ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

FORMAL SAFETY ASSESSMENT OF ENGINE ROOM FIRES

M.Sc. THESIS

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Department of Naval Architecture and Marine Engineering

Naval Architecture and Marine Engineering Programme

Thesis Advisor: Prof. Dr. Osman Azmi ÖZSOYSAL

JUNE 2013

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To my beloved family,

FOREWORD

I deeply appreciate the encouragement, instruction, and understanding of my advisers Prof.Dr. Osman Azmi OZSOYSAL and Assoc.Dr. Hakan AKYILDIZ. Their attitudes towards research and life will guide me in my future. I would like to also thank Gorkem BENEK, Turgay KOROGLU and Pınar EKSI for all of their help. I am grateful for the help from my friends. Last but not least, I appreciate my parents' support, as always.

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ABBREVIATIONS

ALARP	**:** As Low As Reasonably Practicable
COLREGs	**:** International Regulations for Preventing Collisions at Sea
ETA	**:** Event Trees Analysis
FMECA	**:** Failure Modes, Effects and Criticality Analysis
FSA	**:** Formal Safety Assesment
FTA	**:** Fault Trees Analysis
HAZID	**:** Hazard Identification
HAZOP	**:** Hazard and Operability
HSE	**:** Health and Safety Executive
IACS	**:** International Association of Classification Societies
ILO	**:** Internationa Labor Organisation
IMO	**:** International Maritime Organization
ISO	**:** International Organization for Standardization
MAIB	**:** Marine Accident Investigation Branch
MCA	**:** Marine Coastguard Agency
MEPC	**:** Marine Environment Protection Committee
MSC	**:** Marine and Safety Committee
NFPA	**:** National Fire Protection Association
NASA	**:** National Aeronautics and Space Administration
OHSA	**:** Occupational Safety and Health Administration
OHSAS	**:** Occupational Health & Safety Assessment Series
QRAS	**:** Quantitative Risk Analysis Software
TS	**:** Turkish Standards
USCG	**:** United State Coast Guard

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FORMAL SAFETY ASSESSMENT OF ENGINE ROOM FIRES

SUMMARY

The first thing that comes to mind when the risk is mentioned is the emergence of a negative event. Negative events affect people's life negatively. During determination of risks, time interval, frequency at this time interval, and effects of risk are important parameters. The question of how the risk can be controlled is the main basis of risk management process. The major obstacle at the risk management process is unknown or unpredictable events. Risk is generally determined in the light of knowledge and gains acquired from past accidental events. Accident and event reports, experiences and expert views take part in the risk management process. Main purpose while managing risks is the prevention of risks, if it cannot be prevented, it must be kept under control and cost is reduced to minimum level. When viewed form this aspect, considering risk as a gain is beneficial. Risk is a time-dependent concept. As follows, past hazardous events pose almost no risk nowadays or pose minimum risk. The main factors of this situation are technological advances, new rules in force, increasing importance on human education. However, new risk areas have emerged and will continue to emerge with technological advances. It can be deduced from hence that "Risk has always existed and will continue to be existed in future." Some of the risks have disappeared but new risks have gone into our lives. The first of the most important areas affected by the risk is human life, the second one is environmental damages and the third one is financial losses. Human life is above all of them. Disregarding human life for the sake of pecuniary advantage does not fit to engineering ethics. In determining the measures to be taken to protect human life, there is a need of rule-making organizations and legal sanctions. IMO and ILO are working in accordance with this purpose. In addtion, IACS and Lloyds exist in accordance with this purpose. To make quick decisions in managing risk and to put these decisions into force as soon as possible are essential. Therefore, aforementioned institutions make meeting at regular intervals, determine contemporary risks and make decisions for the disposal of these risks. In determining risks, risk assessment methods are needed. Nowadays many risk assessment methods are available. Some of these methods are "primary risk analysis using checklists, what if? analysis, hazard and operability studies (HAZOP), fault tree analysis (FTA), failure mode and effects analysis (FMEA), hazard analysis and critical control points (HACCP), formal safety assessment (FSA). Beyond these methods, in determining the risk, the question of which risks will be addressed first is significant. In determining the risks, one of the biggest mistakes is to make random evaluations. It is very important to make a systematic approach to determine risks. Thus, risk assessment becomes more objective. In conjunction with objectivity, risk assessment strategies become more transparent. Together with objectivity and transparency, adoption of risks and effects of these risks to the rule-making mechanisms becomes easier. At ths stage, grading risks objectively is the biggest step. Of course, in determining the risks and introducing measures to prevent risks, cost/benefit analysis

of these measures must be done. When viewed from this aspect, the problem of identifying and controlling risks can be addressed as an optimization problem.

In this workout, it is aimed to identification of causes, impacts, frequency and severity of machnery room accidents and is aimed to preventing or reducing to risk of accidents based on accident statistics of Turkish or foreign flagged ships that operate in Turkish or international waters. For this purpose, it has been used Formal Safety Assessment Method and accident data of Republic of Turkey Ministry of Transport, Maritime Affairs and Communications. This workout comprises accident data from 2001 to 2012.

MAKİNE DAİRESİ YANGINLARININ BİÇİMSEL EMNİYET DEĞERLENDİRMESİ

ÖZET

Genellikle risk denilince ilk akla gelen şey, olumsuz bir durumun ortaya çıkmasıdır. Olumsuz durumlar ise insan hayatını kötü yönde etkilemektedir. Risk belirlenirken, zaman aralığı, bu zaman aralığındaki sıklık ve riskin oluşturabileceği etkiler önemli parametrelerdir. Riskin nasıl kontrol edilebileceği risk yönetiminin temelini oluşturmaktadır. Risk yönetiminin önündeki en büyük engel ise bilinemez veya öngörülemez olaylardır.

Risk, genellikle geçmiş kötü veya kazayla sonuçlanmış olaylardan edinilen kazanım ve bilgiler ışığında belirlenmektedir. Risk yönetiminde, kaza veya olay raporları, tecrübeler ve uzman görüşleri önemli yer tutmaktadır. Riski yönetirken ana amaç, riskin engellenmesi, engellenemiyorsa da kontrol altında tutulabilmesi ve zararın minimum düzeye indirilebilmesidir. Bu yönden bakıldığında, riski de bir kazanç olarak görmekte fayda vardır.

Risk, zamana bağlı olan bir kavramdır. Kazanç ve zararları da zamana bağlıdır. Riskin zamana bağlı olma olgusunun üzerinde durmakta fayda vardır. Şöyle ki, geçmişte yüksek risk teşkil eden olaylar günümüzde neredeyse hiç risk teşkil etmemekte veya artık minimum düzeyde risk teşkil etmektedir. Böyle olmasındaki ana etmenler, teknolojik ilerlemeler, düzenlenen ve yürürlükteki yeni kurallar, insan eğitimindeki payın artması ve bilgi birikiminin gün geçtikte artmasıdır. Ancak, teknolojinin ilerlemesiyle yeni risk alanları da ortaya çıkmıştır ve ortaya çıkmaya devam etmektedir. Buradan şunu çıkartabiliriz; "Risk her zaman var olmuştur ve var olmaya da devam edecektir.". Bazı riskler ortadan kalkmıştır ama yeni riskler de hayatımıza girmiştir.

Riskin etkilediği en önemli alanlardan birincisi insan hayatı, ikincisi çevresel etmenler ve üçüncüsü ise maddi etmenlerdir. Bu sıralamada, insan hayatı her şeyin üstündedir. Sırf maddi ve gelecek çıkarlar uğruna insan hayatını hiçe saymak ne mühendislik etiğine ne de insanlık etiğine sığmamaktadır. İnsan hayatını korumak için alınması gereken önlemleri belirlerken kural koyucu kurumlara ve cezai yaptırımlara gereksinim vardır. IMO (Uluslararası Denizcilik Örgütü) ve ILO (Uluslararası Çalışma Örgütü) gibi kurumlar bu amaçlar doğrultusunda çalışmaktadır. Ayrıca, IACS (Uluslararası Klas Kuruluşları Birliği) ve Lloydlar (Klas Kuruluşları) gibi kurumlar bu amaçlar için vardır. Risk yönetilirken hızlı kararlar almak ve bu kararları bir an önce yürürlüğe sokmak esastır. Bu nedenle bahsi geçen kurumlar düzenli aralıklarla toplanmakta, güncel riskleri belirlemekte ve bu risklerin bertaraf edilmesi için kararlar almaktadırlar.

Riskler belirlenirken, risk değerlendirme metotlarına ihtiyaç duyulmaktadır. Günümüzde birçok risk değerlendirme metodu mevcuttur. Bunlardan bazıları, kontrol listelerini (checklist) kullanılarak birincil risk analizi, eğer olursa ne olur? (what if?), tehlike ve işletilebilirlik analizi (HAZOP), hata ağacı analizi (FTA),

normal sistemden sapma ve etkileri analizi (FMEA), tehlike analizi ve kritik kontrol noktaları (HACCP), biçimsel emniyet değerlendirmesi (FSA) gibi metotlardır. Bu yöntemlerin ötesinde, risk belirlenirken öncelikle olarak hangi risklerin ele alınacağı önem arz etmektedir.

Risklerin belirlenmesinde rastgele değerlendirmelerde bulunmak en büyük hatalardan biridir. Riskler belirlenirken sistematik bir yaklaşımda bulunmak çok önemlidir. Böylelikle risk belirlenmesi daha objektif olmaktadır. Objektiflikle beraber risk belirleme stratejileri daha şeffaf olmaktadır. Objektif ve şeffaf yaklaşımlar ve değerlendirmelerle beraber, risklerin ve bu risklerin etkilerinin kural koyucu mekanizmalara benimsetilmesi daha kolay hale gelmektedir. Risklerin objektif olarak derecelendirilmesi bu aşamada en büyük adımdır. Tabii ki riskler belirlenirken ve bu riskler için önlemler öne sürülürken bu önlemlerin maliyet/fayda analizlerinin de yapılması gerekmektedir. Olaya buradan bakıldığında, risklerin belirlenmesi ve kontrol edilmesi problemi bir optimizasyon problemi olarak ele alınabilir.

Risk kavramının geçmişine baktığımızda ise, ilk risk analizleri uzay ve nükleer enerji sektöründe yapılmıştır. Bundaki ana etmen, bu sektörlerde geçmişte çok büyük kazaların yaşanmış olması ve bu kazaların tekrar yaşanmaması ve de yaşanabilecek kazaların etkilerinin en aza indirgenmesi için bir şeyler yapmak gerekliliğidir. Risk kavramının denizcilik sektörünün literatürüne geçmesi ise biraz zaman almıştır. Geçmişte yaşanmış büyük kazalar ve 1988 tarihinde Piper Alpha açık deniz platformunda yaşanan ve 167 kişinin ölümüne neden olan faciadan sonra risk analiz yöntemlerinin denizcilik sektörüne de uygulanması yönünde Uluslararası Denizcilik Örgütü tarafından kararlar alınmıştır.

Uluslararası Denizcilik Örgütü (IMO), denizcilik sektöründe denizde can, mal ve çevre güvenliğine yönelik kurallar koyan ve koyduğu kuralların uluslararası bağlayıcılığı olan bir uluslararası organizasyondur. Yaşanan kazalardan sonra, Uluslararası Denizcilik Örgütü (IMO) tarafından Biçimsel Güvenlik Değerlendirmesi (BGD) nin ele alındığı komisyonlar oluşturulmuştur. BGD; riskleri belirleyen, riskleri azaltmak için ise IMO'nun önerdiği önlemlerin maliyet/fayda analizini yapan, sonrasında ise organizyonların karar verme sürecinde destek sağlayan sistematik bir risk değerlendirme süreci olarak tanıtılmıştır.

BGD; ilk defa Birleşik Krallık tarafından ülkenin açıkdeniz endüstrisindeki risk değerlendirme yaklaşımları baz alınarak önerilmiştir. 1993'te Birleşik Krallık Sahil Güvenlik Teşkilatı (UK's Marine Coastguard Agency) nın önerisiyle, Denizcilik ve Güvenlik Komitesi (Marine Safety Committee-MSC) nin 62. toplantısında BGD ilk olarak ele alınmıştır. 2 yıl sonra 1995'te, MSC 'nin 65. toplantısında BGD gündemde yüksek önceliğe sahip olacak şekilde karar alınmıştır. 1997'de, MSC'nin 68. toplantısında ve Çevre Koruma Komitesi (Marine Environment Protection Committee-MEPC) nin 40. oturumunda, "IMO'nun Karar Verme Sürecinde Biçimsel Güvenlik Değerlendirmesi'nin Uygulanması İçin Geçici Kılavuz" yayımlanmıştır. 1997'deki kılavuz (MSC Circ. 1023) baz alınarak deneme uygulamalarından edinilen tecrübeler, MSC'nin 74. toplantısında ve MPEC'nin 47. oturumunda geçici kılavuzun yerine geçmiştir. Yeni kılavuz, "IMO'nun Karar Verme Sürecinde Biçimsel Güvenlik Değerlendirmesi Kullanımı İçin Kılavuz" olarak adlandırılmıştır (MSC Circ. 1023 ve MPEC Circ. 392, 5 Nisan 2002). Böylelikle risk kavramı ve risklerin yönetilmesi kavramı denizcilik literatürüne girmiştir.

Bu çalışmada ise, Türk ve uluslararası sularda çalışan, Türk ve yabancı bayraklı gemilerin yaşadıkları kazalara göre kazaların nedenlerinin, etkilerinin, sıklık ve şiddetlerinin belirlenmesi ile bu kazaların önlenebilmesi ya da azaltılabilmesi için öneriler vermek amaçlanmıştır. Bunun için Biçimsel Güvenlik Değerlendirmesi Metodu kullanılmıştır. Çalışma için T.C. Deniz, Ulaştırma ve Haberleşme Bakanlığı kaza verileri esas alınmıştır. Çalışma, 2001-2012 yılları arasındaki kaza verilerini kapsamaktadır.

Çalışmanın ilk kısmında, risk kavramının ne olduğu, risk kavramının gelişimi ve tarihçesi, risk kontrolüne ilişkin metotlara yer verilmiştir. Risk kavramıyla ilgili literatürde ne gibi çalışmalara olduğu incelenmiştir.

Çalışmanın ikinci kısmında ise tezin konusu olan Biçimsel Güvenlik Değerlendirmesinin (BGD) ne olduğu, literatürdeki yeri ve gelişimi, BGD üzerine yapılan çalışmalar, BGD'nin nasıl uygulandığı üzerine bilgiler verilmiştir.

BGD metodu, güncel risklerin tanımlanması, risklerin sebeplerinin belirlenmesi, riski kontrol edebilmek için hangi önlemlerinin alınması gerektiği, alınacak önlemlerinin fayda-maliyet analizlerinin yapılması ve de eldeki sonuçlara göre karar verici mekanizmalara öneriler sunulması adımlarından oluşan sistematik bir metottur.

Çalışmanın üçüncü bölümünde, istatistiki değerler ve bu değerlere göre oluşturulan tablolara ve de bu tabloların yorumlanmasına yer verilmiştir. İstatistiki veriler, Türk veya uluslararası sularda seyreden Türk veya yabancı bayraklı gemilerin T.C. Denizcilik, Ulaştırma ve Habercilik Bakanlığı veri tabanında yer alan kaza verilerine dayanmaktadır.

Çalışmanın dördüncü bölümünü ise kaza verilerine dayanarak BGD'nin makine dairesi yangınlarına uygulanması esas oluşturmuştur. Eldeki kaza verileri ve raporları, ayrıca uzman görüşlere dayanılarak makine dairesi yangınlarının çıkış sebepleri belirlenmiştir. Bu sebeplerin sıklık/etki derecelerine göre risk matrisi oluşturulmuştur. Bu matrise dayanılarak en yoğun kaza sebepleri bulunmuştur. Sonraki aşamada ise bu kazaların nasıl kontrol edilebileceği belirtilmiş, kontrol seçeneklerine göre ise maliyet-fayda analizi yapılmıştır. Bundan sonraki aşamada ise çıkan en uygun sonuçlara göre kazaların nasıl azaltılabileceği belirlenmiş ve karar verici mekanizmalara öneriler verilmiştir.

Çalışmanın son kısmını ise sonuçlar ve öneriler kısmı oluşturmaktadır. Bu kısımda BGD'nin çıkan sonuçlar incelenmiş ve gelecek çalışmalarda neler yapılabileceği konusuna değinilmiştir.

Çalışmanın ek kısmını ise Haliç Tersanesi'nde bakımda olan Beyoğlu vapurunun makine dairesi resimleri ve yangın ekipmanlarının resimleri oluşturmaktadır. Beyoğlu vapuru personeli ve Haliç Tersanesi'ndeki mühendislerle makine dairesi ve burada çıkabilecek yangınlar üzerine görüşme yapılmış olup, uzman görüşler elde edilmiştir.

Bu çalışmadaki ana amaç, gemideki güvenliği etkileyen gemi makine dairesindeki yangınların en önemli nedenlerini analiz etmek ve gemi makine dairesindeki yangın güvenliğinin nasıl artırılabileceğine dair rehberlik yapmaktır. Bu amaçla, gemi makine dairesi yangınları üzerine Biçimsel Güvenlik Değerlendirmesi'nin deneme uygulaması gerçekleştirilmiştir. Ele alınan makine dairesi, standart ve insan kontrolündeki bir makine dairesidir.

1. INTRODUCTION

In this workout, it is aimed to identification of causes, impacts, frequency and severity of machinery room accidents and is aimed to preventing or reducing to risk of accidents based on accident statistics of Turkish or foreign flagged ships that operate in Turkish or international waters. For this purpose, it has been used Formal Safety Assessment Method and accident data of Republic of Turkey Ministry of Transport, Maritime Affairs and Communications. This workout comprises accident data from 2001 to 2012.

In first section of this workout, it is given wide coverage to what is the concept of risk, evolution and history of risk concept, and methods for risk controlling. Also, it is examined literature study about risk concept.

In second section, it is informed about what is the FSA, evolution and history of FSA, accomplished workouts and literature survey, and how FSA can be applied.

In third section, it is given place to statistical data, tables and comments about tables. Statistical data is based on accident data of Turkish or foreign flagged ships that operate in Turkish or international waters.

In fourth section, it is explained how FSA can be applied to machinery room fires based on statistical data. Causes of machinery room fires are determined in accordance with accident data and reports, and expert views. Risk matrix is generated with regard to frequency/severity degree of causes. Most encountered causes are determined with respect to this matrix. In next stage, it is indicated that how this accidents can be controlled and what is the cost/benefit of this controls. In last stage, it is aimed to how risk of accidents can be reduced with regard to optimum results and it is given recommendations to decision makers.

In last section of this workout, results and recommendations are argued. Outcomes of FSA are analyzed and it is mentioned to what can be done in future workouts.

2. RISK IDENTIFICATION AND RISK MANAGEMENT

2.1 Risk Identification and Type of Risks

Two basic concepts must be known to understand risk assessment: Hazard and Risk.

"Risk" is a combination of consequences and probability of occurrence of a harmful event. "Risk" is defined in a very wide range from an insignificant event to an accident at the level of disaster.

Risk explains effectively evaluated dangers considering future possibilities (Kuleyn, 2005). Risk is defined in dictionary as possibility of encountering danger or incurring losses. (Kuleyn, 2005).

The mathematical representation of the risk is;

Risk = Probability of Occurrence (P) X Effect or Severity of Event (S)

As mathematical formula suggests, risk has two components; these are probability of occurrence (frequency) and severity (impact) (Kuo, 1998).

Concepts of risk and danger are principally used in the same manner. However, they are completely different from each other. Danger is a property or condition to cause damage under certain circumstances (Kuo, 1998), Risk is a combination of probability of occurrence of a defined danger and size of the effects of this formation (Kuo, 1998).

It is unable to reset risk. However, it is possible to bring it the acceptable level by controlling.

There is a variety of risks types. This risk types can be defined as;

Total risk is the sum of identified risk and unidentified risk.

Identified risk is a risk that is determined for a variety of analysis techniques. The first work at the stage of risk assessment, in practice, is to make the identified risk as the biggest part of the pie. Time period and cost of analysis efforts, quality and technology level of risk management program, are effective in the detection of a greater proportion of the risks.

Concept of acceptable risk is not simple, as it seems at first. Acceptance of risk is a function of risk assessment and risk management. Some of the risks should be accepted. The decision of how much can be or cannot be accepted is within the area of competent authority. Risk is accepted, because it is wanted to take advantage of production that is made by activity that gives rise to the risk. However, the level of risk to the same extent for all activities is not required. This means that some risks are acceptable, while some risks are not acceptable to the same extent (Cadoglu, 2000).

Unacceptable risk is the risk that cannot be ignored. This is a subset of the identified risk that can be eliminated or controlled. Risk mitigation measures must be activated here.

Undetermined risk is yet unidentified risk. It is real and important but it is also unknown and cannot be measured. Some risks cannot be determined ever.

The remaining risk is the risk that is remaining after all risk management efforts. It is considered as risk. In fact, the remaining risk is sum of acceptable risk and undetermined risk. Accident investigations sometimes may reveal some previously undetermined risks (Cadoglu, 2000).

2.2 Risk and Uncertainty

Another concept that is closely related to the risk is uncertainty. Risk is often a concept measured based on statistical data that is related to probability of occurrence of an undesirable event. Uncertainty, however, is used in the absence of statistical data, is a concept that cannot be measured (Cagiran, 1997).

Risk is a measure of the amount of uncertainty that exists. Therefore, to increase the amount of uncertainty means the increase of the probability of occurrence of the risk (Kuleyn, 2005). The uncertainty is not negative or positive alone. Risk is generally considered as negative result, but on the other hand, it is also possible to identify the risk concept with the opportunity concept. When uncertainties is converted into opportunities, they provide a positive contribution to the process outcomes (Kuleyn, 2005).

2.3 Risk Management Process

Sea freight, mostly as a type of transport without alternative, in the case of an accident it causes huge environmental disasters like explosion, fire, marine pollution if it is taken into consideration, all need to do, to minimize the risks that may arise by using all the contemporary systems and devices that human beings has reached. It passes this way through “risk management”.

Risk management is a discipline that aims to reduce uncertainty and negative effects of uncertainty to an acceptable level and it is a proactive approach that provides the prevention of problems before they occur.

A ship that sails in the sea has a very large range of stakeholders. These are, Flag State, Port State, Coastal State, ship owner/renter, operator, cargo owner, ship crew, passengers, ports served, classification societies, other ships and crew of these ships etc.

The biggest advantage of risk management, it can be done before accident occurs, and in this respect, it has an accident prevention feature. In this context, it is essential to be recorded and be evaluated of near misses in risk management.

Risk management provides consistent, continuous and a basic way at every level of the process developed for identifying risk, assessing and controlling while improving performance. Individuals at all levels identify and control hazards throughout this process. Six digits of Risk Management Process are shown in Figure 1 (Cadoglu, 2000).

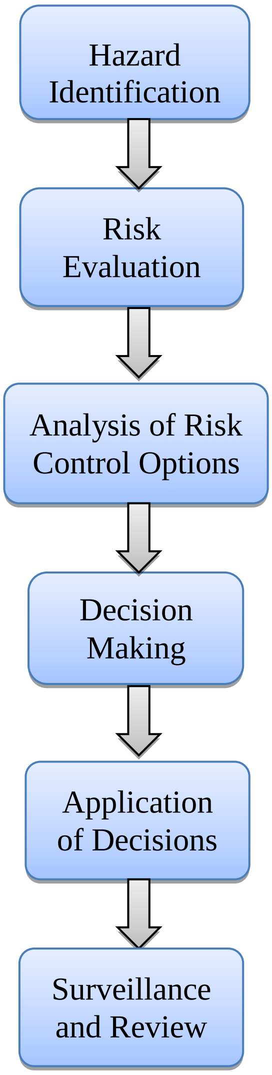

Figure 2.1: Risk Management Process.

1. Hazard Identification: Danger is defined as a potential or an actual situation that may result in loss of equipment or damage to its properties also may cause to death, personnel injury and malfunction of the task.

2. Risk Evaluation: Risk is severity and probability of loss due to exposure to danger. Evaluation phase is a practice of quantitative and qualitative measurement values to determine the degree of risk related to a particular danger.

3. Analysis of Risk Control Options: It investigates precise strategies and tools that degrading, reducing or eliminating the risk. Effective control measures degrade the one of the three arms of risk, which is probability, severity and exposure).

4. Decision-Making: Top executives select all of the controls relevant to the analysis of costs and benefits.

5. Application of Decisions: When control strategies are selected, the development of an implementation strategy and application of this strategy with workforce level and management level is needed.

6. Surveillance and Review: Risk management is an ongoing process throughout the lifecycle of the system, task or activity. Administrators\Leaders present control activities at all levels. If implemented decisions are already in place and right, the system itself will determine its effectiveness.

2.4 Risk Assessment

Risk assessment is an evaluation phase of risk-associated dangers. If it is known to impact of a danger on the work to be done and if it is estimated, that how it is formed, it is called as a risk not as a danger.

Risk assessment in maritime industry is based on determination of dangers in a specific sea area, identification of hazards how often they emerged after the examination of these hazards, and then what would happen if the danger were occurred. After putting forward the main issues risk will come out. The second stage is to determine the level of acceptance of risks after the risk identification made. It is called as risk assessment.

The possibility of an accident is proportional to the total probability defined as cause of danger.

The possibilities can be determined by estimates or real numbers if available. Estimating numerically of an accident probability to the new systems or tasks may not be possible at the beginning of the planning process (Cadoglu, 2000).

Hazard is determination of severity in terms of potential impact on human, equipment or task. Categories of severity are defined to provide a qualitative criterion for the worst accident expected that might arise from the personnel errors, environmental conditions, equipment deficiencies or procedure, system and sub-system failures (Cadoglu, 2000).

2.4.1 Risk assessment methods

Generally, there are two types of risk assessment method (Kuo, 1998).

- Quantitative method
- Qualitative method

In quantitative method, it is used numerical values for probability of the treat, impact of the treat, and these values is processed by mathematical and logical methods to find out risk value (Ozkilic, 2005). Quantitative techniques, if data is convenient, are especially suitable for complex and high-risk programs. Techniques are used such as error and event trees for measurement.

Qualitative method use descriptive values such as high, very high, medium, and small instead of numerical values when it is calculating and expressing the risk (Ozkilic, 2005). While doing a port's risk assessment, a well-considered risk application in a comparative method will give permission to identify of high-risk application without the need to determine the exact value of the risk. With this approach, it has been got through to data that is used in determining the priority of risk control, this method is will be more useful for ports (MSANZ, 2004).

2.4.2 Risk analysis

Risk analysis is core part where mathematical operations and interpretations are done in risk assessment. Main risk analysis is shown below (Ozkilic, 2005):

- Risk Map
- Preliminary Hazard Analysis (PHA)
- Job Safety Analysis (JSA)
- What if?
- Preliminary Risk Analysis Using Checklists
- Preliminary Risk Analysis
- Risk Assessment Decision Matrix
  a) L-Type Matrix
  b) Multivariate X-Type Matrix

- Hazard and Operability Studies (HAZOP)
- Hazard Rating Index
- Rapid Ranking, Material Factor
- Fault Tree Analysis (FTA)
- Failure Mode and Effects Analysis – Failure Mode and Critically Effects Analysis (FMEA/FMECA)
- Safety Audit
- Event Tree Analysis (ETA)
- Cause – Consequence Analysis

Preliminary Hazard Analysis (PHA): Preliminary hazard analysis is a qualitative risk assessment methodology prepared quickly which can be used as a model for studies that are more detailed or at final design stage. In this method, possible undesirable events is firstly defined then resolved separately. Each undesirable event or hazard, possible improvements and preventive measures are formulated. The identified hazards puts order and measures are taken in order of priority. Preliminary hazard analysis is applied in the early design phase by analysts, but it is not an adequate method of analysis alone.

What if?: This method can be applied at any stage of operation and can be executed by less experienced risk analysts. The general question starts with "What if?" and it based on the answers given. Possible consequences of deficiencies are determined and recommendations are identified in each case by individual responsible. This method is an informal method because it depends on experience of teammates of various disciplines and its results are affected too much by experience of the members (Kuo, 1998).

Preliminary Risk Analysis Using Checklists: The purpose of PRA is to assess by determining potentially hazardous components of system or process and is to determine more or less the possibilities of accident per potential hazard. Most likely, the purpose of this method is to quickly determine important problems can be occurred probable. Order to obtain efficient results in the use of checklist, it should be prepared by experienced professionals (Ozkilic, 2005).

Preliminary Risk Analysis (PRA): Preliminary risk analysis is a systematic method to analyze accidents can be occurred while performing an activity.

It has been sought answer of that question to identify accident; “what kind of potential accidents may occur while performing this activity?”

It has been sought answer of that question to identify the events that contribute to; “When doing this activity, what is the most important event contributing to the creation of this accident?”

- Human error
- Hardware fails or error
- System error
- Environmental error
- Management weaknesses etc.

It has been sought answer of that that question to identify preventive and mitigating protection; “While doing this activity, which engineering or management control is used to help in reducing frequency and severity of accident?”.

- Administrative procedures,
- Plans,
- Education and information,
- Equipment etc.

Risk Matrix: Risk matrix is a document containing information about risks such as “likely to occur/effect to result” or “time interval/severity” (Kuleyn, 2005). Risk assessment matrix that is one of the most used approach, has been developed to meet the requirements of the system safety program. Matrix diagrams is an assessment tool which is used to analyze relationship between two or more two or more variable.

L-Type Matrix: 5 x 5 Matrix diagrams (L-Type Matrix), in particular, are used to evaluate cause and effect relations. This method is simple to perform risk analysis, so it is ideal for the analysts, but it is not sufficient for all jobs that include different processes or have flow chart very different from each other and success ratio of method changes by analyst’s experience.

The other component at risk matrix is impact measure. Impact measure that will be used in risk assessment related to maritime operations at ports is dealt with four different points of view. These are (MSANZ, 2004);

- Human risk,
- Financial risk,
- Environmental risk,
- Stakeholders risk.

Referred to fourth clause, losses that affect social stakeholders of port is calculated based upon potential commercial losses that will be occurred due to an incident. For example; a ship ran aground in the port will cause full or partial closure of port a significant period of time and it would lead to the possibility of commercial losses may occur (MSANZ, 2004).

In Table 2.1, it has been given an example of standard risk matrix prepared for use in risk assessment will be done at ports. Together with this matrix, it will be graded by identifying risks, probability and impact categories that a port is faced with (MSANZ: 2004).

Consequence	C4	5	6	7	8	10
	C3	4	5	6	7	9
	C2	3	3	4	6	8
	C1	1	2	2	3	6
	C0	0	0	0	0	0
Frequency		F5	F4	F3	F2	F1

Figure 2.2: Sample Risk Matrix.

The figures indicated above matrix are defined as follows:

0 & 1: Negligible risk (unimportant)

2 & 3: Low risk

4 & 5: Moderate risk (ALARP)

6: Rising risk

7 & 8: Significant risk

9 & 10: High risk

Risks that are included in ALARP region of matrix are taken into consideration insofar costs permit. ALARP is a very helpful and numerically expressed concept for a quantitative risk assessment (Kuo, 1998).

Hazard and Operability Studies (HAZOP):

By chemical industry, it has been developed by taking into account special hazard potentials of this industry. It is a systemically brainstorming study. It has been asked certain structured questions, then in case of these events occurred or not occurred; it has been asked what kind of results come into being. Later, preventive protective measures are identified and after preventive measures have been taken, it is decided whether the remaining risk is acceptable or not. If the remaining risk is in an unacceptable level, actions must be identified (Ozkilic, 2005).

Fault Tree Analysis (FTA):

Concept of fault tree analysis (FTA), is designed for to carry out an assessment of security of intercontinental ballistic missiles targeting control system in 1964 at Bell Telephone Laboratories.

This method is a technique that is based on deductive logic. FTA is a schematic representation of critical or major errors, causes and potential counter measures related to works done at an establishment. In FTA, it is revealed unwanted possible errors and causes by getting to the root of the unwanted event (Kuo, 1998). For example, the cause of a bulb is not lighted up:

- Switch failure,
- Power supply failure,
- Blowing of fuse,
- Loose weld
- Bulb failure,

or may be a combination of these. Therefore, bulb is not lighted up; it is modeled by combining a logic or gate with indicated events.

Taken measures to prevent a peak event are analyzed in detail. Unwanted peak event is identified, then it is analyzed all factors that can cause this event are analyzed

Failure Mode and Effects Analysis (FMEA): Failure Mode and Effects Analysis is used for identification of potential error types and the classification of these type errors according to degree of detection and intensity at the process of product, design and service that are subject to the review. Failure Mode and Effects Analysis aims to determine consequences and severity of consequences by revealing possible types of error. Failure Mode and Effect Analysis is a technique that can be applied in order to prevent growth of problem.

With this technique, the prediction of fatal errors and establishment of preventive actions are possible (Yilmaz, 2000).

The discipline of Failure Mode and Effects Analysis is developed by the U.S. Army.

Event Tree Analysis (ETA): At first, event tree analysis has been involved in nuclear industry, later it is started to be implemented often in other sectors. Event Tree Analysis is a method that shows diagram of flow of results can be emerged after the occurrence of the event selected at first (Kontovas, 2005). Differ from fault tree analysis, this methodology uses inductive logic (Ozkilic, 2005).

The left side of the diagram is connected with the initial event; the right side of it is connected with damage case of factory/enterprise; the top side of it defines the system. If the system is successful, the road goes up side; if not, it goes down side (Kontovas, 2005).

Logic of event tree analysis is opposite to the logic of fault tree analysis. This method can be used on continuous systems or systems in “standby” mode.

2.5 Determination of Hazards

Determination of the hazards forms the basis of all Risk Management process. Of course, if hazards cannot be identified, they cannot be controlled. The effort used to identify hazard will be reflected in a positive way to all Risk Management process (Cadoglu, 2000).

Hazards and factors that cause them are determined by shortcomings that will be corrected and definition of needs for task or system. The list of hazards that are related to each phase of stages or operations of business management are done (Cadoglu, 2000).

The lists of reasons that are related to all kind of hazards that are specified in hazards list are done. A hazard may be due to several reasons. In any case, it tries to find out the real reason.

2.6 Decision Making

The decision maker chooses the preferences of control after obtained information about possible controls. This is not a temporary decision. Decisions are given due to awareness of the hazards and knowledge about how much the hazard control is important in achieve the task or not achieve the task (cost/income analyze). The decision maker should allocate resources in order to control the risk. Within the framework of risk reduction, continue to apply control measures for a small percentage of plus efficiency, after that point it enters in the process of that cost is not too high (Cadoglu, 2000).

It is important to remember that the goal is not the lowest risk level; it is most proper risk level that is beneficial for enterprise.

2.7 Application of Decisions

When the decision was given, the existing resources should be available to complete certain controls. A part of the application phase of the control preferences is to inform the staff about the results and the next decisions. If there is a dispute, managers (decision makers) have to make a logical explanation.

In order to maintain the effectiveness of Risk Management, Risk Controls must be continuous. This means that in order to gain a lot at one time, the responsibility is to maintain.

2.8 Surveillance and Review

The last stage of Risk Management Practices is a stage that is determined the activities performed during the phase of Risk Controls. This phase includes three elements. The first of this, is to observe the effectiveness of risk control; the second of this, is to identify the needs for re-evaluation of the conditions affecting all of the task or a part of the task that is originated from unexpected changes, the third of this, is to learn a lesson from part of future activities that may be similar or identical nature whether positive or negative.

Effective implementation of corrective and preventive patterns of movement, and in order to explore the new hazards, the feedback system should be established. When deciding on the adoption of a risk, these decision elements (benefit and cost comparisons) should be recorded. This process, when an accident or negative results have become real, is provide to revision of risk decision process for see the result of changes in procedures and techniques or where mistakes can be made. Without having a feedback policy (system), it cannot be with the ease of knowing that presumptions are not certain or they contain small errors or they are totally wrong (Cadoglu, 2000).

3. FORMAL SAFETY ASSESSMENT

3.1 Development and Description of Formal Safety Assessment

Analysis of risk was the main concern of energy and aviation sectors before its use in maritime sector. Purpose of using risk analysis methods is the reducing the risk factor before the accident occurs and preventing accidents as far as possible.

In the early 1970s, risk assessment methods was applied in nuclear energy sector. But its first practice was taken part after 1979 Tree Mile Island nuclear accident occurred. After that accident, risk analysis methods for nuclear energy plants has been applied considerably.

In the early 1980s, NASA was introduced first risk assessment criteria for its Apollo space program. After the Challenger accident in 1986, NASA was developed Quantitative Risk Analysis method, after a while two astronaut was tasked with working on this method. In addition, NASA is the first organization that developed Quantitative Risk Analysis Software-QRAS (Kontovas, 2005)

Concept of risk analysis methods has been gone into maritime sectors literature late compared to other sectors. Between 1980 and 2001, 1377 people was seriously wounded and 367 people was lost their lives in maritime industry. In this period, most important accident that cause to 167 people was lost their lives is Piper Alpha offshore platform disaster in 6 June 1988. After that accident, risk assessment methods has become very important (Kontovas, 2005). It has been discovered inadequate managerial methods cause to chain reaction of faults, because of this accident happened. Also fire instability of platform caused to unpreventable events. When this accident evaluated in the manner of risk management, it brought into question that how parameters that are independent from each other come together and cause to a disaster. Probability of occurrence of dangerous accidents that are originated from simple accidents occurred in a sequence was examined (Pate-Cornell, 1993).

Scientific and technological advances brought development in design and construction areas in cargo vessels. Safer, cheaper and faster transportation systems came forward by development of world maritime trade. By spread out of this systems, the need of ships that have more tonnage capacity was increased. The bigger vessels caused to more operational expenditures, and as a consequence of this, safety on the ships has been decreased (Akyildiz, 2012).

In past accidents, incidents like “load shift”, “personnel injury”, “collision”, “structural failures”, “pollution” caused to accidents. In category of accident type, although “collision” and “grounding” has been taken up great part, “fire” considerably caused to dangerous accidents, loss of life and property (Henley, 1992). When type of accidents is handled, most of accidents has become real due to “cargo load”. Statistics show that eventuated accidents was arisen from “human errors”. Another characteristic of cargo vessels is its rare voyage in ballast condition and its short overnight stay in ports (Akyildiz, 2012).

It has been focused on safety of cargo vessels in last 15 years. Because most serious accidents was happened in this period. As a result of this accideents, IMO has begun to apply risk management process called as Formal Safety Assessment to prevent accidents. For IMO, Formal Safety Assessment is a risk management and helping tool to do cost/benefit analysis of practiced options to reduce or remove risks that are existed or have potential to occur (Akyildiz, 2012). FSA firstly introduced by United Kingdom and it is based on risk assessment methods applied in maritime sector of UK (MSA, 1993). IMO firstly examined FSA at 62. Session of MSC at the request of MCA in 1993.

In 1993, MCA proposed a method consist of five steps called Formal Safety Assessment at the 62. Session of IMO. A working group was established by IMO because of FSA was never applied on a ship before.

In 1995, MSC agreed on FSA has priority on its agenda. In 1997, it decided to creation of a temporary guide to apply FSA at the 68. Session of MSC and the 40. Session of MPEC (IMO 1997). FSA guide was updated with regard to experiences at the 74. Session of MSC and the 47. Session of MPEC. New guides was named as “Guidelines for Formal Safety Assessment for Use in the IMO Rule-Making

Process" (IMO, 2002). In 2007, revised guidelines putted together as one at the 83. Session of MSC (IMO, 2007).

FSA has been applied a variety of branches in maritime sector. Thus FSA applied on several ship types and also applied on several accident types. Below it can be found chronological sequence of researches related to FSA.

Wang (2000), was proposed a draft of subjective safety assessment for the decision-making step of FSA when a high degree of uncertainty exist.

Wang (2001), was submitted a draft of FSA. In this draft, risk criteria in terms of ship safety and operational and design applications was available.

Wang and Foinikis (2001), was written an article about FSA and its development in maritime industry. In this workout, accident statistics and design parameters of container ships and application of FSA to container ships was available. In addition, it has been showed to increase safety level in maritime industry based on a proactive and risk basis regime by using FSA methodology.

Lee (2001), was applied FSA methodology in watertight sections of bulk carriers. This workout was came true in cooperation of Korean Lloyd and Seoul National University. At the end of research, 18 hazard identified and 32 risk control measure developed in order to decrease risks.

Kristiansen and Soma (2001), was studied a research for development of safety in international maritime industry. In this workout, deficiencies of existing safety regulations was mentioned and systematic safety management and adaptation of FSA was proposed. Emergency evacuation was proposed as a case.

Roberts and Marlow (2002) was investigated effect of various risk factors on structural failures of bulk carriers. At the end of investigation, it was determined 4 independent risk factor and it was used for safety of bulk carriers.

Lois (2004), was done researches that FSA could be applied to passenger ships. Research included application of FSA to passenger ships and development of FSA. A case study was done for passenger ships.

Fang (2005), was done a study for application of FSA to prevent human errors in ship operations. Navigation simulations was used for this study.

Kontovas and Psaraftis (2006) was exercised on practices to develop FSA method. It was an objective and transparent study.

Hu (2007), was done a study about quantitative risk assessment and modelling included criteria of importance level and frequency in ship navigation. Risk assessment model that forms from fuzzy logic frame was originated from 5 factor consist of accident characteristics. It was proposed that this model could be evaluated under the topic of ship navigation in order to decrease human error.

As a result, FSA has been used from the early 1990s to nowadays in maritime industry. It has updated and reviewed as time goes by.

3.2 Formal Safety Assessment Method

Formal Safety Assessment is described by IMO as: FSA is a systematic methodology considering risk analysis and cost/benefit assessment purpose of safety of human life, environment, health and maritime (IMO, 2007).

There are significant differences between FSA and Safety Case Approach. SCA is based on application of safety precautions for certain type of ships. But FSA is applied for certain dangers and general type of ships. Also two methods adopt same philosophy (Wang, 2001).

FSA is a helping tool which takes part in development of new safety regulations or analysis of old regulations and by this means it equilibrates between technical and operational issues (Dasgupta, 2003).

Most basic feature of FSA that is separating it from other risk assessment methods is its philosophy. In other risk assessment methods, it has been questioning that “Where did mistake do? How can it be fixed?” In FSA methodology, the purpose is the prevention of accident before it has happened. And so it has been questioning that “Where can fault exist? Which safety measures should take in order to prevent accident?” (IACS, 2008).

3.3 The Purpose of Formal Safety Assessment

The purpose of application of FSA in maritime industry is to do a general analysis to increase safety in maritime industry upon ship design, supervision, operation and navigation. FSA has an important role in safety of maritime industry by using as a tool to developing existing regulations or making a major contribution on addition of new regulations to existing ship design, engineering techniques, ship operation and control, safety management standards and regulations (Fang, 2005).

FSA has been developed as a helping tool in decision-making process by IMO. By means of FSA, decision-making procedures become more rational, provide prospective and holistic approaches and consequently a decision-making draft which takes politically a small space and prevents temporary solutions has been constituted.

FSA provides trustable information about risk of hazards, risk control options, cost and benefit of this options for the development of decisions taken in risk management stage (IACS, 2008).

3.4 Basic Definitions

Threat; is the potential for harm or damage to the employees, the workplace and the environment due to physical imperfections of working environment and improper behavior of people.

Hazard; is defined as physical injury, death, disease, loss of property or equipment and any kind of loss arising from this.

Risk; is combination of results and probability of occurrence of a harmful event that may occur. Risk is defined in a very wide range from a minor incident to an accident at the level of disaster.

Risk Management; is systematical application of policies, experiences and resources devoted to evaluation and control of risks that are related to human life and environmental safety.

Due to prepared report in accordance with resolution taken at the 244th meeting of Board of Directors of International Labor Organization (ILO), risk is defined as "Probability of occurrence of an undesired event in a certain period of time or under circumstances, frequency and probability with respect to environmental conditions"; risk management is defined as "All attempts to improve and maintain work safety measures in an organization (Ozkilic, 2005).

Risk Assessment; is a study using qualitative and quantitative methods in order to reveal, eliminate (or reduce to an acceptable level) risks that are originated from working environment and conditions or dangers arising from the existing environment in a systematic way.

In Occupational Health & Safety Assessment Series (OHSAS 18001), risk is defined as combination of probability of occurrence of an identified hazardous event and the result of it; risk management is defined as decision-making process whether the risk is tolerable or not and as a process of calculation of the magnitude of the risk.

According to Turkish Standards (TS) 12100:2010 (Safety of machinery - General principles for design - Risk assessment and risk reduction), risk assessment is a number of logic step that allows systematically revision of hazards.

Formal Safety Assessment is defined as identified hazards, assessed risks and methods of action that has been decided to manage these risks.

Qualitative techniques; define risk with descriptive terms such as high, medium or small.

Quantitative techniques; digitize risk and calculate risk depending on the numerical definitions such as error count of equipment, human error and so on.

Accident; is undesired event that led to death, damage to health, injury, damage, loss or other adverse losses.

Event; is a situation that cause an accident or with the potential to cause an accident (Ozkilic, 2005).

Safety; is a situation that there is no risk of damage, loss. Stay away from inadmissible risk of damage (ISO / IEC Guide).

Hazard Identification, in accordance with OHSAS 18002, is recognition that there is a danger and is identification of the characteristics of it.

3.5 Formation Theories of Accident

Accident can be defined as an event that becomes suddenly, unwanted and unplanned, often cause to death, injury or damage to property or accident are events that come in suddenly out of control after a phenomenon previously unknown occurs and that damage to the physical integrity of the person or damage to the property. Here are some theories below to gain a perspective (Ozkilic, 2005):

Single Factor Theory: This theory comes about concept suggests that an accident emerges because of single cause. If this only reason can be recognized and eliminated, accident will not repeat.

Energy Theory: According to this theory, accidents mostly occur during the transfer of energy. This energy discharge rate is important because the larger the discharge energy, the greater the potential for damage.

Human Factors Theory: This theory bonds accidents to chain of events caused by human error. The theory contains three important factors leading to human error: Overload, not-suitable response and untimely activities. Accidents originated form human error is based on many factors. Of course, reasons such as lack of education, out of keeping with work, incompatibility, lack of knowledge, inexperience, tiredness, being excited or upset, inattentiveness, carelessness, listlessness, looseness, lack of skill and illness, and so on., or have failed to comply with the rules in spite of all, are among the main reasons depending on human factor.

Accident / Incident Theory: This theory is expanded form of human factors theory. In addition, it reveals new elements such as ergonomic deficiencies, decision of making mistake and system errors.

System Theory: Theory reviews any situation that an accident may occur as a system consisting of three components: human, machine and the environment.

Combination Theory: It argues that a single theory alone could not explain all the events. According to this theory, the actual cause of accidents can be achieved with a combination of two or more models.

Multi – Factor Theory: Accident is analyzed and evaluated together with the many factors. This theory and analysis methods are accepted and implemented by many experienced health and safety experts. Accidents are multi-factors and are occurred as a result of a chain of errors, sub-standard practices, the formation of sub-standard conditions.

Domino Effect: Events in this theory are described in analogy with lower each other by ordering five dominoes in a row. Any accident occurs as a result of back-to-back arrangement of five main causes at least. This is called “Chain of Accident”.

Unless one condition is not occurred, the next one does not occur and unless chain is not completed, accident will not occur.

3.6 FSA Methodology

Formal Safety Assessment (FSA) is composed of five steps, according to the FSA guidance document prepared by the IMO is shown in Figure 2.

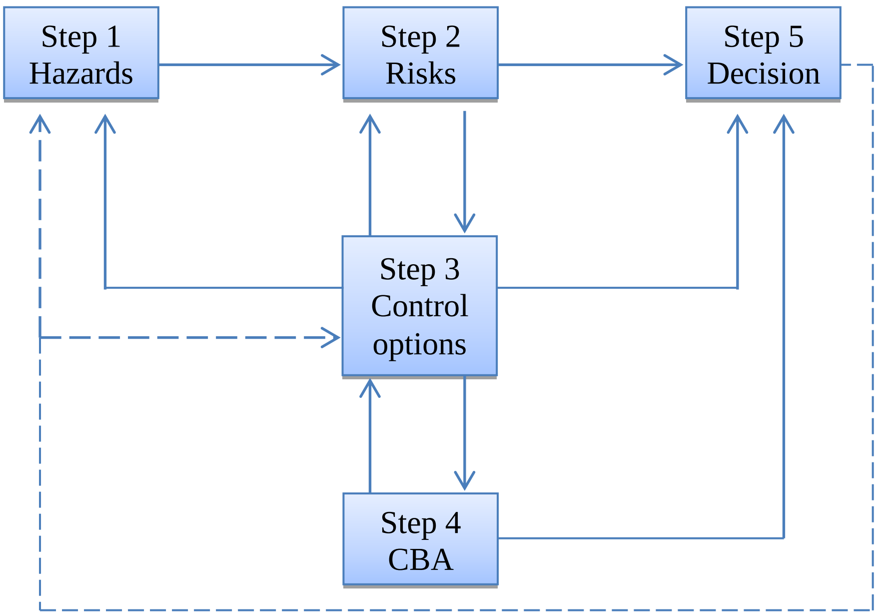

Figure 3.1: FSA Methodology (Akyildiz, 2011).

1. Identification of hazards
2. Assessment of risks
3. Risk control options
4. Cost – Benefit analysis
5. Recommendations to decision-makers

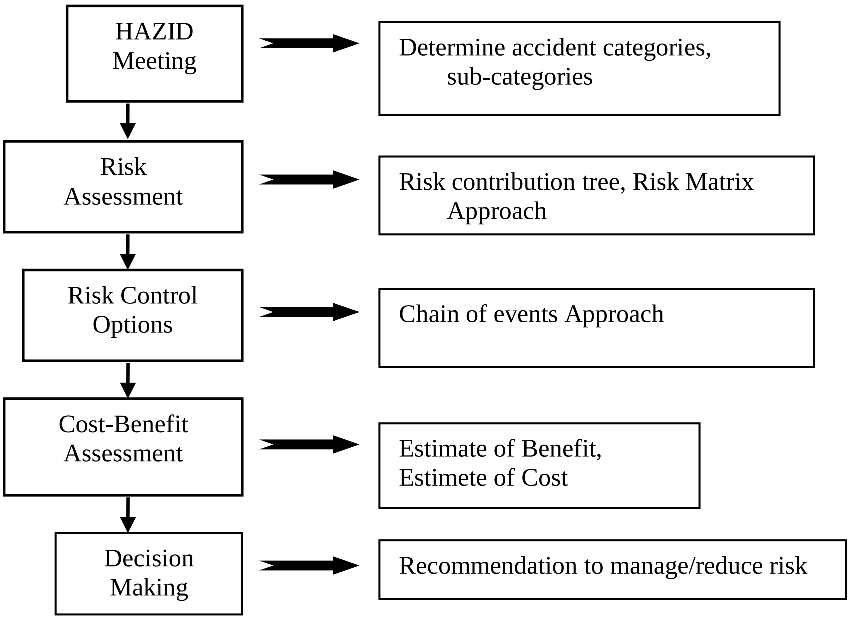

Figure 3.2: Flowchart of FSA Methodology (Akyildiz, 2011).

Before starting to Formal Safety Assessment, decision-makers make identification of obstructive problems related to topic. Purpose of defining problem, is to make in-depth review to make a careful analysis.

According to International Association of Classification Societies (IACS), the flow chart of FSA methodology is shown in Figure 3.1.

Step 1; Identification of Hazards: Hazard identification stage is the most important step in risk management and it is different from other stages. It is objectively analysis of effects that may cause potential harm or damage in system or organization. The purpose of this step is to list dangers, to associate with scenarios and to cascade according to level of risk. In this step, experiences of experts and data banks generated with obtained knowledge from past incidents are effective factors in achieving results (Kontovas, 2005).

Step 2; Risk Assessment: The possibilities combined with most important scenarios that are defined are being explored in the previous step. In the second step, once again, it is needed to emphasize the use of the word probability. If there is no data in hand relevant to the issue before, the calculation is performed taking into account the possible approaches. Most of the time, the focus is on high risk factors at this stage. Overall, “Fault Tree” or “Result (Event) Tree” is generated by the resulting data (MSC Circ.1023).

Step 3; Risk Control Options: To focus on the subject is within the framework of a control. In addition, as results of experiments or measurements are made, definitions are made in order to completely eliminate the risk or reduce the possibility of occurrence/the frequency. With re-evaluation of second step (risk assessment step), more effective results can be obtained (MSC Circ.1023).

Step 4; Cost-Benefit Analysis: For the implementation of each risk control option in the previous step, cost and benefit assessment is evaluated. By doing comparison as a result of assessment was done, classification is done according to needed cost to prevent disaster (Kontovas, 2005; MSC Circ.1023).

Step 5; Recommendations to Decision-Makers: This step should include comparisons of all possible risk reduction options and risk reduction options based on effectiveness of their costs. As a result of this comparison, Acceptable or Negligible results should be presented to decision-makers. All Formal Safety Assessment (FSA) should be calculated and should be at an acceptable level.

FSA is not to decide, is to produce decision. The FSA has its own limitations. FSA is not a magic wand to solve all security problems in the maritime industry or to eliminate all risk factors and to make decisions. In any case, the outputs have been limited to the inputs and processes done are parallel with this. In the other hand, FSA is a valuable and valid tool to produce decision for IMO (Kontovas, 2005).

Acceptance of risk existence where human activities has existed is not a fatalistic approach, it is only the acceptance of a truth. When safety aims, it must be accepted that there is always a risk to a certain extent. In other words, it must be complied with the following principles in safe approach:

Phase 1	What can go wrong?	Hazard Identification
Phase 2	How often does it be?	Risk Analysis, Frequency,
	How bad could it be?	Probability, Impact
Phase 3	How can it be improved?	Risk Control Options
Phase 4	How much does it cost?	Cost Assessment
	How much does it cost more?	
Phase 5	Is it worth to do all these?	Tips

3.6.1 Step-1 identification of hazards

According to Merriam-Webster Dictionary, meaning of the word 'Hazard', is the occurrence of an event that is unplanned and unthought-of before.

According to IMO MSC/CIRC 1023, Hazard is defined as potential threats to human life, human health, property or environment.

The aim of Hazard Identification is to list the dangers, to associate with the scenarios and to cascade according to level of risk. In this step, experiences of experts and data banks generated with obtained knowledge from past incidents are effective factors in achieving results (Kontovas, 2005)

Hazard Identification covers systematic identification of hazards and determination of incidents or costs resulted from this hazards.

Identification of hazard is always being a factor that has been obtained because of strong and effective punishment experience.

Hazard and Operability (HAZOP) study is the most effective hazard identification (HAZID) method used in the maritime industry.

Hazard and Operability (HAZOP) can be defined as an examination of impact of hazard over activities/processes. This process is done by an experienced team that is consisting of independent groups and an independent leader who manages and guides these groups.

The strength of HAZOP (Kontovas, 2005);

- It has been emerged as a result of an in-depth analysis. And its advantages and disadvantages are well known.
- The user is to be formed using the expertise of personnel.
- It is a systematic and versatile study and it includes any kind of hazard.
- It is effective against all technical and human-caused errors.
- It includes advanced formulas as well as being a safety guide.
- With the discipline and organization provided from environment, working team reveals various solutions and ideas.

The weaknesses of HAZOP (Kontovas, 2005):

- The success of this study depends on the level of knowledge of the team leader and the team, and level of the work.
- Hazard identifications produced during operation are those that affect the process, it does not contain other types of hazard.
- To do an effective and useful study, it should be got rid of intermediate procedures and avoided from details. This is not possible in practice.
- Documents length (to ensure that a complete record).

The first step to improve the safety of any waterway in planning is to collect the data that belongs to appropriate field in a healthy way. Other required information like date of accident, severity (the number of people that is killed and wounded), type (conflict, from rear (stern), from front, from side, vehicle/vehicle, vehicle/fixed object conflict/collision etc.), lighting, navigational aids related problems etc. should be collected from accident reports.

In maritime industry, matrix approach foundation of risk assessment facilitates the comparison of risk levels. Risk matrices provide great benefit to downgrade to simplify sophisticated approaches.

Risk = Probability of Occurrence (P) X Effect or Severity (S)

Risk = Probability X Consequence

Risk Index = Frequency Index + Impact Index

3.6.2 Step-2 risk assessment

Risk Assessment, is a comprehensive process to make a decision about estimation of the magnitude of risk and about risk can be tolerated or not.

Within the framework of existing controls, high-risk areas in terms of probability and consequence are determined. A series of result can be considered, the probability and impact estimation are done to produce an estimation of level of risk. Many methodologies is available for making risk analysis, the most appropriate one is selected. Risk analysis is performed with the use of quantitative or qualitative methodologies (Ozkilic, 2005).

The purpose of the second step is to define the distribution of risk. To do this, in order to identify and assess the factors affecting the degree of risk, the work is done on high-risk areas. Another purpose of this is to establish a connection between occurrence and frequency of accidents for IMO's decision-makers. In risk assessment stage, to decide on the acceptability of risk, a comprehensive decision is making on the importance of the risk.

To show diagrammatic distribution between different accident categories and their sub-categories, Risk Distribution Trees are used. Causes of accidents and stages of development of accidents are shown using Fault Tree Analysis (FTA) and Event Tree Analysis that is widely used in FSA study. In addition, other enhanced techniques can be used. Risk analysis methods are examined in detail before.

Fault tree (FTA) methodology are logical diagrams showing the relationship between the causes of events that are single or in combination, likely to be occurred. This method is a technique based on deductive reasoning. Fault tree is to define paths of errors and is to define ways will cause physical and human-induced errors

FTA is an analyst technique that focuses on a particular error event. If two or more lower-level event causes to occurrence of a higher-level event, this is described with a logical diagram too (MSC/Circ 1023).

Event Tree (ETA) analysis is used for analyze of effects of unexpected events, errors and accidents. Because of it shows the pre-accident and post-accident situations, it is the main technique used for analysis of results.

The left side of the diagram is connected with the initial event, the right side of the diagram is connected with the damage case in enterprise and the top side of the diagram defines the system. If the system is successful, the way goes up, if not, it goes down. Success or failure path leads to variable-sized results (MSC/Circ 1023). The logic used in event tree analysis is opposite to the logic used in fault tree analysis. Unlike the fault tree analysis, this methodology uses inductive logic.

In risk assessment, measures of frequency of events are determined in two ways. The first of this method, to use the statistical data of events have occurred in the past, other method is to utilize the frequency index. The first way is usually preferred and used by the IMO.

3.6.3 Step-3 risk control options

It is the discussion of measures to be taken regarding the assessed risks. Risks normally can be reduced by one or several security measure. Reduction in risks occurs on results or on probability of occurrence. Control measurements can be done through "Engineering Control" or "Administrative Control". "Engineering Controls" refers to protection methods, equipment such as barriers and "Port Control System". "Administrative Controls" refers to the path of the publication of articles such as safe operating procedures, safety and security systems.

Necessary changes related to identified risk mitigation and control measures are put into practice, but the control measures primarily reflect the principle of the elimination of hazards and risk. If risk cannot be eliminated, it can be mitigated. Implementing control measures take a long time, because it may be needed to the purchase of education, hardware or hardware changes due to the resistance to change.

3.6.4 Step-4 cost-benefit analysis

The aim of this step is to perform cost and benefit assessment for application of each risk control options in the previous step. As a result of evaluation made, classification is done based on needed cost for preventing the disaster by comparison (Kontovas, 2005).

Sought answer to the question in step 4;

"How much will it cost and to what extent this cost will improve the situation?"

Cost-benefit calculation should be comprehensive as wide as possible. In general, cost includes expenses incurred during the life of the system and includes the initial costs. The benefit rises in value when risk decreases (Kontovas, 2005).

Cost is often dependent on excessive use of monetary units; benefit is dependent on the prevention of the loss of a ship, environmental and economic factors.

Unless enterprises cannot determine the true cost of accidents or do not have this awareness, to reduce or prevent accidents is not possible.

By this kind of analysis, it is calculated total benefits of regulatory measures; these benefits are compared with the total costs; thus, it arises that whether the arrangement is worthwhile or not.

After the Cost-Benefit estimate, this data must be associated with risk reduction.

3.6.5 Step-5 suggestions to decision-makers

The purpose of the last step is to contain comparison of all possible risk reduction options and risk mitigation options based on effectiveness of their costs. As a result of this comparison, Acceptable or Negligible results are presented to decision-makers. All Formal Safety Assessment should be in a calculated and acceptable level.

The most important recommendations for risk control options;

- What is the impact of cost?
- Is the risk has been reduced to the desired level?

Health and Safety Executive of England (HSE) has defended a connection between occupational health & safety and profitability for many years. Unless enterprises cannot determine the true cost of accidents or do not have this awareness, to reduce or prevent accidents is not possible.

Health and Safety Executive of England developed a “Cost Methodology” to determine the cost of losses due to work-related accidents can be prevented and aiming to control the causes of the losses the firms faced. To achieve this goal, this methodology deals the “Work Accident” definition as very broad. Injury, disability, death or illness of the person doing job, losses related to harm to building, facility, equipment, materials or environment, or all unplanned events resulting in losses of work, all of them are evaluated as work accident (Ozkilic, 2005).

Health and Safety Executive of England (HSE) states that risk should be considered in three states. The area of hazards that probability of occurrence of it is frequent and the area of risks that the effect of it is described as disaster are an unacceptable area. Regardless of the cost of assessed risks in this area, risk reduction process has to be done. Another area is a region where frequency of risks is too low and consequences of it are too unimportant at the same time. Risks in this region are at a level of broadly acceptable, any “risk reduction” process is unnecessary. The third zone between other two zones is defined as ALARP (As Low As Reasonably Practicable) zone. In this region, the risks are taken into consideration to the extent of cost allowed. ALARP, for a risk assessment with quantitative approach, is a concept that is very helpful and can be expressed numerically. However, for a risk assessment with qualitative approach, ALARP's position is more abstract.

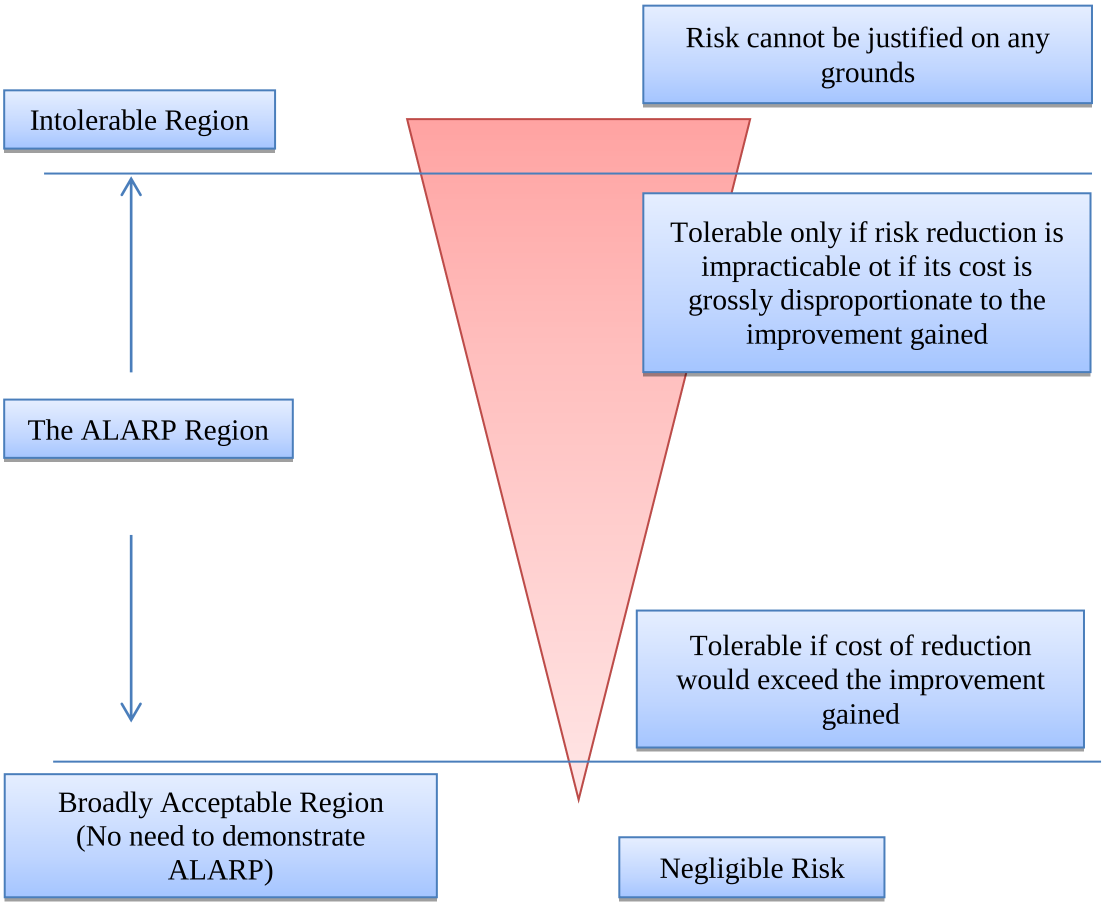

Figure 3.3: ALARP (Akyildiz, 2011).

4. ACCIDENT STATISTICS

Most important step of FSA is the first step that determines accidents. Accordingly it is important to have accident statistics and determines accidents according to data. In this section, it will be dealt with accident data of Republic of Turkey Ministry of Transport, Maritime Affairs and Communications. Scope of this work is involved between 2001 and 2012.

Table 4.1: History-Number of Accidents (MTMAC, 2013).

DATE	NUMBER OF ACCIDENTS
2001	131
2002	93
2003	115
2004	151
2005	147
2006	116
2007	117
2008	206
2009	171
2010	229
2011	161
2012	157
TOTAL	1794
FIRST 7 YEARS	124,2857143
LAST 5 YEARS	184,8

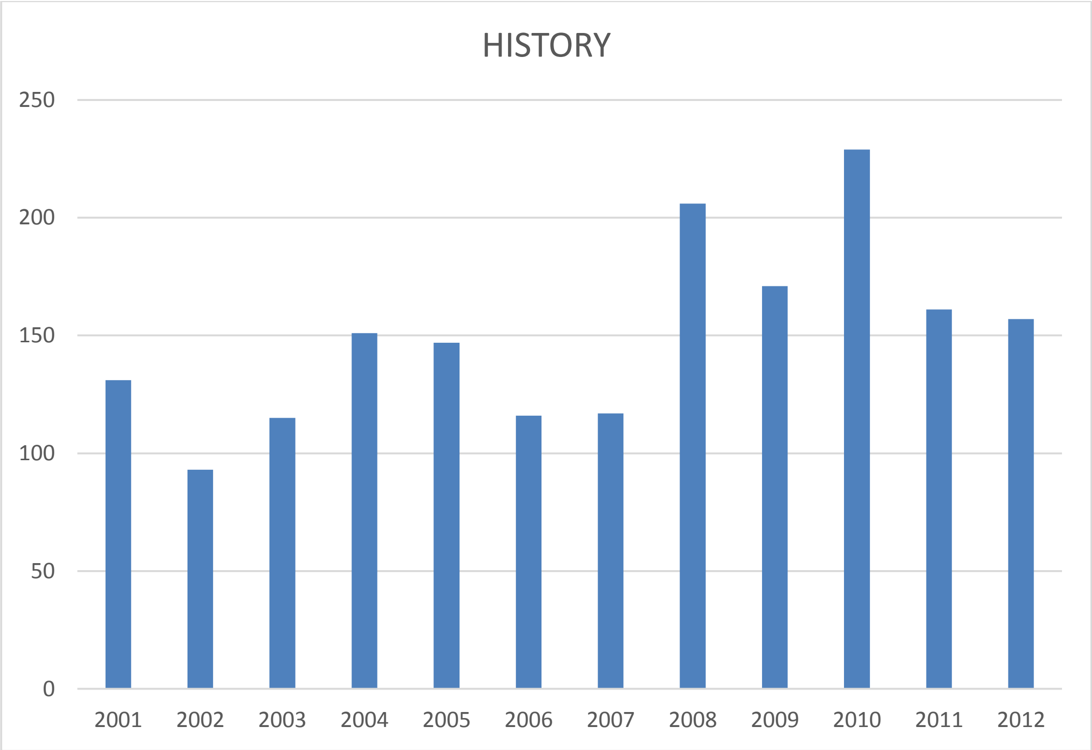

Figure 4.1: History-Number of Accidents (MTMAC, 2013).

If data is classified in terms of history, the number of accidents is maximum at 2010 and is minimum at 2002. Causes of this situation are increasing volume of world trading and expansion of ship fleet etc. In addition, it is experienced %50 more accidents on average at last 5 years compared to first 7 years. It is shown a decrease in accidents after 2010 but still more than first 7 years. Increasing safety precautions is effective at this situation.

Table 4.2: Region-Number of Accidents (MTMAC, 2013).

REGION	NUMBER OF ACCIDENTS
ISTANBUL	786
ÇANAKKALE	299
IZMIR	298
INTERNATIONAL	130
ANTALYA	109
SAMSUN	73
MERSIN	72
TRABZON	27
TOTAL	1794

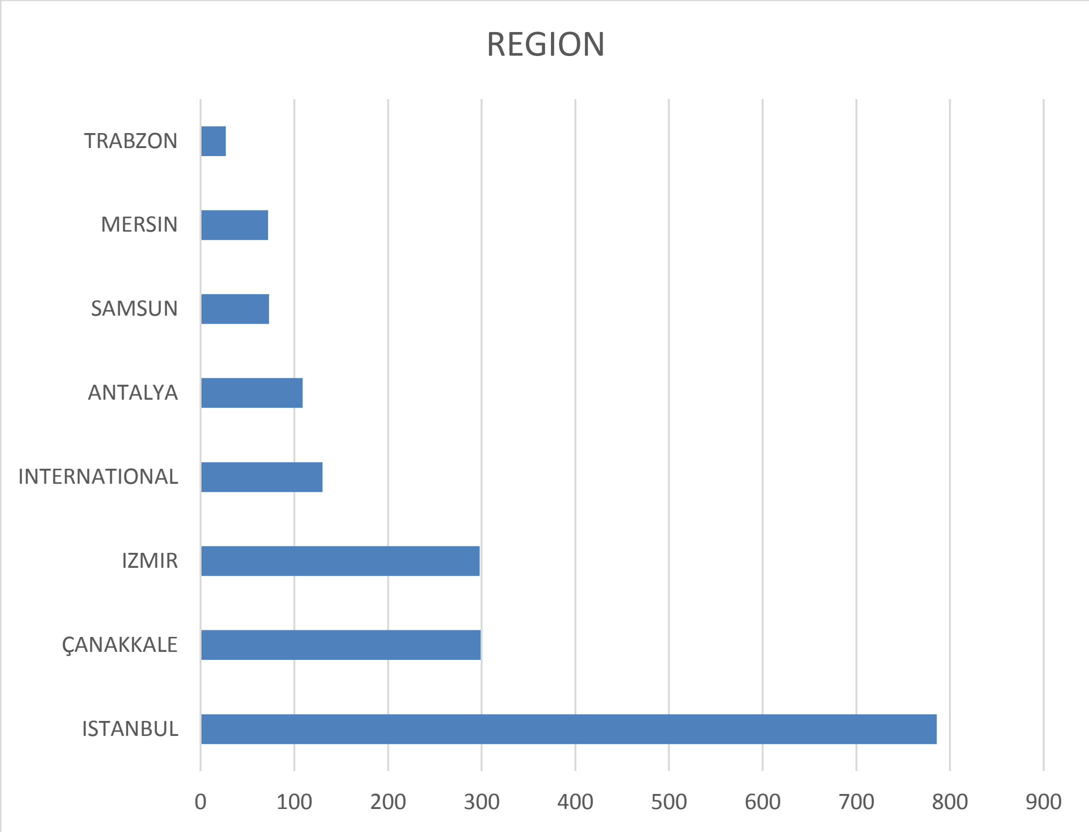

Figure 4.2: Region-Number of Accidents (MTMAC, 2013).

In region-number of accidents graph, the number of accidents is maximum at Istanbul region and is minimum at Trabzon region. Accidents at Istanbul region form the app. %44 percent of all of accidents. Accidents at Izmır region form the app. %17 percent of all of accidents also Accidents at Canakkale region form the app. %17 percent of all of accidents. Causes of excess of accidents in Istanbul region are excessive trade volume in this region, excessive population, connection between Marmara and Blacksea, narrowness of Bosporus, constrained maneuvering etc. also Izmir region has an excessive trade volume. Canakkale region is a transition region. Because of this, accidents in this region is more than other regions.

Table 4.3: Type of Hazard-Number of Accidents (MTMAC, 2013).

TYPE OF HAZARD	NUMBER OF ACCIDENTS
STANDING/GROUNDING	341
COLLISION	273
CAPSIZING	253
FIRE	173
OTHERS	129
HAZARDOUS INCIDENT	97
REQUEST FOR HELP	92
DRIFT	89
CRASH	87
MEDICAL EVACUATION	76
MACHINERY DAMAGE	59
CONTACT	49
MAN OVERBOARD	21
LISTING	14
DAMAGES TO SHIP OR EQUIPMENT	13
MISSING: ASSUMED LOST	11
FLOODING	6
BANDIT ATTACK	5
HULL FAILURE/ FAILURE OF WATERTIGHT DOORS/ PORTS, ETC.	4
EXPLOSION	2
TOTAL	1794

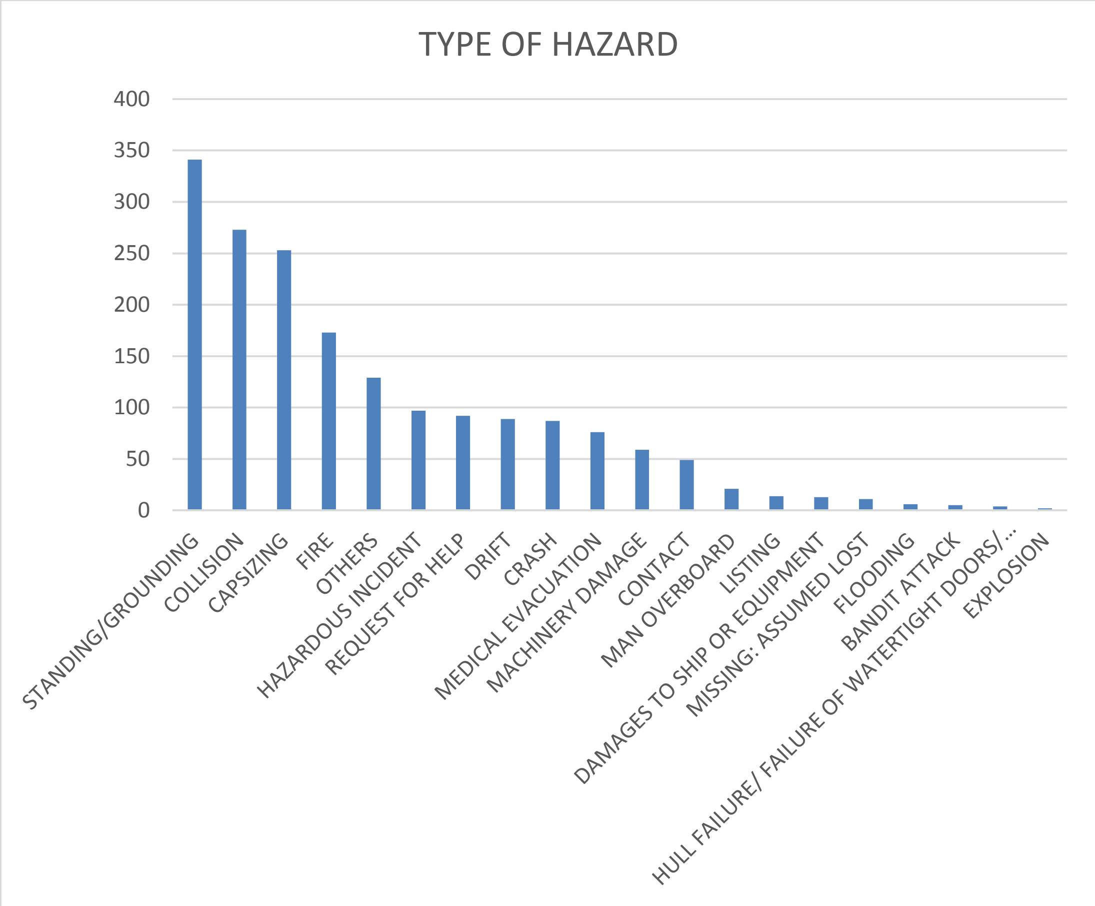

Figure 4.3: Type of Hazard-Number of Accidents (MTMAC, 2013).

In graph, most occurred type of hazard is grounding. Collision, capsizing and fire are other important type of hazards. Grounding forms the approximately %19 percent of all accidents, collision forms the %15 percent, capsizing forms the %14 percent and fire forms the %10 percent of all accidents. Main concern in this thesis is fire accidents. In fire accidents, main concern is fires in machinery room spaces. Machinery room fires are the most encountered type of fires in ships.

Table 4.4: Cause of Hazard-Number of Accidents (MTMAC, 2013).

CAUSE OF HAZARD	NUMBER OF ACCIDENTS
UNKNOWN	487
ADVERSE WEATHER CONDITIONS	281
MACHINERY FAILURE	168
MEDICAL AID	141
IMPERFECT SAIL	130
FLOODING	93
MANEUVERING ERROR	84
PERSONNEL ERROR	61
RUDDER FAILURE	58
FIRE	55
FLOUNDERING	44
ELECTRIC CONTACT	35
MAN OVERBOARD	34
EQUIPMENT FAILURE	34
DEATH INCIDENT	22
LOAD SLIPPING	19
ATTACK	17
INATTENTION	14
HELP	13
EXPLOSION	4
TOTAL	1794

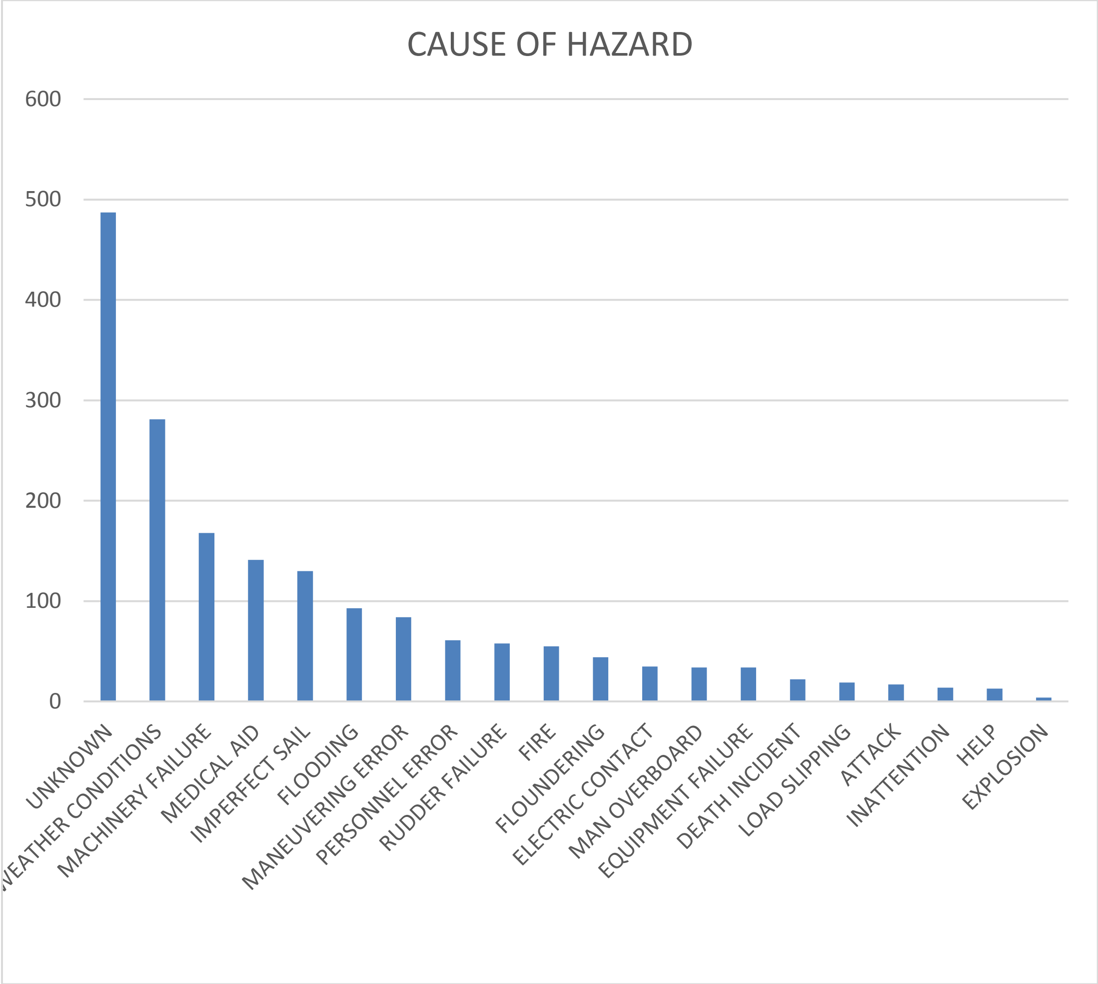

Figure 4.4: Cause of Hazard-Number of Accidents (MTMAC, 2013).

The cause of %28 percent of all accidents is unknown. After this, most important cause of accidents is bad weather conditions. Respectively, the causes of accidents are machinery failure, medical aid(injuries), and imperfect sail.

5. APPLICATION OF FORMAL SAFETY ASSESSMENT ON ENGINE ROOM FIRES

5.1 Identification of Hazards

Main potential hazards that cause to accidents are like below. In this section, statistical data of type of hazards and cause of hazards is taken into consideration.

- Capsizing
- Collision
- Contact
- Crash
- Drifting
- Fire and Explosions
- Grounding
- Listing
- Machinery Failure
- Medical Evacuation
- Others

Main potential hazards that cause to fire in machinery room spaces are like below. This hazards has been examined by an expert point of view and also has been originated from accident investigations and reports.

- Crankcase Explosions
- Gear Box Explosions
- Scavenge Fires
- Tank Explosions
- Bunkering Explosions

Statistical data has been categorized in sub-topics. Each sub-topic has been examined by assigning risk level number based on expert point of view. By using of Risk Ranking Number (RRN), risk matrices have been formed. Due to below chart, some terms described as S1=Remote, S2=Occasional, S3=Likely, S4=Probable, S5=Frequent, F1=Negligible, F2=Minor, F3=Significant, F4=Critical, F5=Catastrophic.

Table 5.1: Frequency/Consequence.

Frequency (F) / Consequence (S)	F1 (Negligible)	F2 (Minor)	F3 (Significant)	F4 (Critical)	F5 (Catastrophic)
S1 (Remote)	1	2	3	4	5
S2 (Occasional)	2	3	4	5	6
S3 (Likely)	3	4	5	6	7
S4 (Probable)	4	5	6	7	8
S5 (Frequent)	5	6	7	8	9

Classification of importance level of hazards is done by like that:

- Negligible: Minor financial loss, no environmental pollution and no loss of life/injuries
- Minor: Moderate financial loss, minor environmental pollution and fire, the crew has been rescued
- Significant: Serious financial loss, moderate environmental pollution
- Critical: Loss of ship, serious environmental pollution, significant loss of life/injuries
- Catastrophic: Loss of vessel, extreme environmental pollution, loss of live

Table 5.2: Rating/Result.

Rating	Result
Negligible	Minor financial loss, no environmental pollution and no loss of life/injuries
Minor	Moderate financial loss, minor environmental pollution and fire, the crew has been rescued
Significant	Serious financial loss, moderate environmental pollution
Critical	Critical: Loss of ship, serious environmental pollution, significant loss of life/injuries
Catastrophic	Catastrophic: Loss of vessel, extreme environmental pollution, loss of live

If it can be dealt with potential hazard definitions, in terms of machinery room fires, events that have potential to cause accidents are;

- Fuel oil
- Lubricating oil
- Hydraulic oil
- Materials that are absorbed oil
- Hot spots
- Damaged or cracked pipes
- Hot work in machinery room
- Flammable materials
- Electrical circuits
- Lights

- Incinerators
- Scavenge dirtiness
- Bilges
- Isolation of pipes
- Static electric
- Production faults
- Human factor (Cleanliness, Not obey to rules etc.)

Table 5.3: Result/Definition.

Definition of Potential Hazards	
Result	Definition
Machinery Room Fire	Fuel oil Lubricating oil Hydraulic oil Materials that are absorbed oil Hot spots Damaged or cracked pipes Hot work in machinery room Flammable materials Electrical circuits Lights Incinerators Scavenge dirtiness Bilges Isolation of pipes Static electric Production faults Human factor (Cleanliness, Not obey to rules etc.)

5.2 Risk Assessment

Causes of machinery room fires should be examined with places that accident is happened. According to this, anchored ships at anchorage ground are called as "Anchored", ships that pass through Bosporus or sail close to the anchorage places or ground called as "Near Cruise", ships that sail in international waters or open seas called as "Distant Cruise", ships that enter to anchorage places and ports called as "Entering to Port", ships that exit from anchorage places and port called as "Exiting from Port", ships that are under repair in shipyards called as "Overhaul".

Table 5.4: Risk Matrix.

Machinery Room Fires						
Cause of Accident	Anchored	Near Cruise	Distant Cruise	Entering to Port	Exiting from Port	Overhaul
Fuel oil	F1S3=3	F3S4=6	F3S4=6	F3S4=6	F3S4=6	F1S3=3
Lubricating oil	F1S3=3	F3S4=6	F3S4=6	F3S4=6	F3S4=6	F1S3=3
Hydraulic oil	F1S3=3	F3S4=6	F3S4=6	F3S4=6	F3S4=6	F1S3=3
Materials that are absorbed oil	F1S3=3	F1S3=3	F1S3=3	F1S3=3	F1S3=3	F1S3=3
Hot spots	F1S3=3	F4S4=7	F4S4=7	F3S4=6	F3S4=6	F1S3=3
Damaged or cracked pipes	F1S3=3	F4S4=7	F4S4=7	F3S4=6	F3S4=6	F1S3=3
Hot work in machinery room	F3S3=5	F1S3=3	F1S3=3	F1S3=3	F1S3=3	F4S3=6
Flammable materials	F1S3=3	F1S3=3	F1S3=3	F1S3=3	F1S3=3	F1S3=3
Electrical circuits	F1S3=3	F3S3=5	F3S3=5	F3S3=5	F3S3=5	F1S3=3
Lights	F1S3=3	F1S3=3	F1S3=3	F1S3=3	F1S3=3	F1S3=3
Incinerators	F1S3=3	F1S3=3	F1S3=3	F1S3=3	F1S3=3	F1S3=3
Scavenge dirtiness	F1S3=3	F3S3=5	F3S3=5	F3S3=5	F3S3=5	F1S3=3
Bilges	F1S3=3	F3S3=5	F3S3=5	F3S3=5	F3S3=5	F1S3=3
Isolation of pipes	F2S2=3	F4S4=7	F4S4=7	F4S4=7	F4S4=7	F2S2=3
Static electric	F1S3=3	F1S3=3	F1S3=3	F1S3=3	F1S3=3	F1S3=3
Production faults	F1S3=3	F1S3=3	F1S3=3	F1S3=3	F1S3=3	F1S3=3
Human factor (Cleanliness, Not obey to rules etc.)	F2S3=4	F1S5=6	F1S2=2	F1S1=1	F1S1=1	F2S5=6

In this section, it is taken account of RRN values of 4 and more. RRN values that are below 4 have not much impact on general risk level. With regard to risk matrix, most encountered causes of machinery room fires are;

- Fuel oil
- Lubricating oil
- Hydraulic oil
- Hot spots
- Damaged or cracked pipes
- Hot work in machinery room
- Electrical circuits
- Scavenge dirtiness
- Bilges
- Isolation of pipes
- Human factor

5.3 Risk Control Options

It must be plotted out that cause of accident - incident – accident – result of accident for all kind of accidents (Akyildiz, 2011)

Do’s (cause of accident has happened and incident has not happened yet)

- Training personnel for prevention of faults of personnel
- Controlling machine and equipment
- Controlling fire equipment

Do’s (incident has happened and accident has not happened yet)

- Providing adequate communication
- Monitoring machine and equipment
- Taking immediate precautions for safety

Table 5.5: Cause of Accident/Result.

Fires in Machinery Room			
Causes of Accident	Incident	Type of Accident	Result
Fuel oil	Failure		Material Damage
Lubricating oil	Failure		Material Damage
Hydraulic oil	Failure		Material Damage
Hot spots	Overheating		Material Damage
Damaged or cracked pipes	Failure		Material Damage
Hot work in machinery room	Inattention	Fire	Lost of Personnel
Electrical circuits	Failure		Material Damage
Scavenge dirtiness	Overheating		Material Damage
Bilges	Inattention		Material Damage
Isolation of pipes	Failure		Material Damage
Human factor	Inattention		Lost of Personnel

Do’s (accident has happened and it must be suppressed before the situation became graver)

- Informing other ships and state authority about accident
- Activating fire suppression systems
- Bringing fire fighting equipment to the accident place

- Intervening in fire
- Taking safety precautions

5.4 Cost/Benefit Assessment

Doing cost/benefit assessment is crucial to show performance of FSA method. Cost/benefit assessment is done by forming a matrix, and it will be acquired some values from this matrix. In this case, maximum values are considered because these values indicate the indispensable necessary actions for preventing accident.

It is a fact that score of precautions that have a high benefit value and have a low cost value at the same time are maximum in general. For example, training of personnel to preventing fault of personnel has a high cost/benefit value because it is cheap and it has a great benefit.

Benefit is graded as, 1=very low benefit, 2=low benefit, 3=moderate benfit, 4=high benefit, 5=very high benefit. Cost is graded as too, 1=very low cost, 2=low cost, 3=moderate cost, 4=high cost, 5=very high cost. Actions to be taken that has a benefit value of 5 and cost value of 1 are the most efficient precautions (Lois, 2004).

Table 5.6: Benefit Scoring System.

	Degree of Benefit	
1	Very low	Gaining very low favor from reducing risk
2	Low	Gaining low favor from reducing risk
3	Moderate	Gaining moderate favor from reducing risk
4	High	Gaining high favor from reducing risk
5	Very high	Gaining very high favor from reducing risk

Table 5.7: Cost Scoring System.

Degree of Cost		
1	Very low	Actions to be taken have a very low cost
2	Low	Actions to be taken have a low cost
3	Moderate	Actions to be taken have a moderate cost
4	High	Actions to be taken have a high cost
5	Very high	Actions to be taken have a very high cost

When doing cost/benefit assessment, actions to be taken are defined and categorized as below:

Training of personnel: Most important step to prevent faults that are originated from personnel is to inform personnel about actions to be done in the ship. Personnel has to have sufficient knowledge. Deficient topics must be identified and training of personnel about these topics is crucial.

Training of fire fighting: Personnel has to have sufficient knowledge about fire fighting. If any deficient knowledge has been existed, personnel has to be educated about these topics. In this case, fire drills and practices are important. Fire drills show the missing points. To prevent fire in case of an emergency, fire drills must be done regularly.

Controlling and monitoring engine and other equipments: Engine and other components of engine must be monitored and controlled regularly in order to be sure about it works properly. Chief engineer has to have sufficient knowledge about this topic. At this stage, log books are important. Log books have to be controlled regularly. All engine data has to be written to the log books.

Inspecting and checking engine and other equipments before starting: Engine and other equipments must be inspected before operating. Log books have to be checked before engine starts.

Fire fighting: Advanced fire fighting equipment must be used in order to suppress fire. New technologies has great advantage nowadays, and clean, ozone-free and harmless fire fighting systems are existed.

Inspecting pipes: All pipe system has to be checked and inspected regularly in certain time intervals. Damaged or cracked pipes can cause to the serious fire. In order to prevent heat discharge from pipes, isolation of pipes is important. Proper and certificied pipes and isolation materials have to be used in engine room. Also, sealing of pipes is important. Flanges and joints has to be inspected regularly. Most of the engine room fires stem from faults of flanges and joints.

Inspecting engine room: Engine room personnel must inspect to the engine room properly. Scavenge dirtiness, uncleanness of engine room, hot spots, defective electrical circuits can cause to serious fires. Crew has to be sure that everything in engine room works properly. Engine room has to be keeped clean continuously.

Table 5.8: Benefit/Cost Assessment of Fire.

	Fire			
	Actions to be taken	Value of benefit	Value of cost	Score
Personnel	Training	5	2	2,5
	Communication skills	5	2	2,5
	Training of fire fighting	5	3	1,6
	Training of communication	5	3	1,6
	Drills	4	3	1,3
Equipment	Conventional fire fighting	5	3	1,6
	Proper materials and isolations	4	3	1,3
	Modern fire fighting	5	4	1,25
	Good design	4	2	2
Procedure	Fire fighting knowledge	5	2	2,5
	Controlling equipments	4	2	2,5
	Monitoring engine	3	1	3
	Cleanliness	4	1	4
	Ability to extinguishing fires	5	3	1,6
	Fire warning	3	1	3

Due to table 5.8, a benefit/cost assessment of actions to be taken to prevent fires in engine rooms is made. Some actions that have a higher score than others are;

- Cleanliness of engine room
- Warning other ships and authorities
- Monitoring engine
- Controlling equipments
- Fire fighting knowledge
- Training of personnel
- Communication skills
- Good design

Above actions have the higher score than other options. These actions have the priority to prevent fires in engine rooms. However, other options are important too.

5.5 Decision Making

Human factor is important in prevention of engine room fires. Some of the sanctions have to be applied to reduce fault of personnel. Training of personnel and training of communication skills are very important to prevent fires or reduce the impact of fires in case of emergency. If an accident has happened, minimum loss of lives and minimum cost of damage are aimed after accident.

Personnel faults are grouped as;

- Faults when giving decision
- Lack of communication
- Inattention of crew
- Be absent at the place of duty
- Misuse of equipments

In case of emergency, role of personnel is important. If personnel does not act properly, serious accidents will become real. In this case, training of personnel is very crucial.

Another cause of accident is lack of communication between personnel. If personnel have communication problems with each other or proper working conditions do not exist, risk of accident will grow. In this case, resolving issues between personnel and providing keeping company with each other are essential matters. Also, lack of knowledge about ship and equipments increase the risk of accident considerably. Personnel has to have technical knowledge about using equipments and training of personnel for using equipment has to be given.

Fire fighting equipment and fire fighting knowledge of personnel are other important matters. Dirtiness of engine room, negligence of monitoring engine, insufficient knowledge about fire fighting can increase the level of risk and severity of accident. A timely response to the fire, to keep engine room clean, to know well what to do in case of emergency are important parameters when preventing risk of fire or reducing impacts of fire.

Another matter is the design matter. Designing engine room to provide comfortable working conditions, easy to access to the engine room and easy to escape from engine room is critical. Well-placed tanks and pipes will reduce the risk of fire.

6. CONCLUSIONS AND RECOMMENDATIONS

In this workout, it is aimed to identification of causes, impacts, frequency and severity of machinery room accidents and is aimed to preventing or reducing to risk of accidents based on accident statistics of Turkish or foreign flagged ships that operate in Turkish or international waters. For this purpose, it has been used Formal Safety Assessment Method and accident data of Republic of Turkey Ministry of Transport, Maritime Affairs and Communications. This workout comprises accident data from 2001 to 2012. In addition, an interview with Halic Shipyard personnel was carried out. Machinery room of Beyoglu ferryboat was investigated and some photos was taken. It might be seen machinery room photos of Beyoglu ferryboat in appendix.

The purpose of application of FSA in maritime industry is to do a general analysis to increase safety in maritime industry upon ship design, supervision, operation and navigation. FSA has an important role in safety of maritime industry by using as a tool to developing existing regulations or making a major contribution on addition of new regulations to existing ship design, engineering techniques, ship operation and control, safety management standards and regulations (Fang, 2005).

FSA has been developed as a helping tool in decision-making process by IMO. By means of FSA, decision-making procedures become more rational, provide prospective and holistic approaches and consequently a decision-making draft which takes politically a small space and prevents temporary solutions has been constituted.

FSA provides trustable information about risk of hazards, risk control options, cost and benefit of this options for the development of decisions taken in risk management stage (IACS, 2008).

In this workout, it is explained how FSA can be applied to machinery room fires based on statistical data. Causes of machinery room fires are determined in accordance with accident data and reports, and expert views. Risk matrix is generated with regard to frequency/severity degree of causes. Most encountered causes are determined with respect to this matrix. In next stage, it is indicated that how this accidents can be controlled and what is the cost/benefit of this controls. In last stage, it is aimed to how risk of accidents can be reduced with regard to optimum results and it is given recommendations to decision makers.

Main potential hazards that cause to fire in machinery room spaces are like below:

- Crankcase Explosions
- Gear Box Explosions
- Scavenge Fires
- Tank Explosions
- Bunkering Explosions

If it can be dealt with potential hazard definitions, in terms of machinery room fires, events that have potential to cause accidents are;

- Fuel oil
- Lubricating oil
- Hydraulic oil
- Materials that are absorbed oil
- Hot spots
- Damaged or cracked pipes
- Hot work in machinery room
- Flammable materials
- Electrical circuits
- Lights
- Incinerators
- Scavenge dirtiness
- Bilges
- Isolation of pipes
- Static electric

- Production faults
- Human factor (Cleanliness, Not obey to rules etc.)

After determining potential hazards, risk matrix has been formed. It is taken account of RRN values of 4 and more. RRN values that are below 4 have not much impact on general risk level. With regard to risk matrix, most encountered causes of machinery room fires are;

- Fuel oil
- Lubricating oil
- Hydraulic oil
- Hot spots
- Damaged or cracked pipes
- Hot work in machinery room
- Electrical circuits
- Scavenge dirtiness
- Bilges
- Isolation of pipes
- Human factor

When doing cost/benefit assessment, actions to be taken are defined and categorized as below:

- Training of personnel
- Training of fire fighting
- Controlling and monitoring engine and other equipments
- Inspecting and checking engine and other equipments before starting
- Fire fighting
- Inspecting pipes
- Inspecting engine room

After forming a benefit/cost matrix, benefit/cost assessment of actions to be taken to prevent fires in engine rooms is made. Some actions that have a higher score than others are;

- Cleanliness of engine room
- Warning other ships and authorities
- Monitoring engine
- Controlling equipments
- Fire fighting knowledge
- Training of personnel
- Communication skills
- Good design

Above actions have the higher score than other options. These actions have the priority to prevent fires in engine rooms. However, other options are important too.

After that it is tried to give recommendations about accidents:

Human factor is important in prevention of engine room fires. Some of the sanctions have to be applied to reduce fault of personnel. Training of personnel and training of communication skills are very important to prevent fires or reduce the impact of fires in case of emergency. If an accident has happened, minimum loss of lives and minimum cost of damage are aimed after accident.

Personnel faults are grouped as;

- Faults when giving decision
- Lack of communication
- Inattention of crew
- Be absent at the place of duty
- Misuse of equipments

In case of emergency, role of personnel is important. If personnel does not act properly, serious accidents will become real. In this case, training of personnel is very crucial.

Another cause of accident is lack of communication between personnel. If personnel have communication problems with each other or proper working conditions do not exist, risk of accident will grow. In this case, resolving issues between personnel and providing keeping company with each other are essential matters. Also, lack of knowledge about ship and equipments increase the risk of accident considerably. Personnel has to have technical knowledge about using equipments and training of personnel for using equipment has to be given.

Fire fighting equipment and fire fighting knowledge of personnel are other important matters. Dirtiness of engine room, negligence of monitoring engine, insufficient knowledge about fire fighting can increase the level of risk and severity of accident. A timely response to the fire, to keep engine room clean, to know well what to do in case of emergency are important parameters when preventing risk of fire or reducing impacts of fire.

Another matter is the design matter. Designing engine room to provide comfortable working conditions, easy to access to the engine room and easy to escape from engine room is critical. Well-placed tanks and pipes will reduce the risk of fire.

In conclusion, FSA is a very effective tool to identify hazards, assess risks, control risks, determine benefit/cost of control options, and give recommendations to decision makers. In this thesis, it is tried to explain how FSA apply to the engine room fires. Some outcomes from this method have been acquired. Most important and effective outcome is human factor. Reducing or controlling risks that are originated from human fault is very crucial. Controlling risks related to the human fault is very beneficial and cost-effective. But human factor is not a very objective matter. It is not transparent nor determinable matter. In future workouts, FSA should be relatable to the human factor. Fuzzy logic and artificial neural networks should be used.

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APPENDICES

APPENDIX A: Machinery room photos of Beyoglu ferryboat

APPENDIX A

Figure A.1: Sprinkler System Tank.

Figure A.2: Sprinkler Alarm System.

Figure A.3: Manifold system.

Figure A.4: FM-200 Extinguishing System and N2 (Nitrogen) Activation Unit.

Figure A.5: Firefighting Clothes in Red Box.

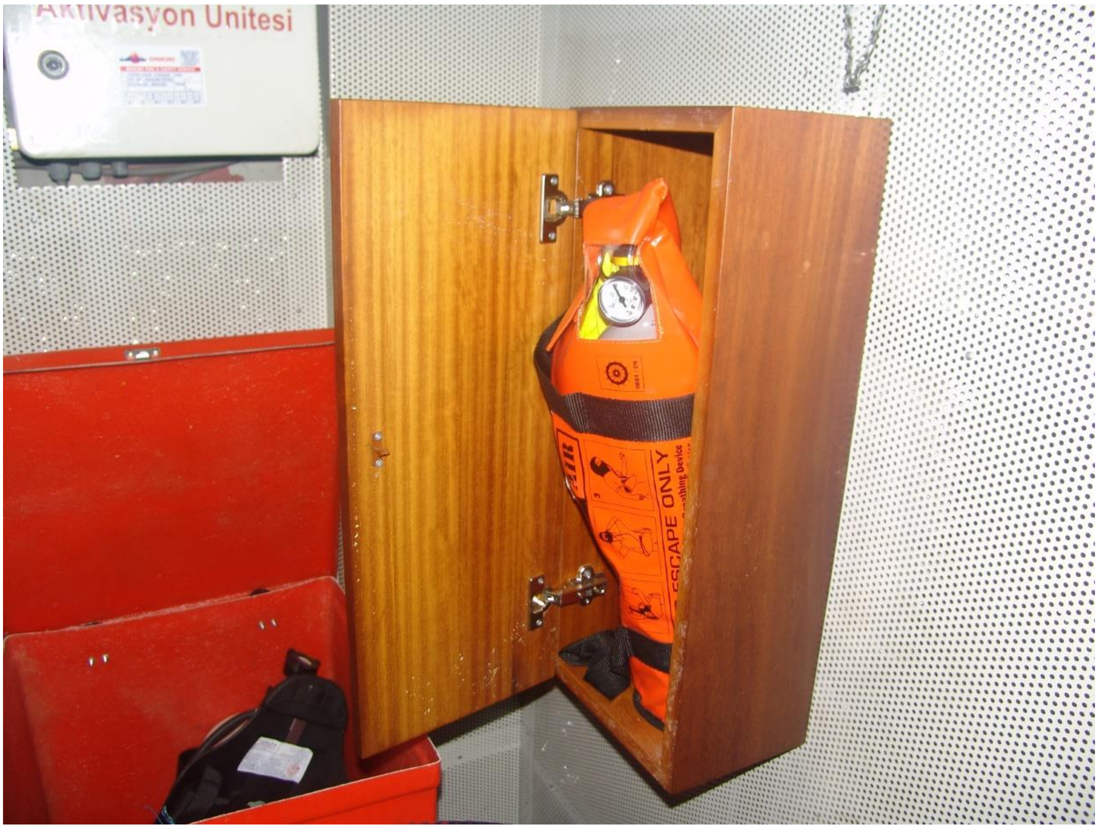

Figure A.6: Emergency Escape Breathing Device.

Figure A.7: Gun for Foam Making System.

Figure A.8: Portable Extinguishers.

Figure A.9: FM-200 Alarm System.

Figure A.10: Fire and Bilge Pump Boards.

Figure A.11: Fire Extinguishing Hose.

Figure A.12: Fire and Bilge Pumps.

Figure A.13: FM-200 Tank.

Figure A.14: Foam Tube.

Figure A.15: Sprinkler Control System.

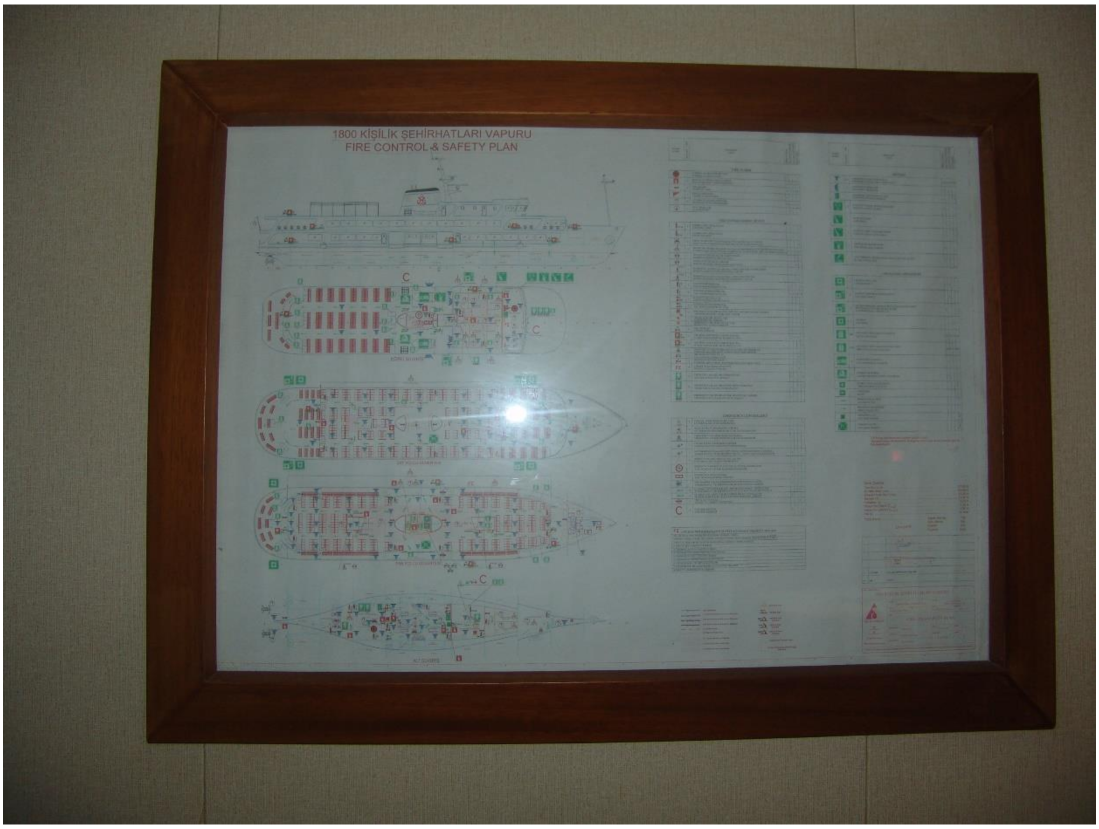

Figure A.16: Fire Control&Safety Plan.

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