⑧ Interfering and coordinating marine traffic in case of accidents in order to minimize the loss of life and property, the marine pollution and other economical losses and also ensuring continuity of traffic as soon as possible.

⑨ Keeping record of transit ships and providing to national or international organizations in case of need.

⑩ Providing, the necessary information that might help for decision to captains during navigation.

⑪ Keeping communication between the ship and "Ship Traffic

Services Center" at minimum or stopping it for good. (Silent VTS)

⑫ Ensuring of the communication system in the form that will enable Coast Guard Commands to conduct own missions.

⑬ Surveillance and support ship traffic in the strait with high care under every environmental conditions day and night.

⑭ Minimizing the need for special device on board and providing the services of the ships apart from the existing device, chance and abilities.

The aim of Turkish Straits Vessel Traffic Services which is financed and completed by the own Turkish sources is not to accelerate or slow down the sea traffic in Turkish Straits but to take necessary precautions to ensure navigation safety in the area.

The length of Istanbul VTS is 55 nm which is divided into four sectors, namely Sector Turkeli, Sector Kavak, Sector Kandilli and Sector Kadikoy. Each sector is controlled by a different VTS operator and different VHF channels is allocated for each. While the sectors were determined, the field where an operator can monitor effectively and the number of ships that will be placed in this area and the density of communication with these ships are taken into consideration (Istikbal, 2005 and Ozgurce, 2005).

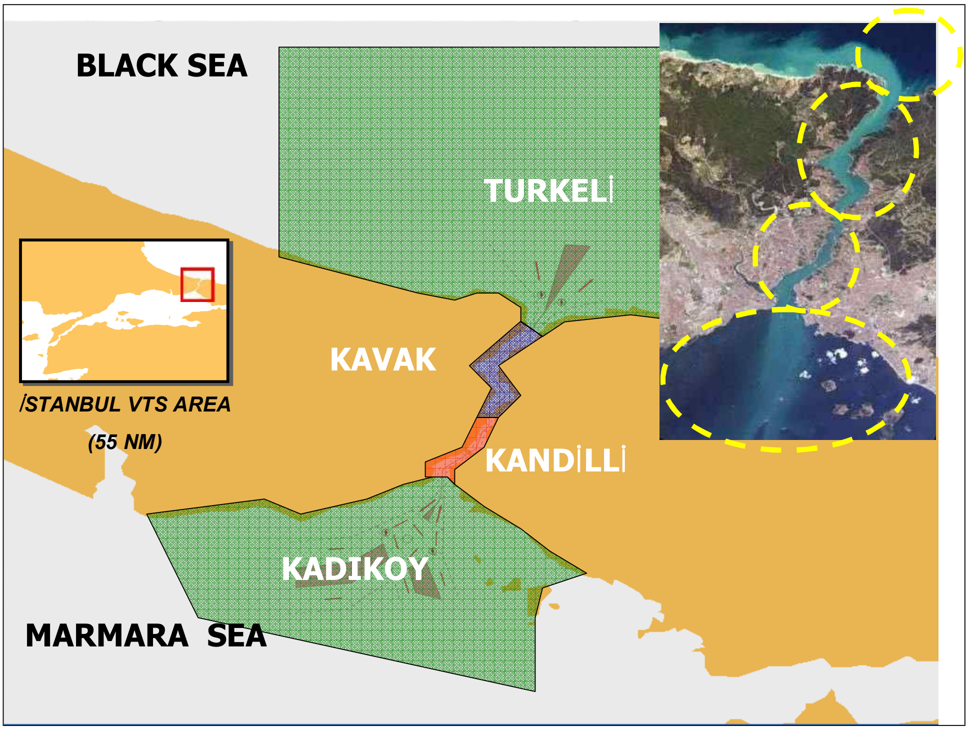


Figure 2.14 Sectors of Istanbul VTS

Chapter 3 Marine Traffic Risk in the Istanbul Strait

3.1 Analysis of Marine Traffic Statistics

3.1.1 Survey of previous studies and statistics

Local traffic management can be described as defining dangers and taken necessary precautions to minimize the risks in a certain marine traffic area (Park, 2005). Therefore, in order to carry out local traffic management, there is a necessity to find degree of danger in the research area. For this purpose, marine traffic parameters such as traffic volume, frequency of collision avoidance maneuver, traffic density, traffic flow and potential encounter are investigated (Park, 2005). In this chapter local traffic volume, traffic flow and potential encounter number of local traffic vessels and possibility of collisions are investigated in order to find degree of danger in the southern entrance of the Istanbul Strait. Finally by utilizing those, most risky areas are determined in the southern entrance of the Istanbul Strait. In this chapter, various date of maritime accidents in the Istanbul Strait are utilized such as, T.C. Prime Ministry, Undersecretariat for Maritime Affairs, Turkish Maritime Pilots' Association, Turkish Marine Research Foundation (TUDAV), related publications, internet sites and studies of Kum (2006), Ece (2006) and Yurtoren (2004).

Local marine traffic vessels which are running in the research area are investigated. The timetable, main origin-destination (OD) and voyage duration of each have been examined through internet and information centers. Hence, traffic flow and detailed ship movement in the research area determined which were given by separate timetable for weekdays, Saturdays and Sundays. Finally weekly, monthly and yearly amounts of ship movement were calculated in the research area. After calculating the amount of ship movement in the research area, Istanbul Harbor Master Local Traffic Guideline and the study of Yurtoren (2004) are utilized in order to define main traffic flow in the research area. Istanbul Harbor Master Local Traffic Guideline gives recommended course to local traffic skippers as seen in Figure 3.1 and Yurtoren (2004) indicates marine traffic flow by carrying out a traffic survey in the research area as seen in Figure 3.2. He utilized a berthed passenger vessel radar for 2 days during peak times of marine traffic. Thus, main traffic flows of the local traffic vessels running in the research area are determined as given in Table 3.1.

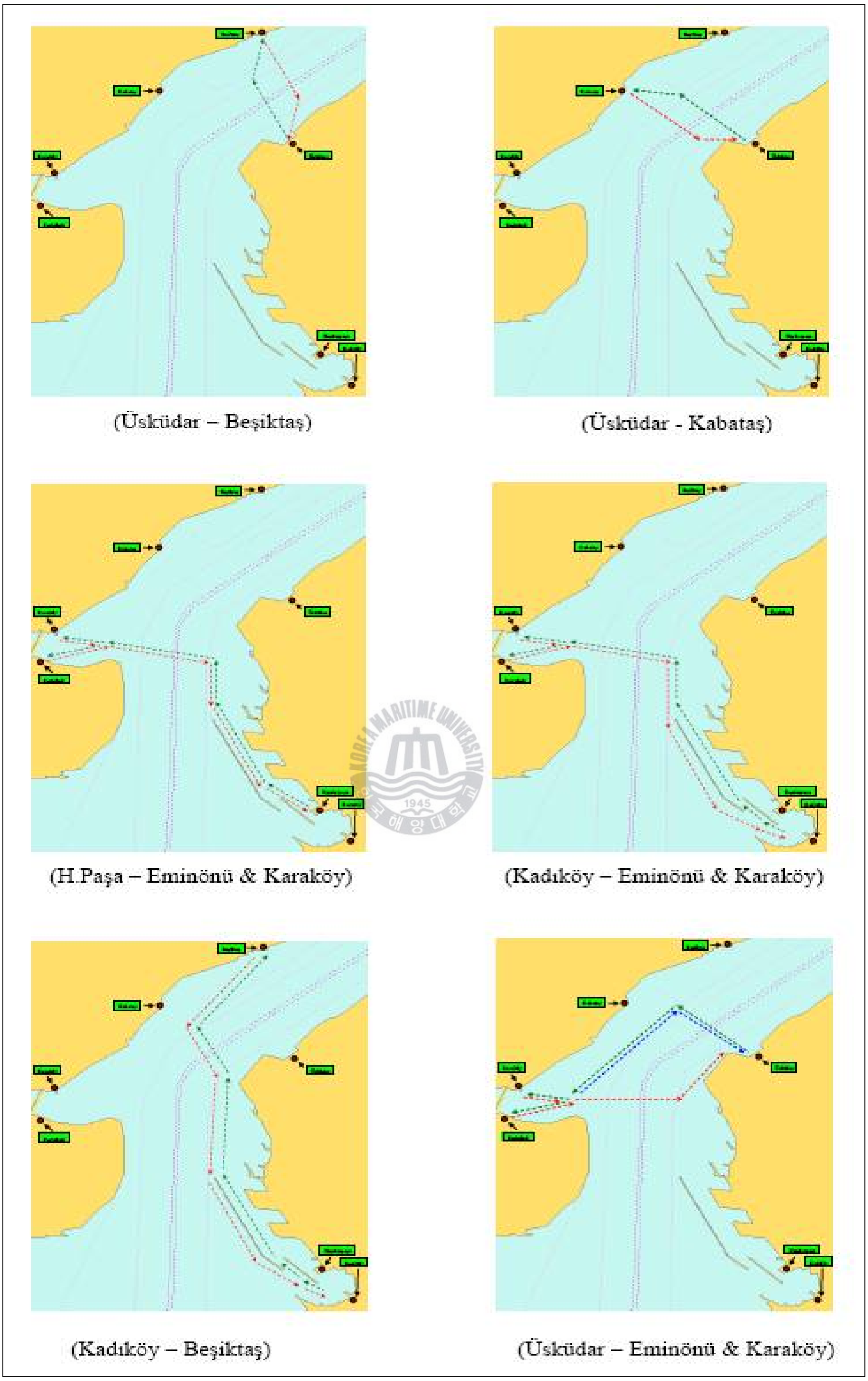


Figure 3.1 Recommended routes by Istanbul Harbor Master Local Traffic Guideline

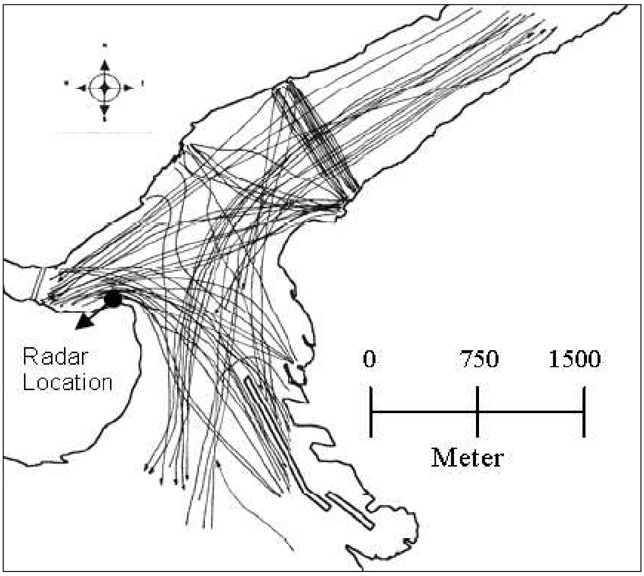


Figure 3.2 Study of Yurtoren (2004) shows
ship tracks in the research area

The research area is highly influenced area by current and wind; therefore local traffic skipper can not navigate easily. Moreover local vessels running in the research area are mainly old vessels with decreased maneuvering capability. Local vessel skippers need to consider requirements of passengers about their tight time schedule. They should also give the way to transit vessel according to COLREG Rule 10 which gives another handling difficulty and time delays for local ships. All these factors are main causes of variations in characteristics of local traffic flow. And that makes it difficult to determine the traffic flow in the research area. Main local traffic flows defined according to origin-destination locations of local vessels as given in Table 3.1, and graphically presented in Figure 3.3.

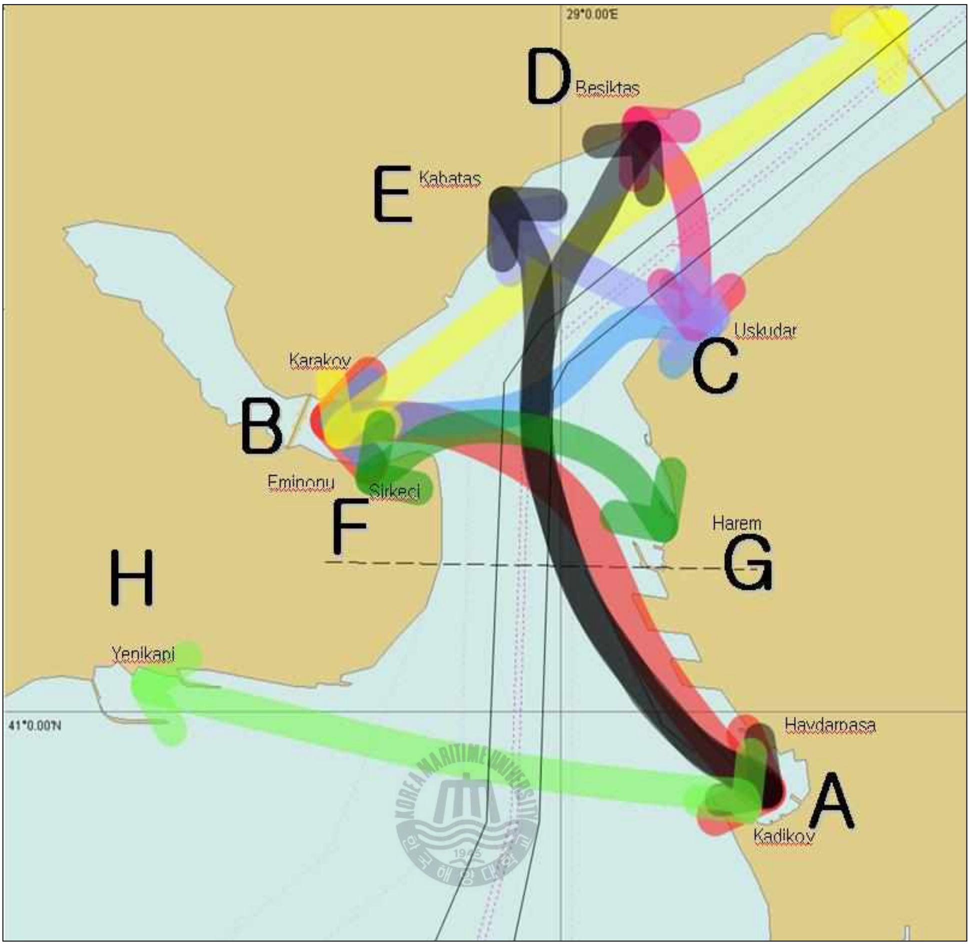


Figure 3.3 Main Traffic Flow lines in the research area

After determination of main traffic flow, data of maritime accidents in the Istanbul Strait obtained from various sources was utilized in order to find collision locations in the research area.

Table 3.1 Determined Origin-Destination (OD) of local traffic in the research area

No	OD Name	OD in detail
1	AB	Kadikoy-Haydarpasa-Karakoy Kadikoy-Eminonu
2	BC	Eminonu-Uskudar
3	AD	Besiktas-Kadikoy Kabatas-Kadikoy-Adalar
4	CD	Uskudar-Besiktas
5	CE	Uskudar-Kabatas
6	FG	Sirkeci-Harem
7	AH	Kadikoy-Yenikapi
8	BD	Karakoy-Besiktas-Cayirbasi

3.1.2 Method

The concept of risk stands central in any discussion of safety. With reference to a given system or activity, the word "safety" is normally used to describe the degree of freedom from danger and the risk concept is a way of evaluating this. The word "risk" is however, not only used in relation to evaluating the degree of safety, but also the risk perception can be viewed differently depending on the contents (Kristiansen, 2005 and Chengi 2007).

In engineering field risk is accepted in relation to safety, and concept of risk is an objective safety criteria. Among engineers the following definition of risk R is normally applied:

$$R = P \times C \qquad \text{(eq. 1)}$$

where

P: Probability of occurrence of an undesired event (e.g. a ship collision)

C: The expected consequence in terms of human, economic and/ or environmental lost

By the definition of risk above it is clear that the probability of occurrence of an undesired event has particular importance. Therefore, the present section of this research is dealing with investigation of ship collision probability in the research area.

As in given below equation 2, possibility of collision can be calculated by dividing number of collisions in a certain time interval by amount of ship movement in a certain area.

$$Pc = Nc/Asm \qquad \text{(eq. 2)}$$

where

Pc: Probability of collision

Nc: Number of collisions

Asm: Amount of ship movement

3.1.3 Results and Discussion

By using probability of collision equation, probabilities are computed for several water ways as given in Table 3.2. In this table data of Korean water ways from 1999 to 2004 were utilized (MOMAF, 2007). And the research area compared with Korean waterways in order to illustrate degree of danger in the research area. As given in the Table 3.2, when compared data from 1999 to 2004 for the research area similar collision probability exist with Busan, Ulsan and Incheon but by the effect of before mentioned traffic volume increase in the Istanbul Strait, probability of collision become almost two times higher than Korean waterways in last 5 year.

Table 3.2 Probability of collisions in Korean waterways and research area

Location	Probability of Collision
Busan	11.68×10^{-6}
Ulsan	10.63×10^{-6}
Incheon	11.18×10^{-6}
Yeosu	1.94×10^{-6}
Research Area	14.29×10^{-6}
Research Area last 5 years	23.31×10^{-6}
Research Area last 13 years	17.78×10^{-6}

Determined main traffic flow, data of collision locations of maritime accidents in the Istanbul Strait obtained from various sources and calculated ship movements are used to compute probability of collision for each OD in the research area for several years as presented in Table 3.3.

Table 3.3 Pc results for each OD flow in the research area for several years

Years	Probability of Collision of Each OD							
	AB	BC	AD	CD	CE	FG	AH	BD
1995	11.9×10^{-6}	5.2×10^{-6}	6.9×10^{-6}	0	0	3.5×10^{-6}	18.9×10^{-6}	1.8×10^{-6}
1996	17.6×10^{-6}	15.5×10^{-6}	12.0×10^{-6}	5.2×10^{-6}	2.6×10^{-6}	0	14.0×10^{-6}	9.2×10^{-6}
1997	14.7×10^{-6}	7.7×10^{-6}	3.4×10^{-6}	0	0	6.9×10^{-6}	9.3×10^{-6}	1.8×10^{-6}
1998	2.9×10^{-6}	7.8×10^{-6}	5.2×10^{-6}	10.4×10^{-6}	7.7×10^{-6}	0	0	7.3×10^{-6}
1999	8.9×10^{-6}	5.2×10^{-6}	5.2×10^{-6}	2.6×10^{-6}	0	3.5×10^{-6}	4.71×10^{-6}	1.8×10^{-6}
2000	8.9×10^{-6}	7.8×10^{-6}	1.7×10^{-6}	2.6×10^{-6}	2.6×10^{-6}	7.0×10^{-6}	4.7×10^{-6}	0
2001	3.0×10^{-6}	2.6×10^{-6}	1.7×10^{-6}	2.6×10^{-6}	2.6×10^{-6}	0	4.8×10^{-6}	0
2002	3.0×10^{-6}	2.6×10^{-6}	1.7×10^{-6}	0	2.6×10^{-6}	0	4.7×10^{-6}	3.7×10^{-6}
2003	8.9×10^{-6}	7.8×10^{-6}	1.7×10^{-6}	2.6×10^{-6}	2.6×10^{-6}	3.5×10^{-6}	4.7×10^{-6}	1.8×10^{-6}
2004	8.7×10^{-6}	0	6.8×10^{-6}	2.6×10^{-6}	0	0	13.7×10^{-6}	1.8×10^{-6}
2005	8.7×10^{-6}	7.7×10^{-6}	5.1×10^{-6}	0	0	0	0	0
2006	0	0	0	0	0	0	0	0
2007	8.6×10^{-6}	7.6×10^{-6}	5.1×10^{-6}	0	0	3.4×10^{-6}	4.5×10^{-6}	1.8×10^{-6}

After annual probability of collisions were calculated, it was difficult to realize the degree of danger of each OD flow line. For this reason average values of last 5 and 10 years have been taken and average values of probability of collision for main traffic flow lines were determined, as given in Figure 3.4.

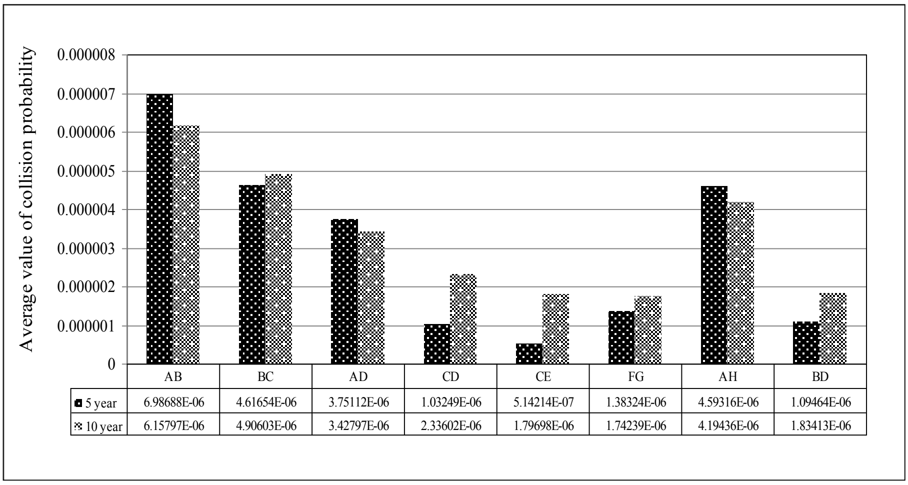


Figure 3.4 Probability of collision for each OD

After computing the probability of collision for each main local traffic flow line, probability of near misses were calculated for each OD in the research area by utilizing Heinrich's principle. According to Heinrich' principle if an accident occurs, there is a probability to have 300 near misses (Park, 2007). Probability of near misses calculated and average values of last 5 and 10 years' are given in Figure 3.5.

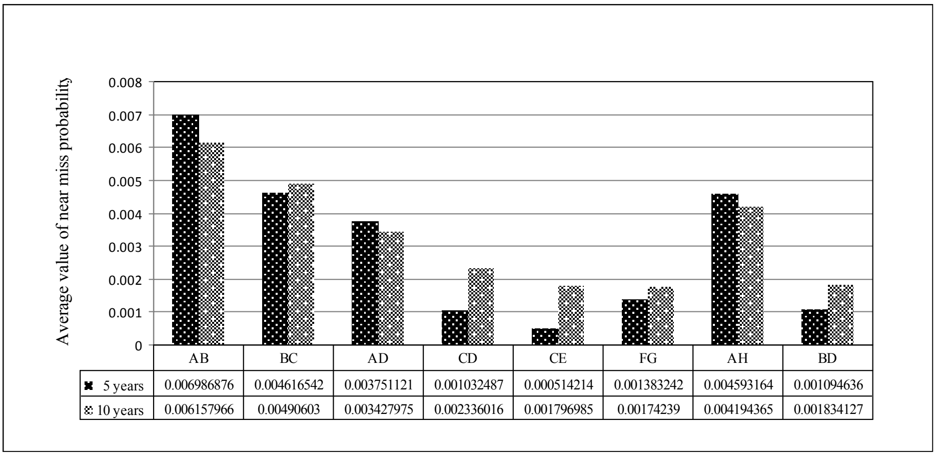


Figure 3.5 Probability of near miss for each OD

Main traffic flow AB is founded as most dangerous line by 0.21% near miss probability according last 5 years average value, which is followed by main traffic flow line BC by 0.13% near miss probability of last 5 years average value, main traffic flow line AH by 0.13% near miss probability of last 5 years average value and main traffic flow line AD by 0.11% near miss probability of last 5 years average value, respectively. AB, BC, AH and AD lines have higher probability values because Eminonu-Karakoy and Kadikoy, which can be called as two major city centers of Istanbul, fall into these lines. 816 local vessels visit Kadikoy and 1,212 local vessels visit Eminonu-Karakoy per day. Total 1,356 local vessels run in a day in both areas and that causes such a high near miss and collision probabilities on those OD. In addition, as given in Figure 3.6, AB, BC and AD lines intersect with each other.

On the other hand the local vessels on AH line may encounter with transit vessels in various possible locations due to being at entrance and exit of the strait, which causes high number of encounters.

After defining main traffic flow, the research area has been divided into three sectors as given in Figure 3.6, namely Sector A1, Sector A2 and Sector A3 according to close passing/ encounter locations of local traffic flow in order to find traffic volume. It has been observed that AH line intersect with transit vessel flow in Sector A1, 4 main local traffic flow lines (AB, BC, AD and FG) intersect with each other and transit traffic flow at different locations in Sector A2 and 4 main local traffic flow lines (BC, AD, CE and BD) intersect with each other and transit traffic flow at different locations in Sector A3.

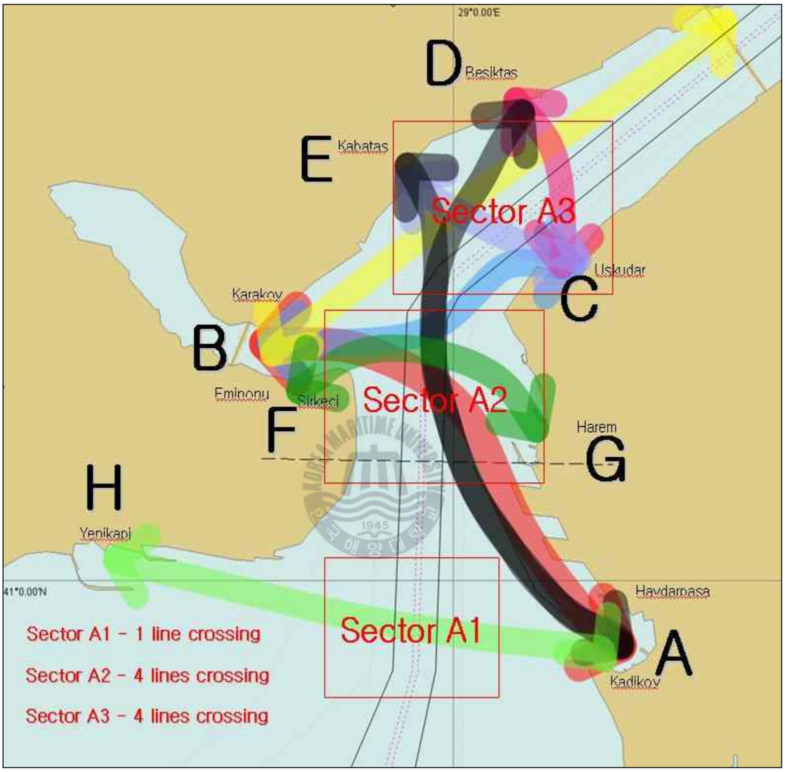


Figure 3.6 Main OD traffic glow and defined Sectors

In order to determine potential encounter in defined local sectors, actual data of departure time, destination, and traffic flow were utilized and voyage durations were assumed according to the study of Aydogdu (2006). Then, as given in Figure 3.7, daily numbers of potential encounters were determined by 10 minute time intervals.

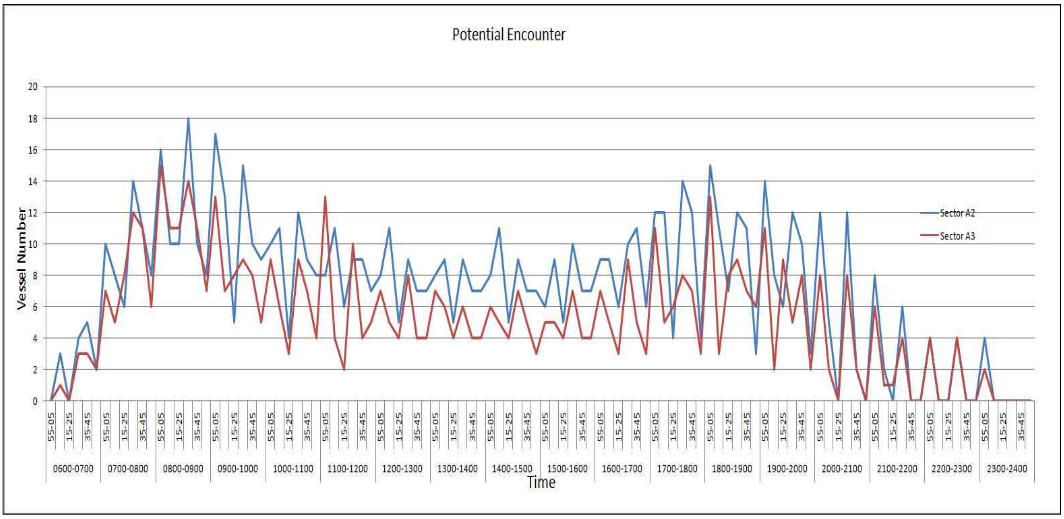


Figure 3.7 Number of potential encounter of local traffic vessels

Also, traffic volume, maximum and minimum number of potential encounters were determined per hour, as given in Table 3.4.

Table 3.4 Potential encounter number and number of local traffic vessel in an hour

Time	Sector	A1	A2	A3
Peak Time	Number of vessel running in an hour	4	73	67
	Max/Min number of potential encounter	2/2	18/8	11/7
Off-Peak Time	Number of vessel running in an hour	4	59	47
	Max/Min number of potential encounter	2/2	11/5	9/4

According to the results, there are 73 different vessels running in a single hour during peak times, with a maximum of 18, and a minimum of 8 vessels being in close location or encountering in Sector A2. In case of off-peak times, the total number of vessels running in the area is 59, with a maximum of 11, and a minimum of 5 vessels being in close location or encountering. The results are similar for Sector A3. 67 vessels run in a single hour, with a maximum of 11, and a minimum of 7 vessels being in close location or encountering during peak times, and a total number of 47 vessels run in a single hour with a maximum of 9, and a minimum of 4 vessels being in close location or encountering during off-peak times. The encounters in Sector A1 are mainly with transit vessels, thus encounters among local vessels is negligible when compared to the other sectors.

Probability of collision in each defined sector calculated and given in Figure 3.8. There is 3 sectors and 4 columns for each sector in the figure. The first columns represent probability of collision, second columns represent number of OD intersect in the sectors, third columns represent number of vessel run in a single peak time hour and fourth columns represent maximum number of potential encounter number in a single peak time hour.

Results for defined sectors compared in Figure 3.8 in order to determine the most dangerous sector which Sector A2 is determined. Results showed that local traffic vessel departure times should be re-arranged in Sector A2 and A3 due to high traffic volume and potential encounters. Also necessary safety precautions should be taken such as more intensive VTS surveillance for both local and transit vessels in Sector A1 in order to minimize existing risks due to vessels encounter .

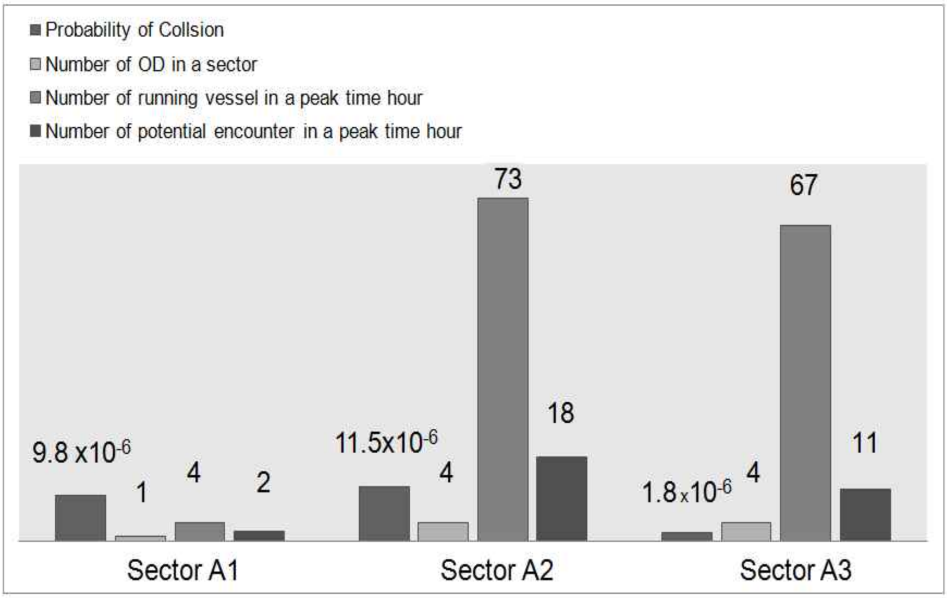


Figure 3.8 Comparative Figures in each defined sector

In this study, encounters of the local vessels with transit vessels were neglected due to small number of passage and indefinite passage schedule of transit vessels. Also some probabilistic values, such as voyage duration were assumed on the basis of experience of field experts.

Unscheduled vessels such as fishing boats and recreation boats were neglected. Besides, times of departure of some lines which have random schedules were assumed by uniform distribution.

This study indicates the risky areas for navigation in the southern entrance of the Istanbul Strait. On the basis of this study, required precautions and long-term policies to maximize safety in the designated areas must be established. This paper also indicates that detailed marine traffic surveys of local and transit traffic are necessary for safe navigation in the Istanbul Strait. Finally, more detailed analysis are required to determine probabilistic values indicated in this study, such voyage durations, effects of environmental factors etc.

3.2 Analysis of Risk Perception by Expert Survey

In the previous section several parameters such as; traffic volume for local vessels, traffic flow and potential encounters of local traffic, in addition possibility of collision were investigated in order to determine the degree of danger in the southern entrance of the Istanbul Strait. Furthermore, risky sectors were determined for this area. On the basis of the results from the previous studies, a questionnaire survey has been conducted to pilots, Vessel Traffic Services Operators (VTS-O), Local Traffic Vessel Captains and Master Marines who had several experience to pass through the Istanbul Strait in order to assess their perceptions of danger, and then proposing a basis for further studies. The aim of this study is to determine most dangerous parameters such as; vessel type, ship length, sector among pre-defined risky local traffic areas and also influence level of external factors and effectiveness level of potential counter measures gathered from the survey. It is also aimed to investigate perception differences among afore mentioned major stakeholders.

3.2.1 Design of Questionnaire Survey

Totally 160 questionnaires were distributed and 146 questionnaires gathered (89.5% return rate) which 5 of them are disregarded due to missing data. 19 pilots (average 6.1 years experience as strait pilot and 17.2 years sea experience), 30 Ocean going captains who have several experiences to pass through the Istanbul Strait (average 11.7 years sea experience), 52 local traffic vessel captains (various competency-license and average 18 years sea experience), a Vice Harbour Master, a pilot boat skipper, 2 tug boat skippers and 36 VTS-O's (average 4.7 years experience as VTS-O and 14.6 years experience on board) participated in this survey as given in Table 3.5. Results were analysed by using SPSS (Statistical Package for the Social Sciences) program version 13.0.

Table 3.5 Number of participants with their experiences

	Number of Participant	Average experience (year)	Average sea experience (year)
Pilot	19	6.11	17.22
VTS-O	36	4.67	14.6
Capt. Ocean going	30	11.73	11.73
Capt. Local Vessel	52	18	18
Others	4	17	
Total	141		
Distributed	160		

A sample of survey question is presented in Table 3.6,

Table 3.6 A sample of survey question (question 1)

Could you evaluate navigational risks in the southern entrance of the Istanbul Strait......

<u>With respect to Ship Type:</u>

a) What is risk level of tanker ships?

Minimum risk		level of risk		maximum risk
① □	② □	③ □	④ □	⑤ □

b) What is risk level of container ships?

Minimum risk		level of risk		maximum risk
① □	② □	③ □	④ □	⑤ □

c) What is risk level of bulk carrier ships?

Minimum risk		level of risk		maximum risk
① □	② □	③ □	④ □	⑤ □

d) What is risk level of passenger ships?

Minimum risk		level of risk		maximum risk
① □	② □	③ □	④ □	⑤ □

e) What is risk level of costal ships?

Minimum risk		level of risk		maximum risk
① □	② □	③ □	④ □	⑤ □

3.2.2 Method

The items of survey were chosen/ decided based on result of previous section. The survey consists of two parts; Part A is to understand Risk Perception of experts by 6 questions, Part B is to take approach of expert regarding exist or potential counter measures. The survey was analysed by using SPSS (Statistical Package for the Social Sciences) program version 13.0.

Reliability of survey responses is tested by Cronbach's Alpha method. Cronbach's α (alpha) is a statistic. It is commonly used as a measure of the internal consistency or reliability of a psychometric test score for a sample of examines. It was first named as alpha by Lee Cronbach in 1951, as he had intended to continue with further coefficients. The measure can be viewed as an extension of the Kuder-Richardson Formula 20 (KR-20), which is the measure's equivalent for dichotomous items. Alpha is not robust against missing data. Several other Greek letters have been used by later researchers to designate other measures used in a similar context (Cronbach, 1951).

This article assigns the use of α to psychology, yet the Cronbach's alpha statistic is widely used in other disciplines, e.g. social sciences, business studies and nursing. This article uses the term "item", while recognizing that items are variable. Manipulated items are commonly referred to as variables.

Cronbach's α is defined as

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K}\sigma_{Yi}^{2}}{\sigma_{X}^{2}}\right) \qquad \text{(eq. 3)}$$

Where;

K: the number of components (K-items or testlets),

σ_x^2: the variance of the observed total test scores for the current sample of persons,

σ_{Yi}^2: the variance of component,

i: the current sample of persons (Devellis, 1991).

Alternatively, the Cronbach's α can also be defined as,

$$\alpha = \frac{K \times \bar{c}}{(\bar{V} + (K-1) \times \bar{c}} \qquad \text{(eq. 4)}$$

Where;

K: the number of components (items or testlets),

$\bar{V}$: the average variance for the current sample of persons,

$\bar{c}$: the average of all covariances between the components across the current sample of persons.

The standardized Cronbach's α can be defined as

$$\alpha_{standardized} = \frac{K \times \bar{r}}{(1 + (K-1) \times \bar{r}} \qquad \text{(eq. 5)}$$

Where;

K: the number of components (items or testlets),

$\bar{r}$: the mean of the $\frac{K \times (K-1)}{2}$ non-redundant correlation coefficients (i.e., the mean of an upper triangular correlation matrix or the mean of lower triangular correlation matrix)

The homogeneity of response variances is tested by Levene’s statistics. Levene's test is an inferential statistic used to assess the equality of variances in different samples. Some common statistical procedures assume that variances of the populations from which different samples are drawn are equal. Levene's test assesses this assumption. It tests the null hypothesis that the population variances are equal. If the resulting p-value of Levene's test is less than some critical value (typically 0.05), the obtained differences in sample variances are unlikely to have occurred based on random sampling. Thus, the null hypothesis of equal variances is rejected and it is concluded that there is a difference between the variances in the population (Levene, 1960).

Procedures which typically assume homogeneity of variance include analyse of variance and t-tests. One advantage of Levene's test is that it does not require normality of the underlying data. Levene's test is often used before a comparison of means. When Levene's test is significant, modified procedures are used that do not assume equality of variance. Levene's test may also test a meaningful question in its own right if a researcher is interested in knowing whether population group variances are different.

The test statistic, *W*, is defined as follows:

$$W = \frac{(N-k)}{(k-1)} \frac{\sum_{i=1}^{k} N_i (Z_{i'} - Z_{''})^2}{\sum_{i=1}^{k} \sum_{j=1}^{N_i} (Z_{ij} - Z_{i'})^{2'}} \qquad \text{(eq. 6)}$$

where;

W: the result of the test,

k: the number of different groups to which the samples belong,

N: the total number of samples,

Ni: the number of samples in the ith group,

Yij: the value of the jth sample from the ith group,

$$Z_{ij} = \begin{cases} \left|Y_{ij} - \overline{Y_{i'}}\right|, & \overline{Y_{i'}} \text{ is a mean of } i-th \text{ group} \\ \left|Y_{ij} - \tilde{Y}_{i'}\right|, & \tilde{Y}_{i'} \text{ is a mean of } i-th \text{ group} \end{cases}$$

$Z_{''} = \frac{1}{N}\sum_{i=1}^{k}\sum_{j=1}^{N_i} Z_{ij}$ is the mean of all Z_{ij}

$Z_{i'} = \frac{1}{N_i}\sum_{j=1}^{N_i} Z_{ij}$ is the mean of the Z_{ij} for group I.

The significance of *W* is tested against $F(\alpha, k-1, N-k)$ where *F* is a quantile of the F test distribution, with $k-1$ and $N-k$ its degrees of freedom, and α is the chosen level of significance (usually 0.05 or 0.01). For the testing significance of differences between alternatives the conventional analyse of variance (ANOVA) technique is performed. For the details of theory of ANOVA please refer to various statistical hand books (e.g.

Freedman, David A., 2007).

3.2.3 Results and Discussion

The reliability of the survey is tested by Cronbach's Alpha method and results are presented in Table 3.7.

Table 3.7 Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Number of Items
0.771	0.782	34

The survey consists of two parts as mentioned in the introduction. Part A has 6 questions with sub-items and Part B has only one question with sub-items. Items in Part A are evaluated and graded in Five Likert Scale; from "1-minimum/ lowest risk' to "5-maximum/ highest risk". Effect levels of external forces are evaluated by the last item of part A and graded from "1-not effective" to '5-extremely effective". Similarly, effectiveness level of risk mitigating counter measures are evaluated in Part B and graded from "1-not effective" to "5-extremely effective". Number of participants (N), mean values and standard deviations are obtained via Descriptive Statistics and mean values are indicated by graphics.

3.2.3.1 Risk evaluation with respect to ship type and crew

Participants evaluated navigational risk level of tanker ships, container ships, bulk carries, passenger ships and costal ships which navigate in the southern entrance of the Istanbul Strait with respect to ship type in terms of maneuver characteristic, cargo condition, etc. Participants also evaluated risk level of afore listed ship types with respect to crew condition by means of considering training level, workload, working condition, etc. The results revealed that tanker ships are the most dangerous among ship types with a mean of 4.4 points on a Five Likert Scale (60.3% of participant agreed on the highest risk level and 22.7% of them gave high risk level) and with respect to crew background by a mean of 3.68 points on a Five Likert Scale (31.2% of participant agreed on the highest risk level and 31.2% of them gave high risk level). Passenger ships are determined as less dangerous among ship types with a mean of 2.2 points on a Five Likert Scale (34.8% of participant agreed on the lowest risk level and 30.5% of them gave low risk level) and with respect to crew background by a mean of 2.04 points on a Five Likert Scale (39% of participant agreed on the lowest risk level and 29.8% of them gave low risk level). Table 3.8 present result of Levene's test.

Table 3.8 Results of Levene's test

	Levene's Statistic	df1	df2	Sig.
Tanker	0.684	4	136	0.604
Container	9.110	4	136	0.000
Bulker	3.891	4	134	0.005
Passenger	1.353	4	136	0.254
Coastal Ship	1.780	4	136	0.136
Tanker Crew	0.376	4	134	0.127
Bulker Crew	0.100	4	134	0.982
Passenger Crew	2.547	4	133	0.42
Coastal Ship Crew	1.668	4	134	0.161

Stakeholders have given different risk perception weights for the risk level with respect to ship type and crew on board, but variances of weights are determined non-significant ($p > .05$) except container and bulk carrier ($p < .05$) with respect to ship type and passenger ($p < .05$) with respect to crew condition . It is assumed that stakeholders have common approach regarding risk perception, despite of different risk perception weights. The results also revealed that stakeholders consider training level, workload, working condition, and etc. of crew on board. For instance, all stakeholders gave higher risk level for crew (depends on training, working condition, etc) than ship type to coastal ships as given in Figure 3.9 and 3.10. It is also assumed that stakeholders in the Istanbul Strait have high situational awareness regarding ship type and crew characteristics, and consequently, it promotes navigational safety in the Istanbul Strait.

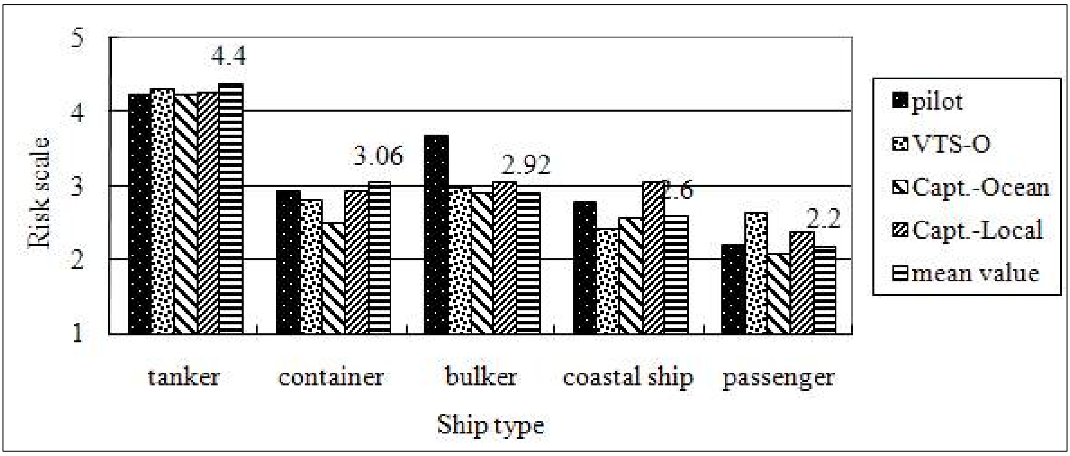


Figure 3.9 Risk evaluations among stakeholders with respect to ship type

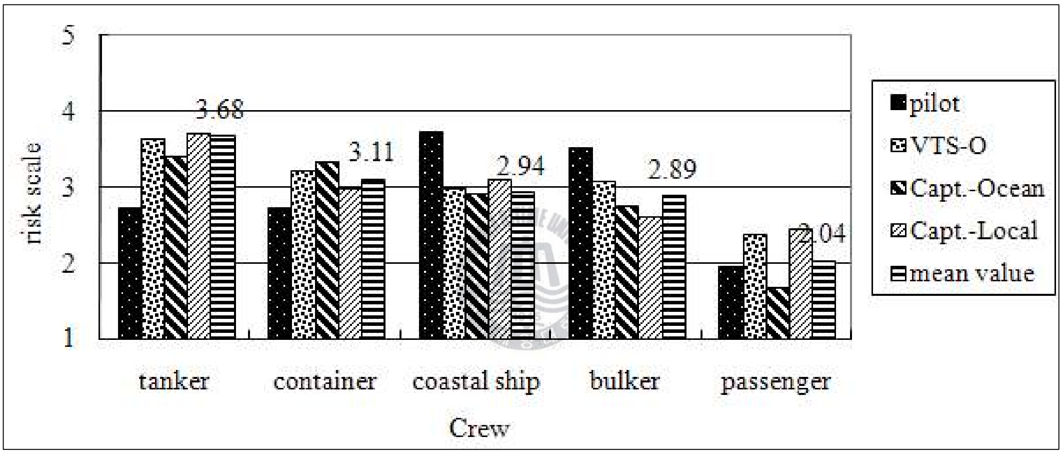


Figure 3.10 Risk evaluations among stakeholders with respect to crew

3.2.3.2 Risk evaluation with respect to ship length

Participants evaluated effect of ships length on safe navigation in the southern entrance of the Istanbul Strait. It is determined that 250 meters and over ship length is the most dangerous/ extremely dangerous ship length with a mean of 4.66 points on a Five Likert Scale (78.7% of participant agreed on the highest risk level) and also length between 200 meter and 249 meter is dangerous ship length/ extremely dangerous with a mean of 4.41 points on a Five Likert Scale (56.7% of participant agreed on the highest risk level and 29.1% of them gave high risk level) as shown in Figure 3.11. The results revealed that stakeholders have same risk perception (p > .05) regarding risk level of ships length which increase parallel to increase of ship length.

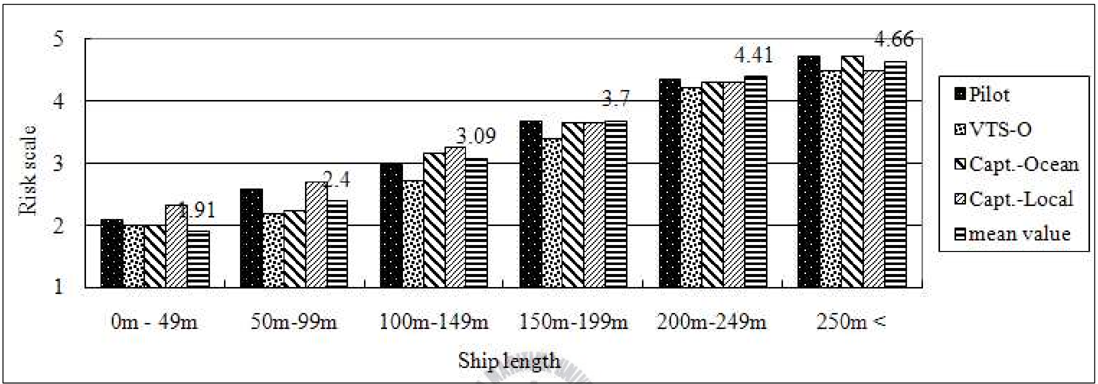


Figure 3.11 Risk evaluation among stakeholders with respect to ship length

3.2.3.3 Risk evaluation of pre-defined local traffic zone

In the previous section traffic flow was investigated in the southern entrance of the Istanbul Strait - the area of 7.5 miles lying between the line connecting Moda Burnu to Bakirkoy and Bogazici Bridge, 8 main origin-destinations (OD) were defined as main routes for the local traffic. Probability of collision and near miss were calculated/ simulated for each OD. Therefore, research area was divided into 3 sectors namely Sector A1, Sector A2 and Sector A3. In the summary, Sector A2 was determined as the most risky area due to high traffic volume, then Sector A1, although lowest traffic volume and potential encounters in Sector A1 due to being entrance and exit point of the Strait.

Participants evaluated risk of these sectors (A1, A2 and A3) by questionnaire survey. Sector A2 is determined as the most dangerous sector with a mean of 4.29 points on a Five Likert Scale (55.3% highest risk level), Sector A3 is the second with a mean of 3.27 points on a Five Likert Scale (19% highest risk level, 27% high risk level and 29.1% moderate risk level) and Sector A1 is less dangerous sector with a mean of 2.88 points on a Five Likert Scale (19% high risk level, 29.1% moderate risk level and 22.7% low risk level) as shown in Figure 3.12 and Table 3.9. It is assumed that stakeholders have common risk perception for pre-defined local traffic areas; risk perception weight of local traffic skipper is less than others and awareness of stakeholders regarding hidden risk in sector A1 could be improved.

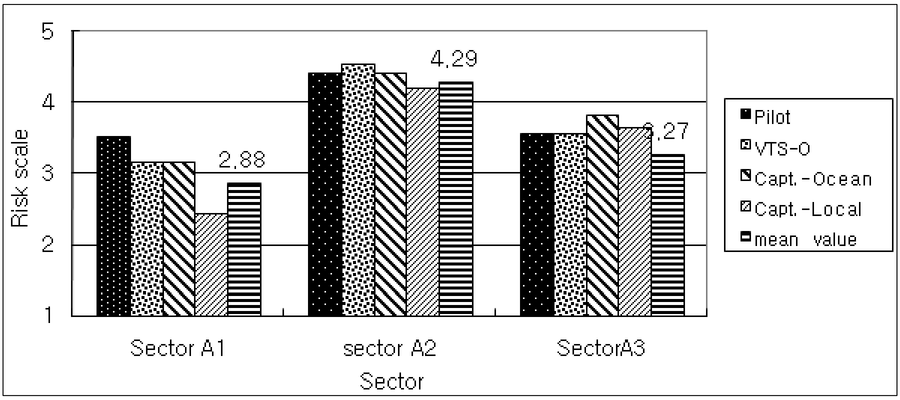


Figure 3.12 Risks evaluation result among stakeholders for pre-defined sectors

Table 3.9 Risk evaluation among stakeholders for pre-defined sectors

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
						Lower Bound	Upper Bound		
Sector A1	Pilot	19	3.53	1.073	0.246	3.01	4.04	2	5
	VTS-O	36	3.17	1.207	0.201	2.76	3.58	1	5
	Capt. O.	12	3.17	0.835	0.241	2.64	3.70	2	5
	Capt. L	18	2.44	1.199	0.283	1.85	3.04	1	5
	Others	55	2.55	1.303	0.176	2.19	2.90	1	5
	Total	140	2.88	1.249	0.106	2.67	3.09	1	5
Sector A2	Pilot	19	4.42	0.769	0.176	4.05	4.79	3	5
	VTS-O	36	4.56	0.652	0.109	4.33	4.78	3	5
	Capt. O.	12	4.42	0.669	0.193	3.99	4.843	3	5
	Capt. L	18	4.22	1.114	0.263	3.67	4.78	2	5
	Others	55	4.07	1.136	0.153	3.77	4.38	1	5
	Total	140	4.29	0.956	0.081	4.13	4.45	1	5
Sector A3	Pilot	19	3.58	0.961	0.221	3.12	4.04	2	5
	VTS-O	36	3.58	0.967	0.161	3.26	3.91	2	5
	Capt. O.	12	3.83	0.718	0.207	3.38	4.29	3	5
	Capt. L	18	3.67	1.029	0.243	3.15	4.18	1	5
	Others	55	2.71	1.536	0.207	2.29	3.12	1	5
	Total	140	3.27	1.285	0.109	3.06	3.49	1	5

3.2.3.4 Risk evaluation of crossing and encounter situations

Participants evaluated risk level of "local-local traffic vessel", 'local-transit vessel" and "transit-transit vessel" for crossing/ encounter situations. Transit-transit vessel crossing/ encounter situations were determined as the most risky/ highly dangerous situation in the research area with a mean of 3.80 points on a Five Likert Scale (34.8% of participant agreed on the highest risk level and 26.2% of them gave high risk level), then transit-local traffic with a mean of 3.40 points on a Five Likert Scale (19.9% of participant agreed on the highest risk level and 34.8% of them gave high risk level) and local-local traffic vessel with a mean of 3.80 points on a Five Likert Scale (10.6% of participant agreed on the highest risk level, 24.8% of them gave high risk level and 27.0% moderate risk level) as shown in Table 3.10 and Figure 3.13.

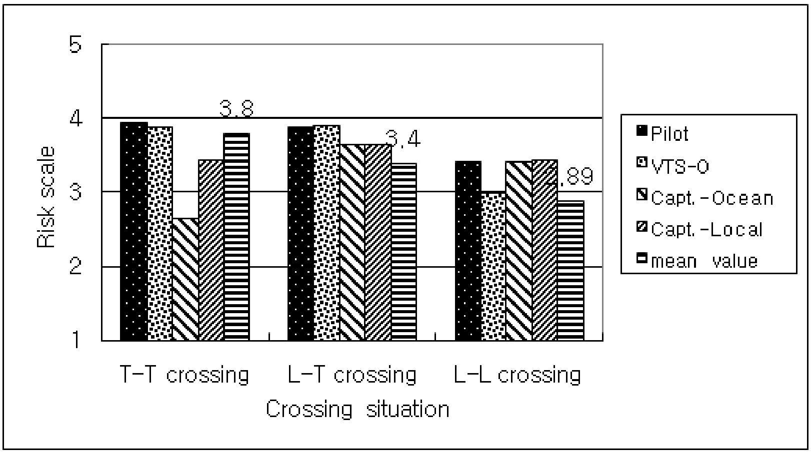


Figure 3.13 Risks evaluation results among stakeholders for encounter/crossing situations

Table 3.10 Risk evaluation among stakeholders for encounter/ crossing situations

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
						Lower Bound	Upper Bound		
Local Local	Pilot	19	3.42	0.902	0.207	2.99	3.86	2	5
	VTS-O	35	3.00	1.163	0.197	2.60	3.40	1	5
	Capt. O.	12	3.42	0.996	0.288	2.78	4.05	2	5
	Capt. L	18	3.44	1.199	0.283	2.85	4.04	1	5
	Others	55	2.35	1.391	0.188	1.97	2.72	1	5
	Total	139	2.89	1.295	0.110	2.67	3.11	1	5
Transit Local	Pilot	19	3.89	0.994	0.228	3.42	4.37	2	5
	VTS-O	36	3.92	0.937	0.156	3.60	4.23	1	5
	Capt. O.	12	3.67	0.778	0.225	3.17	4.16	2	5
	Capt. L	18	3.67	1.085	0.256	3.13	4.21	1	5
	Others	55	2.75	1.456	0.196	2.35	3.14	1	5
	Total	140	3.40	1.285	0.109	3.19	3.61	1	5
Transit Transit	Pilot	19	3.95	0.848	0.195	3.54	4.36	2	5
	VTS-O	36	3.89	0.887	0.148	3.59	4.19	2	5
	Capt. O.	12	2.67	0.778	0.225	2.17	3.16	2	4
	Capt. L	18	3.44	1.247	0.294	2.82	4.06	2	5
	Others	55	4.05	1.177	0.159	3.74	4.37	1	5
	Total	140	3.80	1.107	0.094	3.61	3.99	1	5

According to collision statistics of the Istanbul Harbor from 1991 to 2005, totally 203 collisions occurred and 107 of them were between transit-transit vessels, 54 of them were between local-transit vessels, 42 of them were between local-local traffic vessels which support the result of survey. Stakeholders have common approach in regard to crossing/ encounter situation and it is in compliance with collision statistics except one case which is that master mariners consider transit-transit vessel crossing/ encounter situation with moderate risk level. Hence, it is assumed that risk perception of stakeholders is similar, but situational awareness of master mariners regarding transit-transit vessel crossing/ encounter situations could be improved.

3.2.3.5 External factors

Participants evaluated the effect level of current, wind restricted visibility, local traffic and excursion boats, fishing vessel and yacht on navigation in the southern entrance of the Istanbul Strait. Restricted visibility is determined as extreme effective parameter with a mean of 4.33 points on a Five Likert Scale (65.2% of participant agreed on the extreme effective), and is followed by fishing vessel and yachts (mean 3.75 points, 34.8% of participant agreed on the extreme effective and 25.5% of them gave highly effective), current (mean 3.80 points, 24.8% of participant agreed on the extreme effective and 29.8% of them gave highly effective) and local traffic and excursion boats (mean 3.23

points, 15.6% of participant agreed on the extremely effective and 37.6% of them gave highly effective) as highly effective parameters on safe navigation. According to the result of survey, as shown in Figure 3.14, pilots gave more effect weights on external forces, but it would be concluded that stakeholders have same approach for the effect of external forces (all $p > .05$) depend on one-way ANOVA.

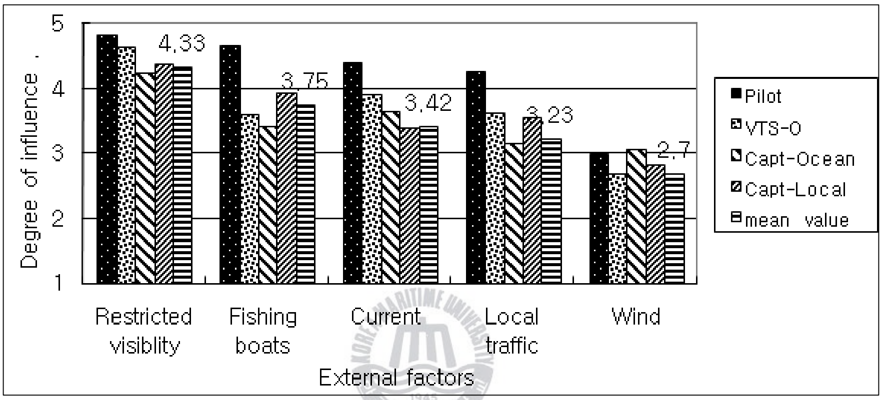


Figure 3.14 Effect evaluations of external factors among stakeholders

3.2.3.6 Potential counter measures

Participants evaluated the effectiveness of exist/ potential counter measures to reduce risks in the southern entrance of the Istanbul Strait. Continuity of one-way traffic, which is implemented since 2003 due to under water tunnel project, was determined as the most effective counter measure with a mean of 4.57 points on a Five Likert Scale (78% of participant agreed on the extremely effective). The others are; controlling of vessel crossing and meeting (mean 4.36 points, 60.3% of participant agreed on the extremely effective and 24.1% of them gave highly effective), VTS implementation (mean 4.23 points, 49.6% of participant agreed on the extremely effective and 33.3% of them gave highly effective), control of minimum speed (mean 3.65 points, 32.6% of participant agreed on the extremely effective and 25.5% highly effective), control of maximum speed (mean 3.46 points, 28.4% of participant agreed on the extremely effective and 21.3% of them gave highly effective), a new TSS implementation by considering current local and transit traffic conditions (mean 3.27 points , 20.6% of participant agreed on the extremely effective and 31.9% of them gave highly effective), Local Traffic Control Centre (LTCC) implementation (mean 3.09 points, 21.3% of participant agreed on the extremely effective and 21.3% of them gave highly effective) as shown in Figure 3.15.

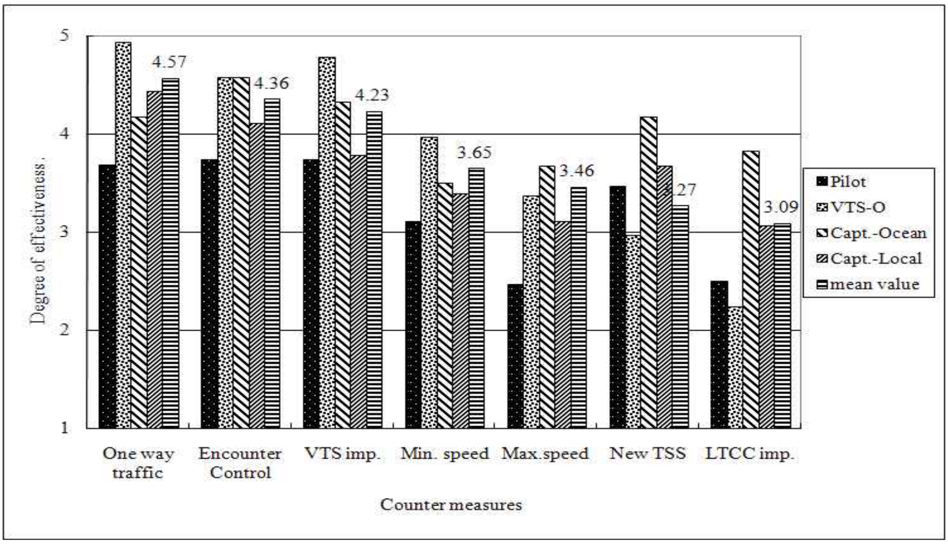


Figure 3.15 Effectiveness evaluation of counter measures among stakeholders

Stakeholders have given different effectiveness weights for the counter measure to reduce risks in the southern entrance of Istanbul Strait, but variances of weights are determined non-significant ($p > .05$) except control of maximum speed and controlling of vessel crossing and meeting ($p < .05$). Hence, it is assumed that stakeholders have common approach regarding risk perception, despite of different risk perception weights.

Table 3.11 Result of Levene's test for countermeasure

	Levene's Statistic	df1	df2	Sig.
VTS Implementation	4.576	4	136	0.002
LTCC Implementation	3.012	4	131	0.020
New TSS	3.237	4	134	0.014
Control of max. speed	1.488	4	135	0.209
Control of min. speed	3.317	4	134	0.013
Control of crossing/meeting	2.297	4	136	0.062
one-way traffic	15.133	4	136	0.000

3.3 Analysis of Environmental Stress (ES) by Real Time Traffic Simulation

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

3.3.1 Design of Simulation Scenarios

In order to perform risk analysis in 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 12:00 as off peak time and 18:00 as peak time, on the basis of actual traffic data (Figure 2.9). The simulations are run on the ship handling simulator with the supervision of experienced captains and the results are analysed using Environmental Stress Model.

The number of local vessels, their types, voyage durations and voyage frequencies are determined on the basis of actual timetable data. In order to design detailed routes of the local traffic vessels, the study of Yurtoren (2004) is used as given in Figure 3.2 (Aydogdu, 2006). 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 (2004) study. After preparation of scenarios, simulations are run by actual ocean going officers and masters who have pass through the research area. The scenarios are run 19 times for peak and 19 times for off peak times and the navigational data are stored automatically by the ship handling simulator. The stored data are than analysed to calculate ES values which represents quantitative amount of navigational difficulty in the research area. The results of the stress assessment analysis is then converted to graphical presentation to demonstrate the places where the stress level reach to maximum. The graphs given in Figure 3.16 and Figure 3.17 demonstrate the quantitative value of stress (ES value) with respect to distance traveled by the vessel, for peak time and off peak time simulations separately. In this study, stress level vs. distance graphic is preferred rather than stress vs. time graphic, since the time of travel can vary in each simulation depending on the route, speed etc. preferences of the navigating officer.

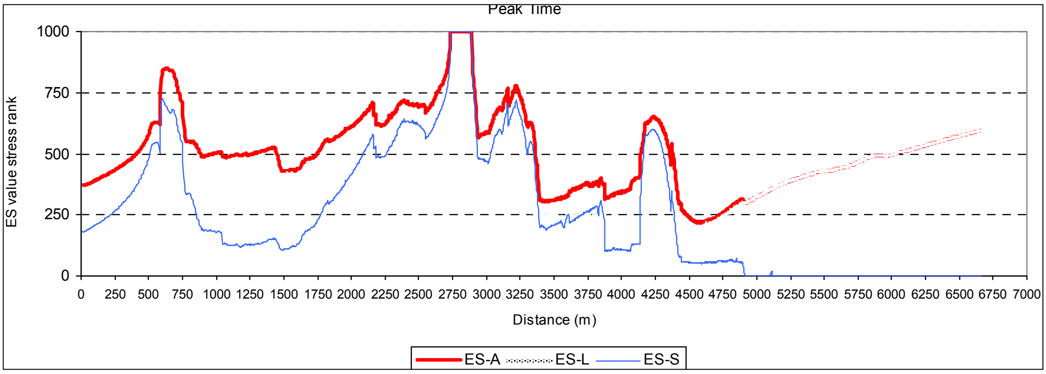


Figure 3.16 Distance-ES value analysis; peak time

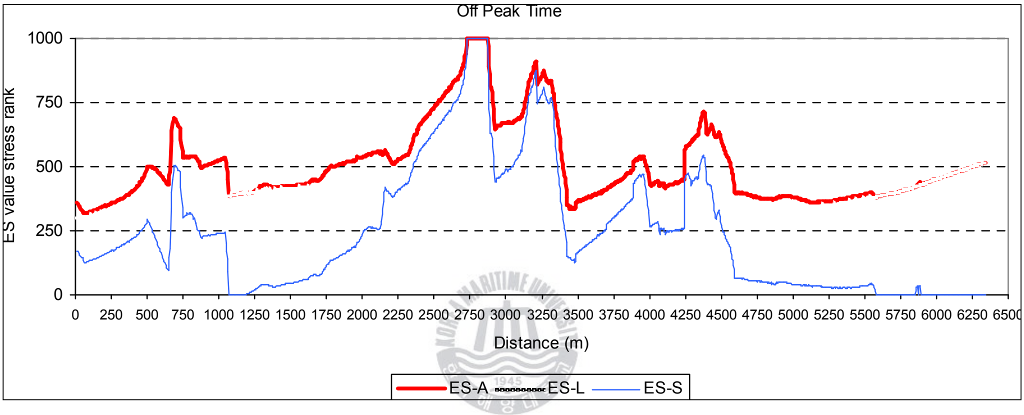


Figure 3.17 Distance-ES value analysis; off peak time

On the basis of stress level vs. distance data, the individual stress level at every single location along the vessel path can be determined. For more detailed results, total voyage distance are divided into 500-meter-long sections, and average stress level in each section are calculated as given in Figure 3.18 and Figure 3.19. It can be easily recognized that the stress level is maximum between 2,500 and 3,500 meters from south to north of the vessel path for both peak and off peak time simulations. Finally in order to seize average stress level of the research area both in peak and off peak times, average stress levels have been prepared.

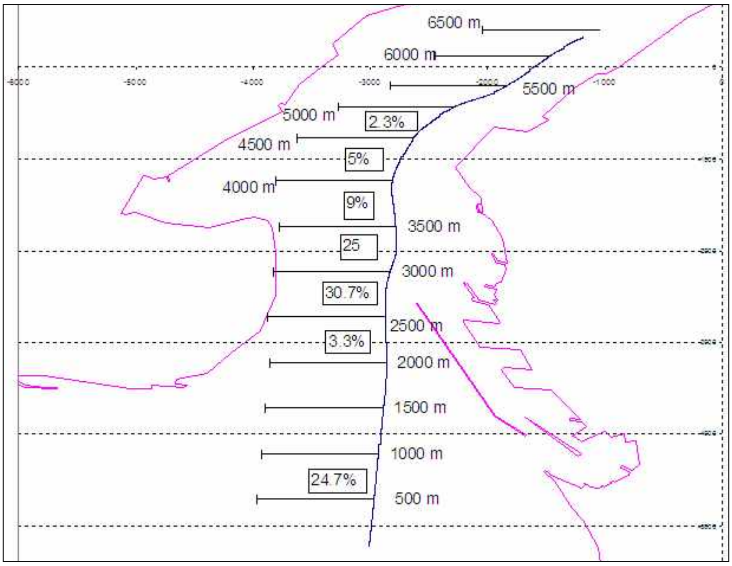


Figure 3.18 Individual risk values of the vessel path at peak time

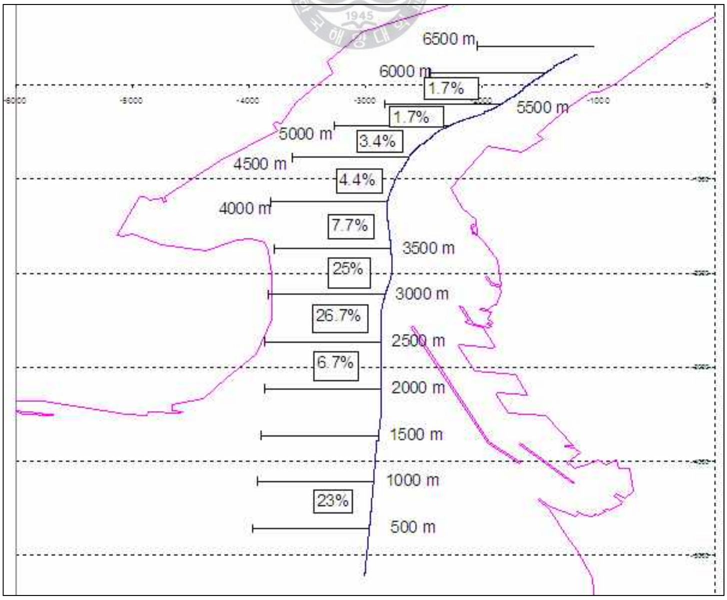


Figure 3.19 Individual risk values of the vessel path at off peak times

3.3.2 Methodology

3.3.2.1 Models for assessment of waterways safety

IALA (International Association of Marine Adis to Navigation and Lighthouse Authorities) recommend two models for assessment of waterways safety. One of which is called PAWSA (Ports and Waterways Safety Assessment model), developed by the United States Coast Guard, carries out a qualitative Risk Assessment. The other is called IWRAP (IALA Waterway Risk Assessment Program), developed by the Canadian Coast Guard in conjunction with the Technical University of Denmark and the Maritime Simulator Centre Warnemünde, carries out a quantitative Risk Assessment. The two models can be used individually, sequentially or in parallel. However, in this research Environmental Stress Model (ES Model) is used. Below merit and demerits of this three models are listed. (IALA, 2008)

◆ *Ports and Waterways Safety Assessment (PAWSA) Model*

A Risk-Based Tool for Waterway Management Decisions

The PAWSA is a systematic process that builds on the results of expert evaluation. It is a structured approach for obtaining expert judgments on the level of waterway risk. The process also addresses the effectiveness of possible intervention actions for reducing risk in the waterway. A select group of waterway users / stakeholders evaluate risk factors and the effectiveness of various intervention actions.

Table 3.12 Merit and Demerits of PAWSA Model

Merit	○ A workshop study ○ Rather than risk analysis such as guidance for a report ○ Usage of stake holder opinion ○ Could be useful for evaluation of risk control measures
Demerit	○ Wide attendance is required ○ Results are relatively can change upon to participants ○ Not sufficient to determine risk control measures

◆ *The IALA Waterway risk Assessment program (IWRAP) Model*

The IWRAP model has been developed to provide a standardized method of assess the risk within a waterway. The output from IWRAP can be used to assess the risk in each section of a waterway and in turn determine degree of risk to navigation throughout the entire waterway. IWRAP compromises of a computer programmer that uses statistical data relating to vessels, navigational methods and channel conditions to produce results relating to collisions and grounding.

Table 3.13 Merit and Demerits of IWRAP Model

Merit	○ Useful for cost benefit analysis by calculation meeting of vessel/year, probability of collision and grounding per 10,000 direct passing ○ Dividing to water way into parts to determine the risky areas
Demerit	○ Data entering to program is not sufficient to describe risks in Istanbul Strait. ○ Calculates under keel clearance for grounding but does not consider potential malfunctions on ships which occurs frequently during passage of ships through the Istanbul Strait

◆ *Environmental Stress (ES) Model*

ES model is a quantitative model for evaluating the difficulty of shiphandling arising from restrictions in manoevring water areas and arising from traffic congestion (Inoue, 2000). In the model stress values are introduced as difficulty indices and these values are calculated on the basis of residual time until a danger becomes a reality. This model also clarifies the acceptance criteria of the stress value based on a mariners; perception of safety.

Table 3.14 Merit and Demerits of IWRAP Model

Merit	○ Good to determine risky areas in terms of stress in a water way ○ Marine Traffic Fast Time Simulation and Latent ES is convenient to find how to arrange TSS ○ Simulator experiments and results are convenient to apply ○ Good for assessment of Risk Control Measure (i.e. new designed of TSS)
Demerit	○ Not accepted widely ○ Coefficient numbers derived from only Japanese Captains & Pilots

Feature of ES Model is more fitting with the objective of this study. Hence, ES Model is chosen for this study. Nevertheless, in the future studies, PAWSA and/or IWRAP models are envisioned to be utilized in order to assess effectiveness of outcomes.

3.3.2.2 Environmental evaluation based on maneuvering difficulty assessment

There is no restriction in ocean in terms of the water area available for maneuvering and if there is sufficient Time to

Collision (TTC), regardless of the direction in which the ship proceed, mariner feels no stress and difficulty in ship-handling. In restricted waterways, the water area available for maneuvering and TTC regardless of the ship's direction is limited. Thus the topographical environment causes the mariner considerable stress and creates difficulty in ship-handling. Based on this idea topographical Environment Stress was defined as difficulty imposed on navigator for ship handling due to surrounding environment. When other ships are present in the vicinity, and there is a danger of collision with other ships according to the direction of sailing, the navigator feels additional stress. The stress becomes particularly great when there is limited TTC, regardless of the direction of the ship. Hence, marine traffic environment stress is defined as ship handling difficulty imposed on navigator due to surrounding marine traffic environment.

Level of burden imposed on navigator due to surrounding marine traffic environment would be quantitatively measure and influence of different characteristic environment could be expressed systematically which is required to determine level of tolerance for countermeasures. Environmental Stress Model- ES model has been developed in order to satisfy this requirement which would quantitatively express ship handling difficulty feeling of a navigator due to ship handling restricting environmental condition such as natural condition, topographical condition, equipment condition and traffic condition.

Environment Stress Value defined as difficulty imposed on navigator until being clear of a concealed environmental condition during execution of ship operation. More specifically, Land of ES value- ES_L defined as ship handling difficulty imposed on mariner due to topographical marine environment and Ship of ES value- ES_S defined as ship handling difficulty imposed on mariner due to marine traffic environment. ES_L and ES_S combined as Aggregation of ES value- ES_A.

3.3.2.3 Calculation of environment stress value

Navigation freedom of a navigator limited by surrounding marine environment due to topographical condition such as breakwater, land, shoals etc and quantitative marine environment stress value express burden of a navigator due to ship handling difficulty.

On the other hand, in relation between navigator and marine traffic environment, other vessels navigating in the surrounding area restrict navigator freedom. Burden on mariner depends on level of restriction of surrounding vessels during collision avoidance maneuvering which is quantitatively expressed as environment stress value.

Environment stress values are calculated as below;

① Current course of ship considered as center and investigate hazard in range of ±90 degree from center

② Calculate TTC (R/V) on each degree graduation Δψ- divide Distance (R) to hazard by current ship speed

③ Calculated navigator ship handling difficulty based on TTC (R/V)

④ Calculate total ship handling difficulty by sum each calculated value

Traffic environment stress values and topographical environment stress values are calculated based on time to collision parameters (time until being clear of hidden danger during navigation in a given environment). These values enable to express ship handling difficulty felling of a navigator due to surrounding topographical environment and marine traffic in numeric index. Thus, it would be possible to express how navigator overcomes difficulty by maneuvering.

Stress values obtained for each degree from current ship course and represented by

$$SJL = f(R/V) \quad \text{(eq. 7)}$$

and

$$SJS = f(R/V) \quad \text{(eq. 8)}$$

Here SJL is subjective judgment of navigator in relation to TTC (time to collision) with obstacles and SJS is the subjective judgment of mariner in relation to TTC with ships, R is distance to obstacle or other ship and V is own ship speed. Coefficient number which is obtained by ship handling simulator and questionnaire used to calculate SJS and SJL stress values. The scales of subjective judgment 0~1,000 consist of numeric values with seven steps from 0 (extremely safe) to 6 (extremely dangerous).

3.3.2.4 Calculation method of environment stress value

Below given steps are followed to calculate concrete Environment Stress Value

Step 1- Consider the ship's course in the range of 180°

Step 2- Calculate the TTC (R/V) for each one degree graduation in the range of 90° centered on the present course.

Step 3- Convert the TTC into the mariner's perception of safety for each one degree.

The below given conversion formula is a regression equations found through ship-handling simulator experiments (31-subjects) and a questionnaire survey (573-answers).

$$SJL = \alpha \times TTC + \beta \qquad \text{(eq. 9)}$$

$$SJL = \alpha \times (R/V) + \beta \qquad \text{(eq. 10)}$$

where;

$\alpha = -0.00092 \times \log 10(GT) + 0.0099$ if GT≤ 10,000

$\alpha = -0.006671 \times \exp\{-7 \times 10 - 6(GT)\}$ if GT≥ 10,000

$\beta = -3.82$

SJL: Ship handling difficulty navigator feels till being clear of danger

R: distance to danger (m)

V: speed of ship (m/s)

GT: Gross Tonnage

α, β: Coefficient number

Relation between navigator feeling and SJL value as below;

+3: Extremely Safe

+2: Fairly safe

+1: Somewhat safe

0: Neither safe nor dangerous

- 1: Somewhat dangerous

- 2: Fairly dangerous

- 3: Extremely dangerous

Danger feeling for same subject would change upon relative bearing of subject. According this fact cosine function used from front to 110 degree starboard and port directions in or order bearing weight value correction which used for hidden danger bearings. If there is no danger in any direction, the SJ value of 0 extends over 180°, so 0x180=0 is assigned as the minimum stress value. If there is immediate danger, regardless of the ship's direction, the SJ value of 6 extends over 180°, so 6x180≈ 1,000 is assigned as the maximum stress value. The stress ranking is set up by classifying the range of stress values as 0 to 1,000 as shown in Table 3.15. The rank of stress can be classified according to the extent to which a dangerous situation causes a particular level of SJ value in the range of 90° around the present ship's course.

Table 3.15 Classification of subjective judgment, ES value and final decision

Mariner's subjective judgment	Es value Stress rank	Decision	
0 Extremely safe	0	Negligible	Acceptable
1 Fairly safe		Negligible	Acceptable
2 Somewhat safe		Negligible	Acceptable
3 Neither safe/dangerous	500	Marginal	Acceptable
4 Somewhat dangerous	750	Critical	Unacceptable
5 Fairly dangerous	900	Catastrophic	Unacceptable
6 Extremely dangerous	1000	Catastrophic	Unacceptable

If SJ value less than 500, it is negligible used means there is not any restriction or sufficient time to be clear of danger and acceptable ship handling difficulty feeling on mariner. If SJ value in between 500~750, it is marginal means there is certain restriction and still acceptable ship handling difficulty feeling on mariner. If SJ value in between 750~900, it is critical means there is restriction, insufficient time to be clear of danger, ship handling is difficult and unacceptable ship handling difficulty feeling on mariner. If SJ value in between 900~1,000, it is catastrophic means there is no time to be clear of danger or very limited time, a collision or grounding imminent and unacceptable ship handling difficulty feeling on mariner.

3.3.2.5 Calculation method of traffic environment stress values

Below given steps are followed to calculate concrete Traffic environment stress value

Step1- Set up domain area. Domain area is oval zone area around own ship and other ships are not supposed to incur. It is used for calculation of near miss situations.

Step2- Consider the ship's course in the range of 180°

Step3- Calculate the TTC (R/V) for each one degree graduation in the range of 90° centered on the present course. Here target ships are considered as a dot and calculated TTC to domain area. (very similar working principle with RADAR)

Step4- Convert the TTC into the mariner's perception of safety for each one degree.

The below given conversion formula is a regression equations found through a questionnaire (573-answers) survey.

$$SJS = \alpha \times (TTC \times V / Lm) + \beta \qquad \text{(eq. 11)}$$

$$SJS = \alpha \times (R / Lm) + \beta \qquad \text{(eq. 12)}$$

$$SJS = \alpha \times (R') + \beta \qquad \text{(eq. 13)}$$

$$\alpha = 0.00192 \times Lm$$

In case contact with target ship

crossing from starboard side: $\beta = -0.65 \times \log(Lm) - 2.07$

crossing from port side: $\beta = -0.65 \times \log(Lm) - 2.35$

head-on situation: $\beta = -0.65 \times \log(Lm) - 2.07$

overtaking situation: $\beta = -0.65 \times \log(Lm) - 0.85$

where;

SJS: feeling ship handling difficulty level due to distance to target ship

R: distance between own ship and target ship

V: relative speed between own ship and target ship

Lm: average ship length of own ship and target ship

R': distance between own ship and target ship based on Lm-average ship length

α,β: coefficient number based on simulator experiments and questionnaire surveys

Relation between navigator feeling and SJS value as below;

+3: Extremely Safe

+2: Fairly safe

+1: Somewhat safe

0: Neither safe nor dangerous

- 1: Somewhat dangerous

- 2: Fairly dangerous

- 3: Extremely dangerous

If there is no danger in any direction, the SJS value of 0 extends over 180°, so 0 x 180=0 is assigned as the minimum stress value. If there is immediate danger, regardless of the ship's direction, the SJ value of 6 extends over 180°, so 6 x 180≈ 1,000 is assigned as the maximum stress value. The stress ranking is set up by classifying the range of stress values as 0 to 1,000 as shown in Table 3.15. The rank of stress can be classified according to the extent to which a dangerous situation causes a particular level of SJS value in the range of 90° around the present ship's course. SJS values classified as acceptable value (negligible and marginal) and unacceptable value (critical and catastrophic).

3.3.2.6 Calculation of aggregated environment stress value

In the case of evaluation of Traffic environment stress and Environment Stress at the same time, aggregated environment stress value calculated as below;

Step1- Compare ship handling difficulty due to land obstruct on the navigating direction and surrounding target ships in each one degree gradation in the range of ±90 centered on the present.

Step2- Calculate biggest difficulty value based on TTC for each one degree graduation

Step3- Aggregate calculated stress values for each one degree gradation in the range of ±90 centered on the present

Aggregated stress value is executed environmental stress value calculated as below formula

$$ES\_L = \sum_{\psi} \{W_{\psi} (R/V)_{land} \longrightarrow SJL\} \qquad \text{(eq. 13)}$$

$$ES\_S = \sum_{\psi} W_{\psi} (R/V)_{ship(i)} \longrightarrow \max[SJS_i]\} \qquad \text{(eq. 14)}$$

$$ES\_A = \sum_{\psi} \max\{SJL, SJS\} \qquad \text{(eq. 15)}$$

3.3.2.7 ES Calculation analysis in Istanbul Strait

The average ship length and its standard deviation were obtained from Istanbul Harbor Master. The size of a ship is generated according to normal distribution and in the ±2σ range where σ is standard deviation of ships' length for intended statistics. Table 3.16 shows ships particular used in simulation which is prepared based on statistics from 1996 to 2003 of each type of ship passing through the Strait (Category-1) and ships particular used for local traffic in the Strait (Category-2). The classification of Category 1 vessels are based on three groups: Small size ships-SSS (20-999 Gross Tonnage), middle size ships – MSS (1,000-9,999 Gross tonnage) and big size ships-BSS (10,000 Gross tonnage and over). Category 2 vessels are also classified as small crossing ship (SCS), middle crossing ship (MCS) and big crossing ship (BCS).

Table 3.16 Ships particular for simulation

Transit Ships				Local Traffic Ships			
	Average LOA(m)	Standard Deviation	Perc. (%)		Average LOA(m)	Standard Deviation	Perc. (%)
Small Size Ship (20~999 GT)	69	10	9.1	Small Size Ship (23-30 m)	21.5	5	67.4
Middle Size Ship (1000~9999 GT)	119	25	67.4	Middle Size Ship (30-67)	35	10	23.2
Big Size Ship (Over 10000 GT)	220	50	23.5	Big Size Ship (over 67 m)	70	15	9.5

According to marine traffic data, total numbers of ships generated in both ways southbound and northbound are 6.2 ships per hour. The time interval for ships generated is decided using an exponential function. The shortest time interval is set up as 10 minutes. The time interval for ferries crossing the Strait is decided by examining the timetables of ferries during rush hours in each period. As shown in Table 3.17, the speeds of ships generated is set up according expert opinion obtained during questionnaire survey and study of Yurtoren (2004). Speeds vary between northbound and southbound under the influence of currents. The speeds of large ferries were set up for each ship in service ranging 9~12 knots by consulting experts opinion and local traffic timetables.

Table 3.17 Ships speed distribution for simulation

	Average Speed (knt)		STDEV
	Northbound	Southbound	
Transit Ships	10	12	1
Small Size Crossing Ships	9.5		1
Middle Size Crossing Ships	15		4
Big Size Crossing Ships	11		2

Generating points of ships are considered to be distributed normally on a gate line to the designed standard route, and ships are designed to navigate along the standard route. By calculating the standard deviation (σ) of the distribution as functions of the width of the waterway and the volume of traffic, generating points were then regarded to be distributed normally on the gate line ranging ±2σ, based on Inoue (1977)'s track distribution model. However, when the traffic separation schemes are considered, the generating points are distributed normally on the width of the designed passage range.

3.3.3 Results and Discussion

Results indicate what the average stress level due to shiphandling difficulty imposed by local traffic is for a transit vessel while passing through the southern entrance area of the Istanbul Strait. The results imply that the stresses exposed on mariner by the local ships (ES_S) are much higher than the stress exposed on mariner by the topographic objects (ES_L) as given in Figure 3.20 and Figure 3.21.

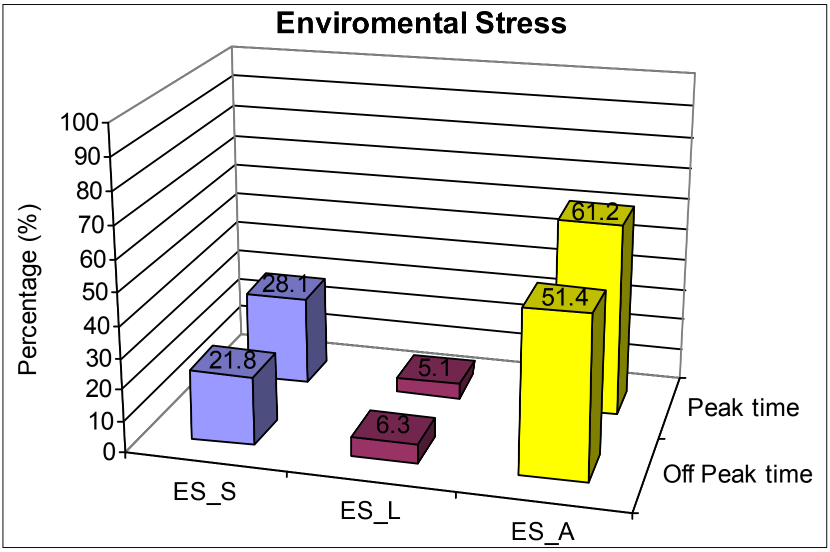


Figure 3.20 Comparison of simulator experiment results, total stress

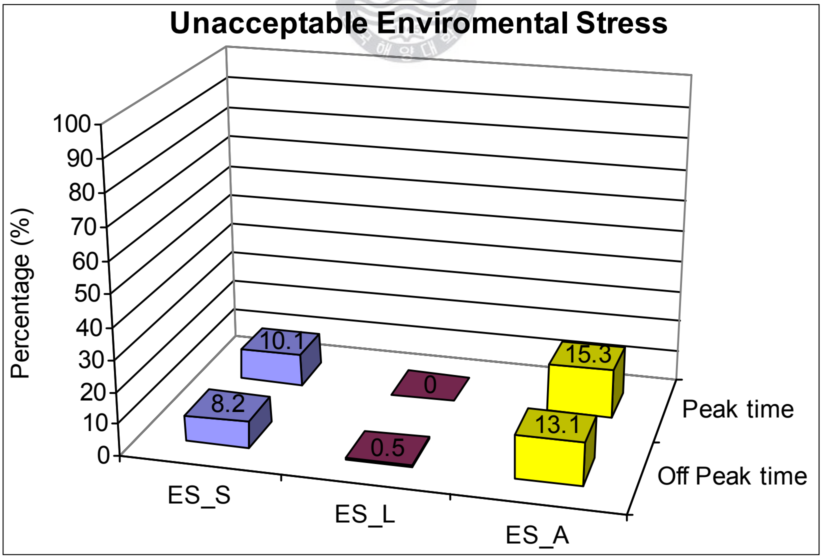


Figure 3.21 Comparison of simulator experiment results, unacceptable risks

On the basis of the results, most risky area for maritime traffic in the southern entrance of Istanbul Strait is between 2,500 and 3,500 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, it can be realized that this area has extremely dense local traffic, since approximately 73 vessels running in this area during peak times.

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 indicate that there is strong need for improvement of navigation safety.

Chapter 4 Investigation of Potential Countermeasures to Improve the Marine Traffic Safety Situation

4.1 Background

Safety is a human perceived quality that determines to what extent the management, engineering and operation of a system is free of danger to life, property and the environment (Chengi, 2007). Ultimate aim of this study is improvement of navigation safety in the research area. In the previous chapter, dangers in the research area are presented by collision probability, expert survey and real time ship handling simulator studies and outcomes of those studies show necessity of risk reduction. Risk reduction term used to describe the moving of a hazard from one location higher on the risk scale to a lower location (Chengi, 2007).

In this chapter, current marine traffic situations during peak and off-peak times are simulated and analysed by Latent ES Model. Afterwards, change of marine traffic parameters such as vessel size, traffic flow, traffic direction are investigated and various traffic separation schemes for local marine traffic (LTSS) are proposed in order to lower scaled stress due to ship handling difficulty in the research area.

4.2 Methodology: Latent-ES

A range of traffic management measures are implemented in difficult waterways such as port and narrow channels. Vessel traffic safety management means the implementation, of concrete measures to improve traffic safety in ports and waterways with the consent of the relevant people. It is also important to being able to assess risk level in a waterway for improvements of navigational safety. By the environmental stress model it is aimed to satisfy risk assessment demand and risk assessment index. It is important for vessel traffic safety to measure how ship operation system influenced which consist of ship-navigator-environment relation. ES model can numerically demonstrate the current safety level and/or quantitatively calculate the relationship between the measures to be taken and the improvement of safety and the reduction of ship handling difficulties imposed on mariners.

In order to investigate vessel traffic safety, it is needed to measure how much difficulty imposes on navigator due to surrounding marine environment. Since the present paper applies marine traffic fast time simulation, Latent ES concept (L-ES value) (Inoue, 1999) is used. L-ES was introduced to exclude influence of the individual skill differences and navigator personality and guarantee the universality of the results in evaluating shiphandling difficulty. L-ES values are obtained by calculating the stress value, assuming that own ship sails at a fixed speed along a fixed route without making any collision avoidance actions against encountering ships. This is intended to avoid concealing information on stress levels that each encounter would naturally impose on the mariner by taking collision avoidance actions against other ships. The extent of such latent environmental stress is considered to indicate the necessity for collision avoidance maneuvers.

ES value is an index between 0 and 1,000, and it is classified on four major rankings which are Negligible, Marginal, Critical and Catastrophic levels. Table 3.15 indicates levels of subjective judgment and their corresponding ES value. Rankings of stress value and final decision for acceptance are also presented. The empirical works of the present study were accomplished on three steps (Figure 4.1). Marine traffic fast time simulations are performed under the predefined conditions such as different marine traffic parameters such as increase number of transit ship, different transit ship length, and one-way traffic. L-ES value is calculated for two main components: terrestrial objects as land (L-ES_L) and navigating objects as ships (L-ES_S). An aggregated result of all components is also defined as L-ES_A value.

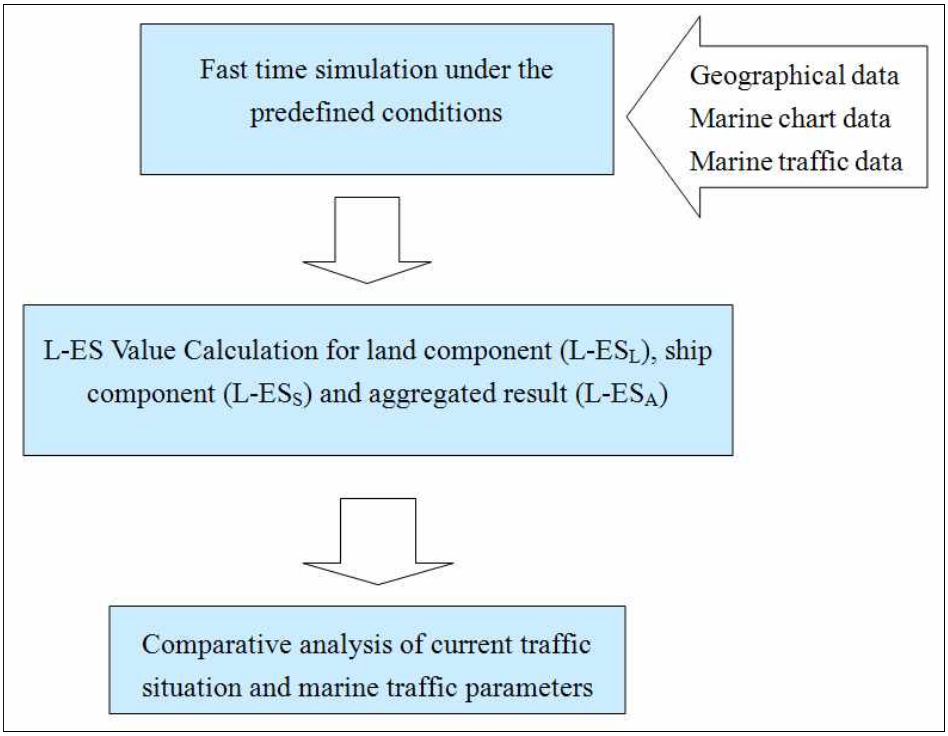


Figure 4.1 The design of comparative analysis the Istanbul Strait

The generation of traffic flow in the Istanbul Strait was carried out based on the data of AIS class A/B which are obtained from Undersecretaries of Maritime Affairs. Two days data from 24th and 25th of July, 2009 are analysed and ships tracks are demonstrated on Google Earth program as seen in Figure 4.2. Since 1st July of 2008, it is mandatory to use AIS Class B device for local marine traffic vessel in Turkey which allows analyzing and presenting actual ship tracks in the research area. The average ship length and the size of a ship are generated according to Table 3.16 and Table 3.17.

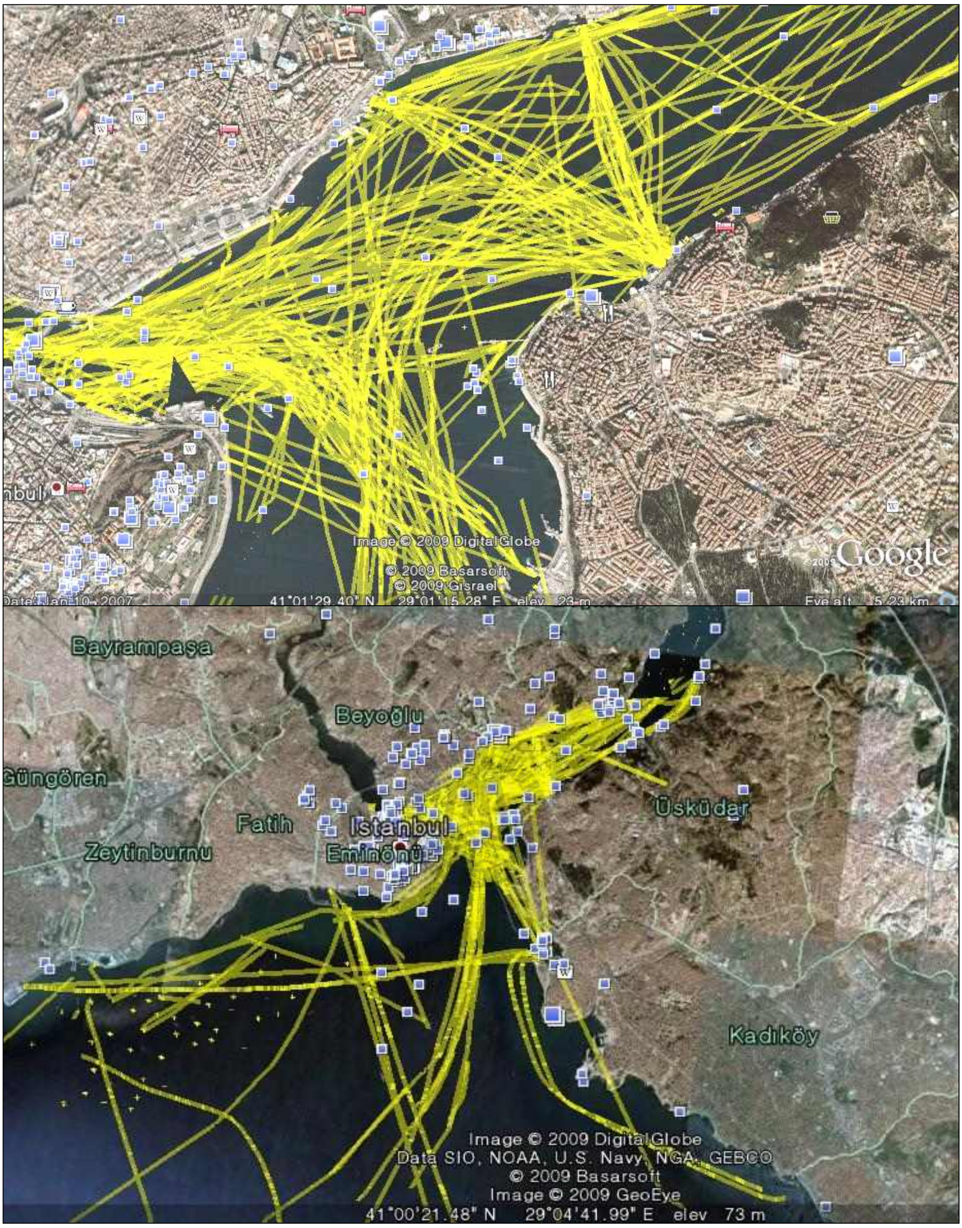


Figure 4.2 Ship tracks for southern entrance obtained by AIS data

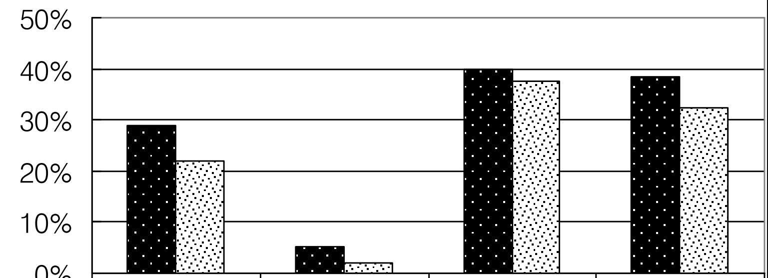
The time interval for ships generated iss decided using an exponential function. The shortest time interval is set up as 10 minutes. The time interval for ferries crossing the Strait is decided by examining the timetables of local traffic vessels.

Generating points of ships are considered to be distributed normally on a gate line orthogonal to the designed standard route, and ships are designed to navigate along the standard route as it is indicated in previous empirical work.

Unscheduled vessels such as fishing boats and recreation boats are neglected. Besides, times of departure of some lines which have random schedules are assumed by uniform distribution.

4.3 State of Present Marine Traffic in the Research Area

L-ES assessment results show that research area is highly dangerous waterway. Result of marine traffic fast time simulation for current traffic situations, indicates that 28.8% of marine traffic create unacceptable stress during peak times and 22.0% during off-peak time in the research area (Figure 4.3).



	Total Area	Sector A1	Sector A2	Sector A3
peak time	29%	5%	40%	38%
off peak time	22%	2%	38%	32%

Figure 4.3 L-ES_A unacceptable stress percentages for peak and off-peak time

Results also show that Sector A2 is most dangerous sector with

39.8% unacceptable stress during peak time and 37.6% during off-peak time. Due to high encounter situations in Sector A2, occurrence of unacceptable stress level does not decrease significantly during off peak time. Although stress level decrease significantly in other sectors and in total area. This result implies that decrease of traffic density not lead to decrease of stress level in the defined area. It also implies necessity of alternative solutions in sector A2. Sector A2 is followed by sector A3 with 38.3% unacceptable stress during peak time and 32.5% during off-peak time and by sector A1 with 5.2% unacceptable stress during peak time and 2.1% during off-peak time. When results are scrutinized, it is observed that stresses are mainly caused by L-ES_S marine traffic in the research area, percentage of unacceptable stress are so high in Sector A2 and A3 but reasonable in Sector A1 (Figure 4.4).

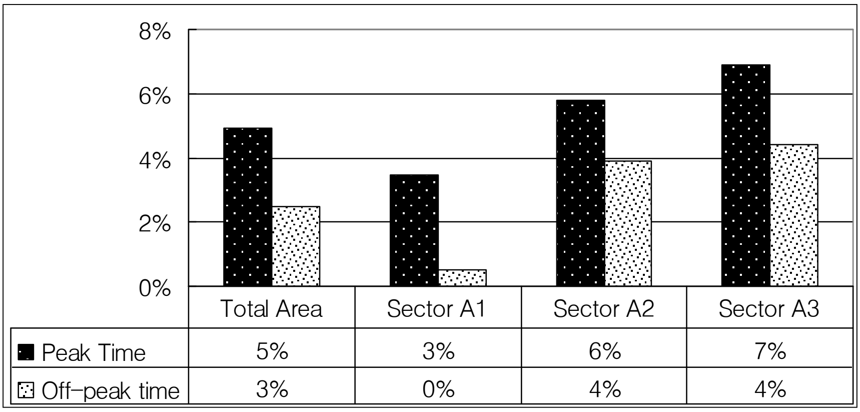
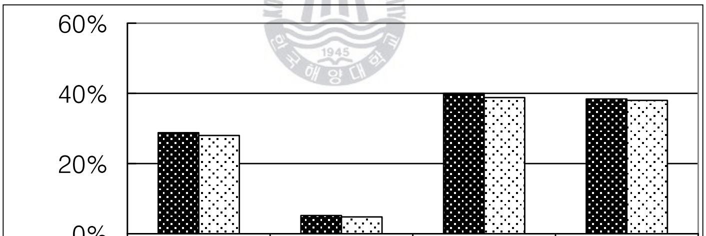


Figure 4.4 L-ES_S unacceptable stress percentages for peak and off-peak time

4.4 Recommended Local Marine Traffic Routes

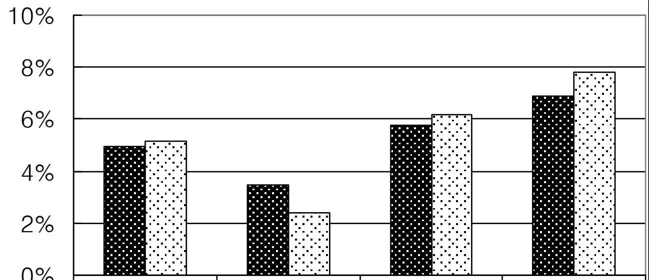
Istanbul Harbor Master Local Traffic Guideline which is put in force in 2007 by T.C. Prime Ministry Undersecretariat for Maritime Affairs is aimed to improve maritime safety in the jurisdiction of Istanbul Harbor Master and gives recommended routes for local marine traffic vessels. Marine traffic situation as per recommended routes by guide line (RLMTR) is simulated and compared with present peak time traffic condition (PPTC). L-ES_A result of PPTC indicates that 28.8% of marine traffic creates unacceptable stress and L-ES_A result of RLMTR indicates that 28.1% marine traffic crates unacceptable stress in the research area (Figure 4.5).



	Total Area	Sector A1	Sector A2	Sector A3
PPTC	28.8%	5.2%	39.8%	38.3%
RLMTR	28.1%	4.9%	38.6%	38.0%

Figure 4.5 L-ES_A unacceptable stress percentages for PPTC and RLMTR

L-ES_A results show that RLMTR help to reduce scaled stress in the total research area despite traffic related stress (L-ES_S) increases (Figure 4.6).

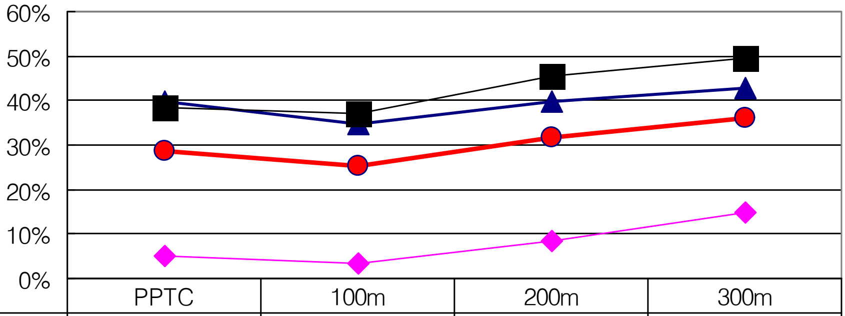


	Total Area	Sector A1	Sector A2	Sector A3
PPTC	4.9%	3.5%	5.8%	6.9%
RLMTR	5.2%	2.4%	6.2%	7.8%

Figure 4.6 L-ES_S unacceptable stress percentages for PPTC and RLMTR

4.5 Change of Vessel Size

Vessel size has direct effect on ship handling difficulty in a waterway. During simulation studies, transit vessel data from 2003 to 2009 which was obtained from Istanbul Harbor Master is utilized. Distribution of ships lengths are analysed and used in traffic data accordingly. In order to find out effect of ship length change, simulation studies carried out in the research area. Marine traffic situations in case transit ship length only 100 meter, 200 meter and 300 meter are investigated and result are compared with PPTC as given in Figure 4.7. Results show that when the transit ship length increase, level of stress also increase in parallel as expected. Especially in Sector A2 and A3, in case of only 300 meter length ship transit passage stress level increase enormously (Figure 4.7). Results of marine traffic fast time simulation are in compliance with result of expert survey regarding effect of ship length/size on safe navigation.



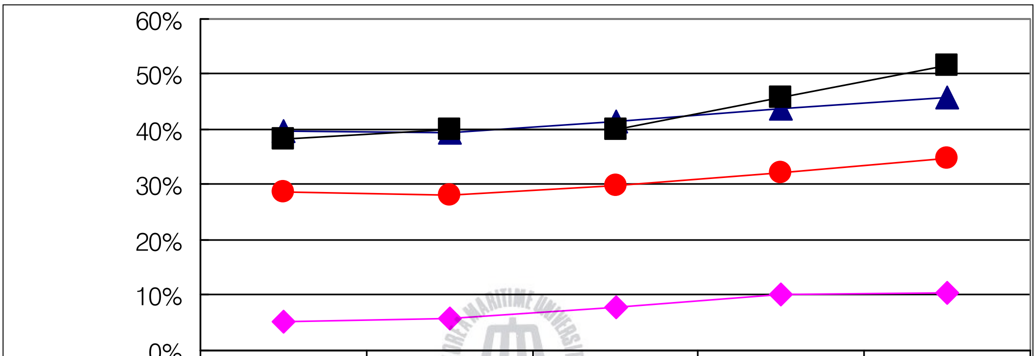
	PPTC	100m	200m	300m
Total Area	28.8%	25.3%	31.6%	36.0%
Sector A1	5.2%	3.4%	8.6%	14.7%
Sector A2	39.8%	34.7%	39.7%	42.7%
Sector A3	38.3%	37.2%	45.5%	49.7%

Figure 4.7 L-ES_A unacceptable stress percentages for PPTC and several vessel sizes

4.6 Change of Traffic Flow

4.6.1 Change of Number of Transit Ship

As briefly explained in chapter 2.3, four-directional marine traffic exist in the research area. These are transit traffic that passes through Istanbul Strait in the directions of North and South bound and local traffic in the directions of East and West bound. Transit traffic has shown tendency to increase in last decade. Thus, in this section it is aimed to demonstrate change of environmental stress in the research area by the change number of transit ship. In the present traffic situation average 6.2 transit ships pass through Istanbul Strait in an hour. 5, 10, 15 and 20 transit ships passage cases are simulated and investigated. Result show that 28.0% unacceptable stress occurs in case 5 transit ship passage in an hour, 29.9% unacceptable stress in case 10 transit ships passage, 32.1% unacceptable stress in case 15 transit ships passage, 34.8% unacceptable stress in case 20 transit ships passage through Istanbul Strait in the research area. Stress level increase linearly by the increase of number of transit ship and it is obvious that research area is a dangerous waterway and increase number of transit ship increase potential risks.

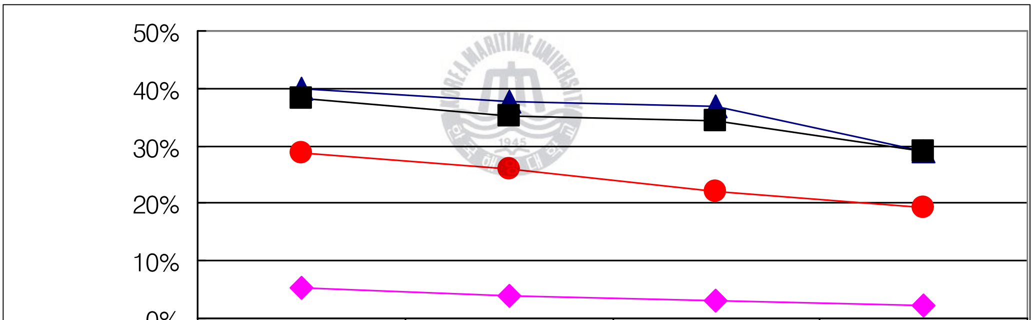


	PPTC	5 transit	10 transit	15 transit	20 transit
Total Area	28.8%	28.0%	29.9%	32.1%	34.8%
Sector A1	5.2%	5.8%	7.8%	10.0%	10.4%
Sector A2	39.8%	39.5%	41.4%	43.9%	45.8%
Sector A3	38.3%	40.0%	39.9%	45.7%	51.5%

Figure 4.8 L-ES_A unacceptable stress percentages with increase number of transit ships

4.6.2 Change of Number of Local Traffic Frequency

Marine traffic fast time simulation program does not have function to set up departure time of ships. Therefore, it was not possible to investigate time arrangement in this study. However, in this section, it is envisioned to postpone departure of local traffic vessel during peak time in order to reduce number of vessel encounter and consequently stress level due to shiphandling difficulty. Situations that local traffic vessel departures postponed 10 minutes, 20 minutes and 30 minutes respectively are envisioned. In order to simulate envisioned cases the number of local traffic ships are reduced 17%, 33% and 50% respectively and the change of stress levels in research area are analysed. Results are shown that occurrence of unacceptable risk decrease to 25.9%, 22.1%, and 19.1% respectively in case postponement of local traffic during peak times 10 minute (17% reduction of local traffic), 20 minute (33% reduction of local traffic) and 30 minute (50% reduction of local traffic).



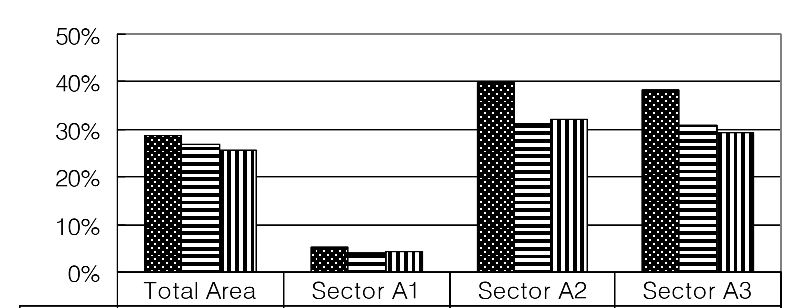
	PPTC	10min	20min	30min
Total Area	28.8%	25.9%	22.1%	19.1%
Sector A1	5.2%	3.8%	3.2%	2.2%
Sector A2	39.8%	37.7%	36.8%	29.0%
Sector A3	38.3%	35.1%	34.3%	29.2%

Figure 4.9 L-ES_A unacceptable stress percentages with increase number of transit ships

4.7 Improvements by Control of Traffic Direction

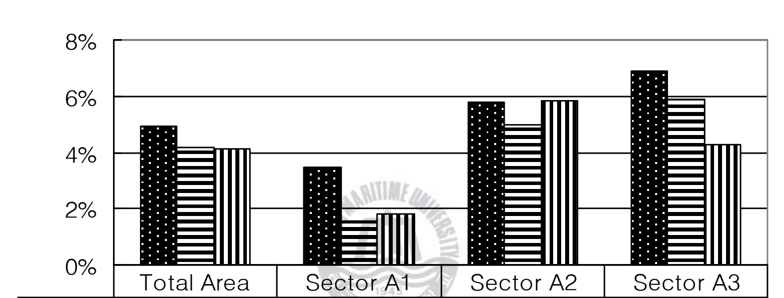
The Marmaray tunnel is an undersea rail tunnel being constructed to link the European and Asian sections of Istanbul, running under the research area in Sector A2. Project has commenced in 2005 and since than one-way traffic is implemented in Istanbul Strait. It is envisioned to be completed by 2013 and there are on going discussions to continue one-way traffic implementation after Marmaray Project (DTOD, 2009 and UBAK, 2010). Also results of expert survey revealed that one-way traffic implementation is most effective countermeasure. Thus, one-way traffic conditions in case only southbound (SB) transit vessel and only northbound (NB) transit vessel are simulated, analysed and results are presented in Figure 4.11.

Figure 4.10 The Marmaray Tunnel



	Total Area	Sector A1	Sector A2	Sector A3
PPTC	28.8%	5.2%	39.8%	38.3%
SB	26.7%	4.0%	31.2%	30.8%
NB	25.7%	4.3%	32.1%	29.2%

Figure 4.11 L-ES_A unacceptable stress percentages in case one-way traffic implementation



	Total Area	Sector A1	Sector A2	Sector A3
PPTC	4.9%	3.5%	5.8%	6.9%
SB	4.2%	1.5%	5.0%	5.9%
NB	4.1%	1.8%	5.9%	4.3%

Figure 4.12 L-ES_S unacceptable stress percentages in case one-way traffic implementation

Results show that one-way traffic implementation is highly effective to reduce stresses in the research area which is in compliance with result of expert survey. Potential stresses are quite high in Sector A2 and A3 which highly effect research area at the end. Overall unacceptable stress percentage decrease 2.1% in case of SB one-way traffic and 3.1% in case of NB one-way traffic. It may not be considered as effective to reduce stress level but stress percentage decrease 8.6% in case of SB one-way traffic, 7.7% in case of NB one-way traffic in Sector A2 and 7.5% in case of SB one-way traffic, 9.1% in case of NB one-way traffic in Sector A3. Results also show that in case of only NB traffic more ship handling difficulty occurs in Sector A2 when compare with only SB traffic situation. Vice verse happens in Sector A3 and more ship handling difficulty occurs in case of only SB traffic. Moreover, results show that one-way traffic implementation contributes significantly for improvement of navigation safety in sector A2 and sector A3.

4.8 Improvements by Use of Traffic Separation Scheme for Local Traffic

Current navigation scheme in the Istanbul Strait is set by IMO in 1998 which is not considering local marine traffic vessel. Local marine traffic vessels have to comply with COLREG Rule 10 and according to traffic and current conditions. Eventually marine traffic vessels cross from one side to other side of Istanbul Strait.

In this section an attempt made to organize local marine traffic by taking COLREG Rule 10 and IMO Ships' Routeing in consideration in the research area. According to general provision on ships' routeing traffic separation scheme is defined as "A routeing measure aimed at the separation of opposing streams of traffic by appropriate means and by the establishment of traffic lanes.” Traffic lane is defined as “An area within defined limits in which one-way traffic established. Natural obstacles, including those forming separation zones, may constitute a boundary.” Roundabout is defined as “A routeing measure comprising a separation point or circular separation zone and a circular traffic lane within defined limits.

Traffic within the roundabout is separated by moving in a counterclockwise direction around the separation point or zone. Precautionary area is defined as “A routeing measure comprising an area within defined limits where ships must navigate with particular caution and within which the direction of traffic flow may be recommended.” And recommended direction of traffic flow is defined as “A traffic flow pattern indicating a recommended directional movement of traffic where it is impractical or unnecessary to adopt an established direction of traffic flow.”

Due to oceanographic structure of research area, unique local traffic separations which are consist of traffic lane roundabout, precautionary area and recommended direction of traffic flow are proposed based on expert opinion and traffic flow analysis, simulated and results are presented. One of the problem as determined in the previous chapter local traffic imposed so high stress on the navigator during passage through Istanbul Strait due to irregular ships movements.

In this section local separation schemes for each pre-determined sectors are proposed and investigated. Proposed LTSSs are prepared based on expert opinion, result of marine traffic survey and result of ES model analysis of marine traffic fast time simulation of present peak time traffic condition. In Figure 4.13 a sample graphic is given which shows catastrophic stress with red color, critical stress with red, marginal stress with yellow and negligible stress with green.

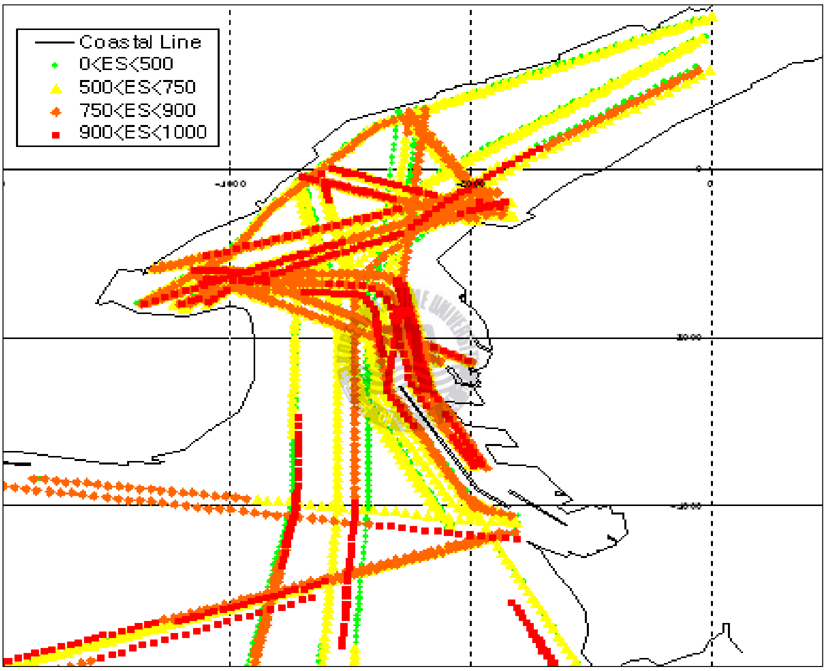


Figure 4.13 A sample graphic shows ES Model analysis result of present marine traffic fast time simulation

It is proposed to set lane for East bound and West Bound vessels. Thus, navigator on transit vessel could observe and understand local vessel movement which would assist to reduce potential risk in the research area. Proposed LTSSs and a sample graphic result of ES model analysis are given in Figures 4.14, 4.15, 4.16, 4.17, 4.18 and 4.19.

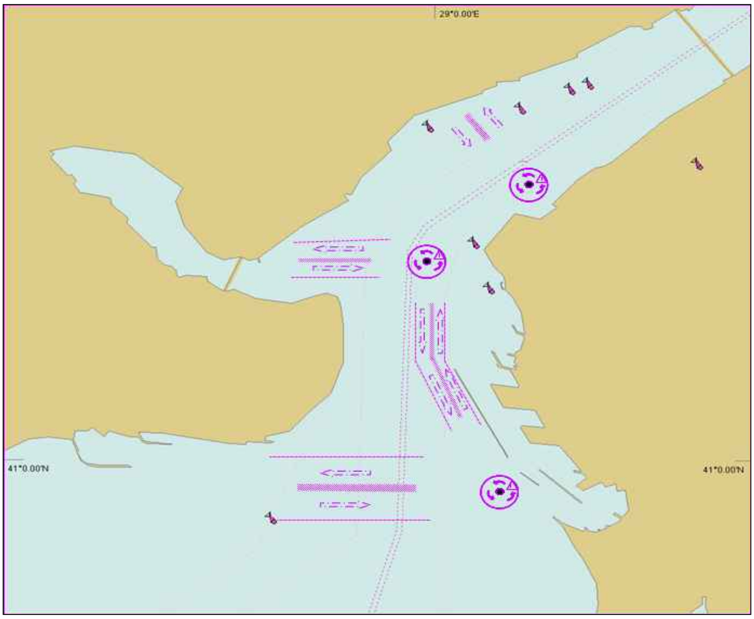


Figure 4.14 Proposed Local TSS 1

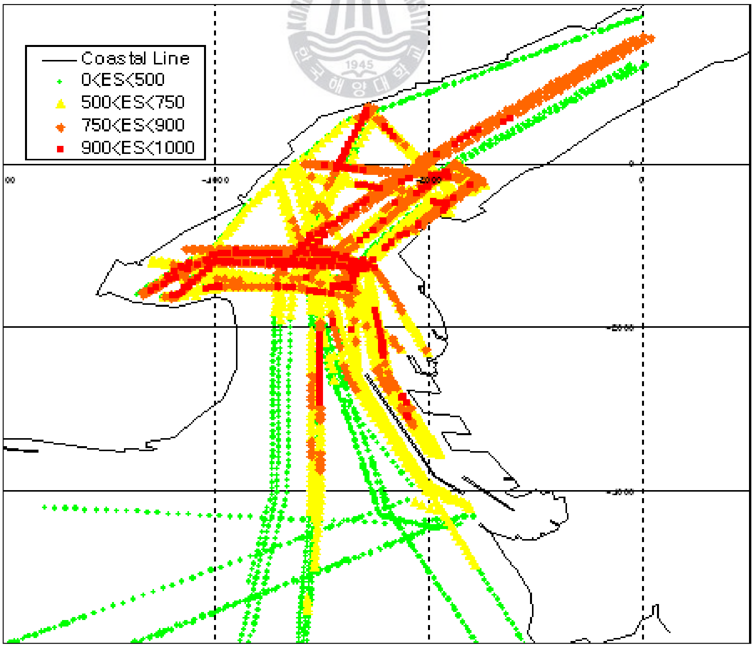


Figure 4.15 A sample graphic shows ES Model analysis result of Proposed LTSS 1

Figure 4.16 Proposed Local TSS 2

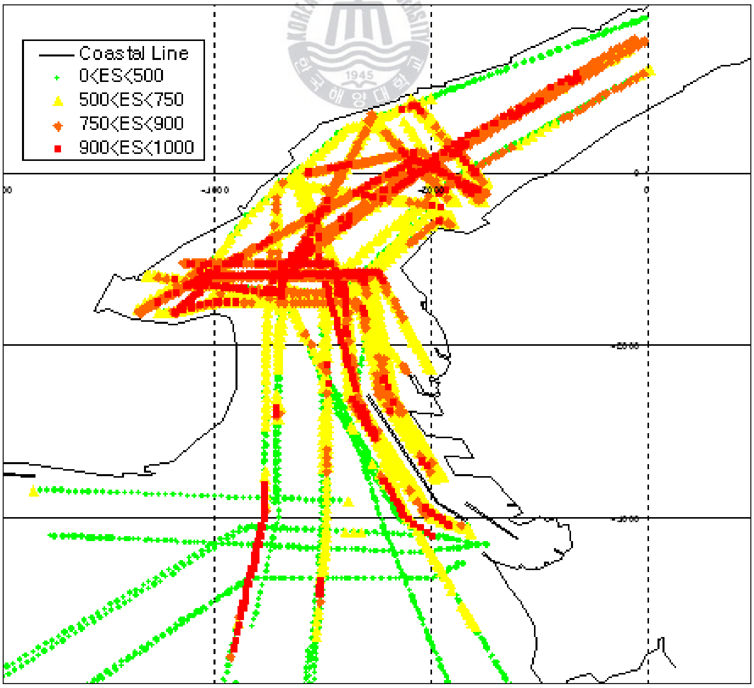


Figure 4.17 A sample graphic shows ES Model analysis result of Proposed LTSS 2

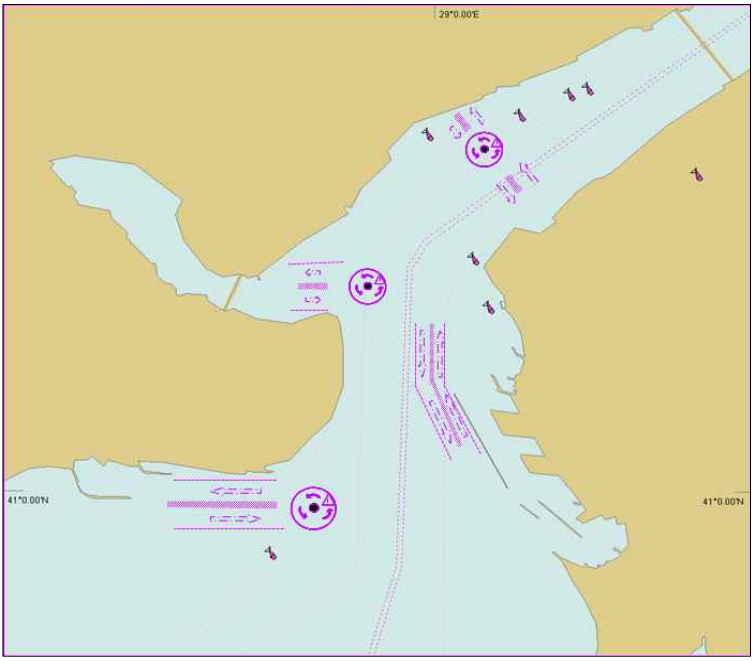


Figure 4.18 Proposed Local TSS 3

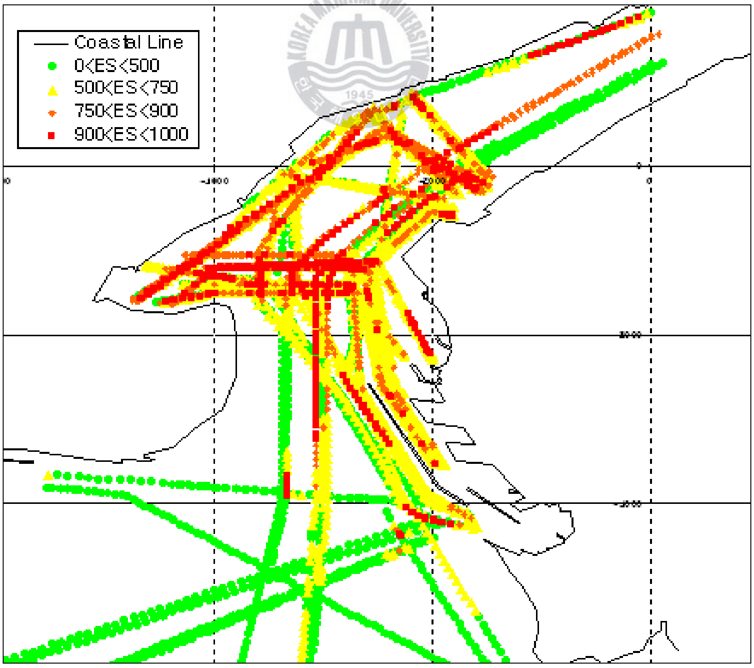


Figure 4.19 A sample graphic shows ES Model analysis result of Proposed LTSS 3

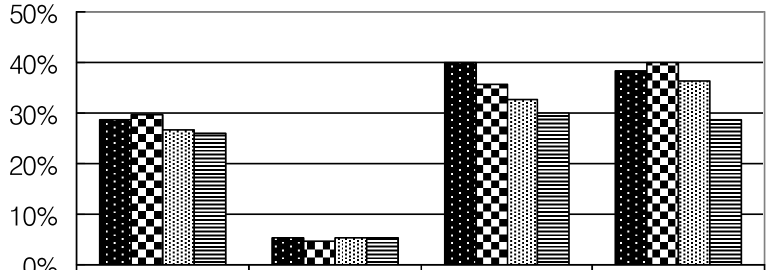
Results presented by Figure 4.20 and Figure 4.21 show that unacceptable stress level increase to 29.7% in case of proposed Local TSS 1 in total research area despite unacceptable stress level decrease to 35.7% in Sector A2 and 4.6% in Sector A1.

Location of round bound in Sector A3 which unacceptable stress level increase to 40.2%, cause close passage between vessel and also to The Maiden's Tower (marked by buoy on the chart).

However, proposed LTSS 1 is the most effective one to improve marine traffic safety in Sector A1 when compare with other proposals.

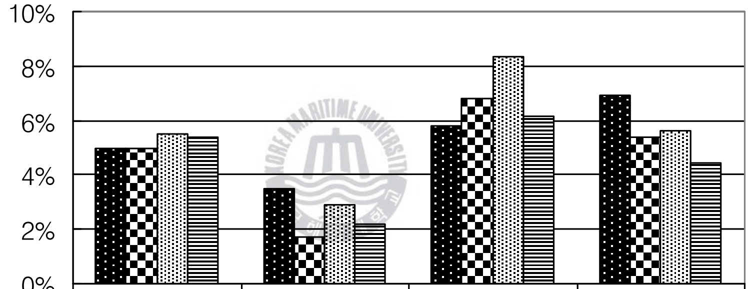
Unacceptable stress level decrease to 26.8% in total research area, 32.8% in Sector A2 and 36.4% in Sector A3 in case of proposed LTSS 2. Unacceptable stress level remains same in Sector A1 in case of proposed LTSS 2 and 3. Unacceptable stress level decrease to 26.1% in total research area, 30.1% in Sector A2 and 28.6% in Sector A3 in case of proposed LTSS 3.

It is concluded that regulating local marine traffic by Local TSS contributes to improvement of navigation safety.



	Total Area	Sector A1	Sector A2	Sector A3
PPTC	28.8%	5.2%	39.8%	38.3%
LTSS P1	29.7%	4.6%	35.7%	40.2%
LTSS P2	26.8%	5.2%	32.8%	36.4%
LTSS P3	26.1%	5.2%	30.1%	28.6%

Figure 4.20 L-ES_A unacceptable stress percentages in case proposed LTSS



	Total Area	Sector A1	Sector A2	Sector A3
PPTC	4.9%	3.5%	5.8%	6.9%
LTSS P1	5.0%	1.7%	6.8%	5.4%
LTSS P2	5.5%	2.9%	8.4%	5.6%
LTSS P3	5.4%	2.2%	6.1%	4.5%

Figure 4.21 L-ES_S unacceptable stress percentages in case proposed LTSS

4.9 Results and Discussion

L-ES assessment results show that research area is highly dangerous waterway. Result of marine traffic fast time simulation for current traffic situations, indicates that 28.8% of marine traffic create unacceptable stress during peak times and 22.0% during off-peak time in the research area (Figure 4.3).

Results also show that Sector A2 is most dangerous sector with 39.8% unacceptable stress during peak time and 37.6% during off-peak time. Due to high encounter situations in Sector A2, occurrence of unacceptable stress level does not decrease significantly during off peak time. Although stress level decrease significantly in other sectors and in total area. This result implies that decrease of traffic density not lead to decrease of stress level in the defined area. It also implies necessity of alternative solutions in sector A2.

Istanbul Harbor Master Local Traffic Guideline which gives recommended routes for local marine traffic vessels and marine traffic situation as per recommended routes by guide line (RLMTR) is simulated. Results show that RLMTR help to reduce scaled stress in the total research area despite increase of traffic related stress (L-ES_S). However, decrease of scaled stress is found insignificant when compared with result of one-way traffic implementation and proposed LTSSs.

Vessel size has direct effect on ship handling difficulty in a waterway. In order to find out effect of change ship length, simulation studies are carried out in the research area. Marine traffic situations in case of transit ship length only 100 meter, 200 meter and 300 meter are investigated and result are compared with PPTC as given in Figure 4.7. Results have shown that when the transit ship length increase, level of stress also increase in parallel as expected. Results of marine traffic fast time simulation are in compliance with result of expert survey regarding effect of ship length/size on safe navigation.

Four-directional marine traffic exists in the research area. These are transit traffic that passes through Istanbul Strait in the directions of North and South bound and local traffic in the directions of East and West bound. Transit traffic has shown tendency to increase in last decade. Thus, it is aimed to demonstrate change of environmental stress in the research area by the change number of transit ship. In the present traffic situation in an hour average 6.2 transit ships pass through Istanbul Strait and 5, 10, 15 and 20 transit ships passage cases are simulated. Results show that stress level increase linearly by the increase transit ship number and it is obvious that research area is a dangerous waterway. Hence, increase number of transit ship can raise potential risks in the research area.

The Marmaray tunnel is an undersea rail tunnel being constructed to link the European and Asian sections of Istanbul, running under the research area in Sector A2 Project has commenced in 2005 and since than one-way traffic is implemented in Istanbul Strait. Results of expert survey revealed that one-way traffic implementation is most effective countermeasure. Thus, one-way traffic conditions in case of only southbound (SB) transit vessel and only northbound (NB) transit vessel are simulated, analysed and results show that one-way traffic implementation is highly effective. one-way traffic implementation improve navigation safety %7.3 in case of only south bound (SB) and 10.8% in case of only north bound (NB) in total area.

Moreover, it improves navigation safety 19.6% in case of only SB and 23.8% in case of only NB in Sector A3, 21.6% in case of only SB and 19.3% in case of only NB in Sector A2 and 23.1% in case of only SB and 17.3% in case of only NB in Sector A1. Due to geographical structure of the Istanbul Strait, in different sectors improvement percentage of navigation safety fluctuate for only south bound and north bound transit passage cases. Howsoever in each case, one-way traffic implementation improves navigation safety.

As per Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREG) Rule 10 of the Collision Regulations which deals with the behavior of vessels in or near traffic separation schemes adopted by the Organization states that ships crossing traffic lanes are required to do so "as nearly as practicable at right angles to the general direction of traffic flow".

This reduces confusion to other ships as to the crossing vessel's intentions and course and at the same time enables that vessel to cross the lane as quickly as possible. Fishing vessels "shall not impede the passage of any vessel following a traffic lane" but are not banned from fishing.

This is in line with Rule 9 which states that "a vessel engaged in fishing shall not impede the passage of any other vessel navigating within a narrow channel or fairway." In 1981 the rules were amended. Two new paragraphs were added to Rule 10 to exempt vessels which are restricted in their ability to maneuvers "when engaged in an operation for the safety of navigation in a traffic separation scheme" or when engaged in cable laying. In 1987 the regulations were again amended. It was stressed that Rule 10 applies to traffic separation schemes adopted by the Organization (IMO) and does not relieve any vessel of her obligation under any other rule. It was also to clarify that if a vessel is obliged to cross traffic lanes it should do so as nearly as practicable at right angles to the general direction of the traffic flow.

In 1989 Rule 10 was further amended to clarify the vessels which may use the "inshore traffic zone". The effectiveness of traffic separation schemes can be judged from a study made by the International Association of Institutes of Navigation (IAIN) in 1981. According to this study, 60 collisions occurred between 1956 and 1960 in the Strait of Dover; twenty years later, following the introduction of traffic separation schemes, number of collision is drop to only 16. In other areas where such schemes do not exist, the number of collisions rose sharply. New traffic separation schemes are introduced regularly and existing ones are amended when necessary to respond to changed traffic conditions. To enable this to be done as quickly as possible the MSC has been authorized to adopt and amend traffic separation schemes on behalf of the Organization (IMO, web).

Based on IMO recommendation, local traffic separation schemes at three different locations for each pre-determined sector were proposed based on expert opinion, result of marine traffic survey and result of ES model analysis of marine traffic fast time simulation of present peak time traffic condition. In the proposed LTSSs, it is considered to local traffic vessel comply with "as nearly as practicable at right angles to the general direction of traffic flow".

Thus, confusion to transit ships due to crossing vessel's intentions and course would be prevented and at the same time would be enabled crossing vessel cross the lane as quickly as possible. Navigator on transit ship would know in which location local traffic should go east bound and west bound. Thus, it could be helpful for improvement situational awareness of navigator on transit ships.

In the present situation, local traffic vessels cross from one side to other side on irregular routes which cause enormous stress on navigator even though local traffic vessel should give the way. Ship handling difficulty imposed on transit vessel due to congested local marine traffic was presented by real time simulation study in chapter 3.3.

Results of marine traffic fast time simulation studies show that LTSS contribute to improve marine traffic safety in the research area. According to results of marine traffic fast time simulation studies, proposed LTSS 1 is most effective to improve navigation safety in Sector A1 and proposed LTSS 3 is most effective in Sector A2 and Sector A3 among proposed LTSS.

In case implementation of proposed LTSS 1, stress level decrease 11.5%in Sector A1. And in case implementation of proposed LTSS 3, stress level decrease 24.3%in Sector A2 and 25.4% in Sector A3.

Hence, according to afore mentioned results, local traffic separation scheme implementation is strongly recommended for the improvement of marine traffic safety in the southern entrance of Istanbul Strait. In the future studies, effectiveness of proposed LTSS can be confirmed by real time simulation and PAWSA studies.

Chapter 5 Conclusion and Recommendation

There are enormous challenges for navigation in the Istanbul Strait due to its geographical, geopolitical and oceanographic structure.

One of the challenges is the local marine traffic which crosses from one side to other of the Strait. Daily, more than 2,100 scheduled and unscheduled crossings take place by passenger and car ferries, passenger boats and sea buses in the southern entrance of the Istanbul Strait. This local traffic mostly effects navigation safety.

In this dissertation, the aim is to improve navigation safety by investigating and proposing counter measures for local marine traffic in the southern entrance of the Istanbul Strait which is the chosen geographical area of research. More specifically, the research area is the zone between the line connecting the Moda Cape and Bakirkoy and the Istanbul Strait Bridge, where the local marine traffic is more congested and poses a threat to navigation safety.

In order to devise these counter measures, local marine traffic parameters such as local traffic volume, traffic flow and probability of collision are analysed by utilizing various statistics. After defining main traffic flow, the research area has been divided into three sectors as given in Figure 3.6, namely Sector

A1, Sector A2 and Sector A3 according to close passing/ encounter locations of local traffic flow. Then, previously conducted expert surveys, real time simulation studies and marine traffic fast time simulation studies are used to examine the various changes of marine traffic parameters.

At the end of the dissertation, a few local traffic separation schemes are proposed to promote navigation safety in the Istanbul Strait.

Findings of the study are listed below:

i. When probability of collision in the Istanbul Strait is compared with various Korean waterways, it is found to be almost two times higher than that of Korean waterways.

ii. The number of vessels running in an hour is 4 vessels in sector A1, 73 vessels in Sector A2 and 67 vessel in Sector A3 during peak times. During off-peak times, there are 4 vessels in sector A1, 59 vessels in Sector A2 and 47 vessels in Sector A3. Results show that local traffic vessel departure times could be re-arranged in Sector A2 and A3 in order to decrease potential encounters and ship handling difficulties. The occurrence of unacceptable risk decreases to 25.9%, 22.1%, and 19.1% respectively when local traffic is postponed during peak times by 10 minutes (17% reduction of local traffic), 20 minutes (33% reduction of local traffic) and 30 minutes (50% reduction of local traffic) in the total research area as shown in the results of the marine traffic fast time simulation experiment. Also, necessary safety precautions should be taken such as more intensive VTS surveillance for both local and transit vessels in order to minimize existing encounter risks.

iii. Findings of the expert survey are as follows:

a) Tankers are determined as the most dangerous ship type to navigate in the southern entrance of the Istanbul Strait;

b) Ships measuring 200 meters in length and over are determined as the most dangerous ship lengths;

c) Sector A2 is the most dangerous pre-defined local traffic area, and it is assumed that stakeholders are not fully aware of hidden risks in Sector A1;

d) Transit-transit vessel encounter/ crossing situations are the most dangerous encounter/ crossing situations in the research area;

e) Restricted visibility has the most negative influence on safe navigation in the research area;

f) one-way traffic implementation is the most significant counter measure in the southern entrance of the Istanbul Strait in order to reduce risks;

g) In general, major stakeholders have common risk perceptions and approaches in the research area;

iv. On the basis of the results of the real time simulation study, the most risky part of the research area is the region between Sarayburnu and Kadikoy which is in Sector A2. On the other hand, this area is on the border of two Vessel Traffic System (VTS) sectors. The Istanbul region is divided into four VTS sectors. Each sector is controlled by different operators. The VTS system allows operators to see other sectors, but the operators must only consider their own sectors. Thus, the VTS sector borders cause confusion and reduce the effectiveness of the VTS. Since the most risky area of the strait is on the border, the research findings strongly recommend that the VTS sector line should be shifted to another location. The results also indicate that there is a necessity for improvement of navigation safety.

v. Results of the marine traffic fast time simulation studies according to the current traffic situation show an unacceptable occurrence rate of 29% during peak times, and a 22% unacceptable occurrence rate during off-peak times in the total research area. Sector A2 is found as being the most dangerous sector because of high encounter situations where stress level does not decrease during off-peak times compared with the other sectors and the total area.

vi. Results of marine traffic fast time simulation studies also show that recommended local marine traffic routes by the Istanbul

Harbor Master Local Marine Traffic Guideline (RLMTR) promote navigation safety in the total research area. However, it is not as effective as the proposed LTSS or one-way traffic implementations.

vii. In addition, results of marine traffic fast time simulation studies show that when the length of transit ships increases, the level of stress increases in parallel, and also stress level increases linearly with the increase in number of transit ships.

viii. Continuity of one-way traffic, which has been implemented since 2003 due to an under water tunnel project, is an on going discussion. One-way traffic implementation is determined by expert surveys as the most effective counter measure with a mean of 4.57 points on a Five Likert Scale (78% of participants agreed that it is extremely effective in terms of risk reduction). Meanwhile, results of the marine traffic fast time simulation revealed that navigation safety improves in total research area by 7.3% in the case of south bound (SB) one-way traffic and 10.8% in the case of north bound (NB) one-way traffic. Moreover, in Sector A3 navigation safety improves 19.6% in the case of SB one-way and 23.8% in the case of NB one-way, in Sector A2 21.6% in the case of SB one-way and 19.3% in the case of NB one-way, and in Sector A1 23.1% in the case of SB one-way and 17.3% in the case of NB one-way. Due to the geographical structure of the Istanbul

Strait, in different sectors improvement percentages of navigation safety fluctuate in the case of one-way south or north bound transit passages. In either case, one-way traffic implementation improves navigation safety. As stated before, the research area is determined as a highly risky waterway. Hence, continuity of one-way traffic implementation is strongly recommended. The VTS in Istanbul could continue to regulate transit ship passage especially during peak traffic times. With one-way transit, the hazards arising from third party vessel actions are largely removed, and risk management is therefore much more within the control of the VTS operators.

ix. Local traffic separation schemes at three different locations for each pre-determined sector were proposed based on the IMO recommendation, expert opinion, results of marine traffic survey, and results of marine traffic fast time simulation of present peak time traffic conditions which is analysed using the ES Model. According to COLREG Rule 10, in a TSS crossing vessels should cross "as nearly as practicable at right angles to the general direction of traffic flow", and this is taken in to consideration when the LTSSs are proposed. Thus, confusion for transit ships due to crossing vessel's intentions and courses would be reduced and at the same time would enable crossing vessels to cross the lane as quickly as possible. Navigators on transit ships would know in which location local traffic should go east bound and west bound. Thus, it could be helpful for the improvement of the situational awareness of navigators on transit ships. In the present situation, local traffic vessels cross from one side to the other on irregular routes which causes enormous stress to transit vessel navigators despite the fact that local traffic vessels must give the way. Ship handling difficulty imposed on transit vessel navigators due to congested local marine traffic was presented by the real time simulation study in chapter 3.3. Results of marine traffic fast time simulation studies show that LTSS contribute to the improvement of marine traffic safety in the research area. According to the results of marine traffic fast time simulation studies, proposed LTSS 1 is the most effective to improve navigation safety in Sector A1, and proposed LTSS 3 is the most effective in Sector A2 and Sector A3 among proposed LTSSs. In the case of proposed LTSS 1, stress level decreases 11.5% in Sector A1, in the case of proposed LTSS 3, stress level decreases 24.3% in Sector A2 and 25.4% in Sector A3. Hence, according to the aforementioned results, local traffic separation scheme implementation is strongly recommended for the improvement of marine traffic safety in the southern entrance of the Istanbul Strait.

In summary, the southern entrance of the Istanbul Strait is a highly risky waterway, and local marine traffic is the main reason for those risks. One-way traffic and local traffic separation scheme implementations promote navigation safety in this area.

In future studies, not only real time simulation studies but also PAWSA studies can be carried out in order to confirm the effectiveness of proposed LTSSs. The marine traffic fast time simulation program, which is used in this study, does not have a function to set up specific departure times for vessels. Only the number of vessels running in an hour can be input. Therefore, a time management study by arranging the departure times of local traffic vessels could not be carried out. However, it could be realized by utilizing a real time simulator in the future.

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List of Published Papers during Doctoral Course

Journals;

1. Volkan Aydogdu et al. (2008), *“Analysis of Marine Traffic Features for Safety Assessment at southern Entrance of the Istanbul Strait-I”*, Journal of Korean Institute of Navigation and Port Research Vol.32,No.7 pp.521~527.
2. Volkan Aydogdu et al. (2010), *"Questionnaire Survey on the Risk Perception in the Istanbul Strait"*, submitted on June 23, 2010 to Journal of Korean Institute of Navigation and Port Research .

Proceedings;

1. Cemil Yurtoren and Volkan Aydogdu (2009) “*Risk analysis of Congested Areas of Istanbul Strait via Ship Handling Simulator”*, Proceeding of the 11th WSEAS International Conference on Automatic Control, Modeling and Simulation, ISBN 978-960-474-082-6, pp.146~152
2. Volkan Aydogdu, Youn-Soo Park, Serdar Kum, Yurtoren Cemil and Jin-Soo Park (2009), *“A Study on Risk Perception at the Istanbul Strait”,* Proceeding of Asia Navigation Conference, Shizuoka, Japan, November 19-21, pp. 201~208.
3. Volkan Aydogdu, Yurtoren Cemil and Jin-Soo Park (2010), *"A study on local marine traffic management to promote marine traffic safety in Istanbul Strait"*, submitted on June 23, 2010 to Asia Navigation Conference, Incheon, Korea

Annex

Questionnaire for Risk Assessment of the Southern Entrance of Istanbul Strait

Good day,

This questionnaire consists of two parts and is prepared to be used in a study called "Local Traffic Management in the Istanbul Strait". In the first part of questionnaire, it aims at determining risks in the southern entrance of the Istanbul Strait due to local marine traffic, risk perceptions of stake holders about those risks and differences of risk perception between stake holders. It also aims at learning stake holders' opinions regarding risk mitigating counter measures in the second part of questionnaire.

In this questionnaire your personal information is not required. Thus your name or any information which could identify you is not requested. Information which is requested about your vocational experience will promote the quality and reliability of the survey and will be used exclusively for academic purposes. Therefore, we assure you that the information will not be given to a third party.

We would like to sincerely thank you for your kind interest and participation in our study.

Dr. Cemil Yurtoren, Volkan Aydogdu

Present Position :

☐ Pilot at Istanbul Strait ☐ VTS Operator

☐ Ocean Going Master ☐ Skipper on Local Traffic Ship

☐ others

Licence :

☐ Pilot ☐ Ocean going Master ☐ Skipper ☐ Others

Vocational Experience :

☐ Pilot ...... years

☐ VTS-Operator ...... years

☐ Local Traffic ...... years

☐ Total sea experience .... years

A- Risk Perceptions

Could you evaluate navigational risk in the southern entrance of the Istanbul Strait:

1) With respect to Ship Type:

a) What is risk level of tanker ships?

Minimum risk		**level of risk**		**maximum risk**
① □	② □	③ □	④ □	⑤ □

b) What is risk level of container ships?

Minimum risk		**level of risk**		**maximum risk**
① □	② □	③ □	④ □	⑤ □

c) What is risk level of bulk carrier ships?

Minimum risk		**level of risk**		**maximum risk**
① □	② □	③ □	④ □	⑤ □

d) What is risk level of passenger ships?

Minimum risk		**level of risk**		**maximum risk**
① □	② □	③ □	④ □	⑤ □

e) What is risk level of coastal ships?

Minimum risk		**level of risk**		**maximum risk**
① □	② □	③ □	④ □	⑤ □

2) <u>With respect to Crew (personnel):</u>

a) what is risk level of tanker ships when consider training level, workload, working condition, etc of crew ?

Minimum risk		**level of risk**		**maximum risk**
① □	② □	③ □	④ □	⑤ □

b) what is risk level of container ships when consider training level, workload, working condition, etc of crew ?

Minimum risk		**level of risk**		**maximum risk**
① □	② □	③ □	④ □	⑤ □

c)) what is risk level of bulkcarriers when consider training level, workload, working condition, etc of crew ?

Minimum risk		**level of risk**		**maximum risk**
① □	② □	③ □	④ □	⑤ □

d) what is risk level of passenger ships when consider training level, workload, working condition, etc of crew ?

Minimum risk		**level of risk**		**maximum risk**
① □	② □	③ □	④ □	⑤ □

e) what is risk level of coastal ships when consider training level, workload, working condition, etc of crew ?

Minimum risk		**level of risk**		**maximum risk**
① □	② □	③ □	④ □	⑤ □

3) <u>With Respect to LOA :</u>

a) What is risk level of vessel between 0-49 meter?

Minimum risk		level of risk		maximum risk
① ☐	② ☐	③ ☐	④ ☐	⑤ ☐

b) What is risk level of vessel between 50-99 meter?

Minimum risk		level of risk		maximum risk
① ☐	② ☐	③ ☐	④ ☐	⑤ ☐

c) What is risk level of vessel between 100-149 meter ?

Minimum risk		level of risk		maximum risk
① ☐	② ☐	③ ☐	④ ☐	⑤ ☐

d) What is risk level of vessel between 150-199 meter ?

Minimum risk		level of risk		maximum risk
① ☐	② ☐	③ ☐	④ ☐	⑤ ☐

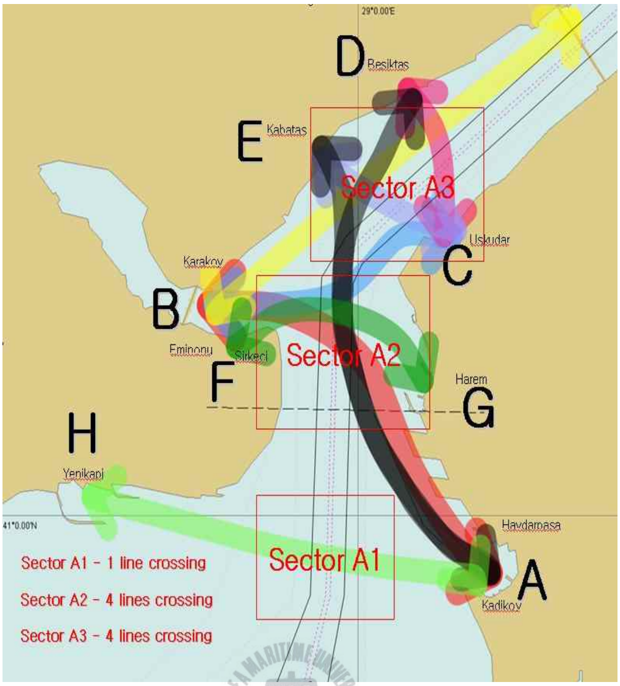
e) What is risk level of vessel between 200-249 meter ?

Minimum risk		level of risk		maximum risk
① ☐	② ☐	③ ☐	④ ☐	⑤ ☐

f) What is risk level of vessel between 250 meter and over?

Minimum risk		level of risk		maximum risk
① ☐	② ☐	③ ☐	④ ☐	⑤ ☐

4) Could you evaluate navigational risk level of sectors pointed on below chart ?:



a) Sector A1

Minimum risk		level of risk		maximum risk
① □	② □	③ □	④ □	⑤ □

b) Sector A2

Minimum risk		level of risk		maximum risk
① □	② □	③ □	④ □	⑤ □

c) Sector A3

Minimum risk		level of risk		maximum risk
① □	② □	③ □	④ □	⑤ □

5) Could you evaluate navigational risk level in the southern entrance of the Istanbul Strait during crossing situations of:

a) local traffic vessel and local traffic vessel ?

Minimum risk		**level of risk**		**maximum risk**
① □	② □	③ □	④ □	⑤ □

b) local traffic vessel and transit passing vessel?

Minimum risk		**level of risk**		**maximum risk**
① □	② □	③ □	④ □	⑤ □

c) transit passing vessel and transit passing vessel?

Minimum risk		**level of risk**		**maximum risk**
① □	② □	③ □	④ □	⑤ □

6) Could you evaluate the effects of following conditions on navigation safety in the southern entrance of the Istanbul Strait:

a) current

Not effective		**level of effective**		**extremely effective**
① □	② □	③ □	④ □	⑤ □

b) wind

Not effective		**level of effective**		**extremely effective**
① □	② □	③ □	④ □	⑤ □

c) restricted visibility

Not effective		level of effective		extremely effective
◀··▶				
① □	② □	③ □	④ □	⑤ □

d) local traffic and sight seeing vessels

Not effective		level of effective		extremely effective
◀··▶				
① □	② □	③ □	④ □	⑤ □

e) fishing vessels and yatch

Not effective		level of effective		extremely effective
◀··▶				
① □	② □	③ □	④ □	⑤ □

<u>B- Risk mitigating counter measures :</u>

Could you evaluate the effectiveness of existent or potential risk mitigating counter measures in the southern entrance of the Istanbul Strait:

a) Vessel Traffic Service (VTS)

Not effective		level of effective		extremely effective
◀··▶				
① □	② □	③ □	④ □	⑤ □

b) Local Traffic Control Center

Not effective		level of effective		extremely effective
◀··▶				
① □	② □	③ □	④ □	⑤ □

c) A new traffic separation scheme (TSS) prepared by taking current local and transit traffic conditions in to considerations

Not effective		level of effective		extremely effective
① □	② □	③ □	④ □	⑤ □

d) Maximum speed implementation in the Istanbul Strait

Not effective		level of effective		extremely effective
① □	② □	③ □	④ □	⑤ □

e) Minimum speed implementation in the Istanbul Strait

Not effective		level of effective		extremely effective
① □	② □	③ □	④ □	⑤ □

f) Controlling vessel crossing and meeting

Not effective		level of effective		extremely effective
① □	② □	③ □	④ □	⑤ □

g) Continuity of one-way traffic implementation (one-way traffic has been implemented since 2003 due to the underwater tunnel project)

Not effective		level of effective		extremely effective
① □	② □	③ □	④ □	⑤ □

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