ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

MODELING AND ANALYSIS OF MAN OVERBOARD AND SEARCH AND RESCUE OPERATIONS

Ph.D. THESIS

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Department of Maritime Transportation Engineering

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MARCH 2023

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

DENİZE ADAM DÜŞMESİ VE ARAMA KURTARMA OPERASYONLARININ MODELLEME VE ANALİZ ÇALIŞMASI

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Orhan GÖNEL, a Ph.D. student of İTU Graduate School student ID 512132001, successfully defended the thesis/dissertation entitled “Modeling and Analysis of Man Overboard and Search and Rescue Operations”, which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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To all man overboard casualties and their relatives,

FOREWORD

Even before I started my Ph.D. study, I have always had great personal expectations about this process. In my Ph.D. study, I wanted to do something that has not been done before, such as an invention or an innovation, but at least I wanted my work to make a difference at some point. I have come to the point where I conclude my Ph.D. study and I think that I have achieved the standards that I set as a target for myself. I chose a subject on which very limited research has been done before. I have done detailed studies with my thesis advisor on the deficiencies and the issues that can be improved that we have identified within the scope of the thesis. I used several different academic methods in this study, and the study had many outcomes.

I would like to express my endless gratitude to my advisor Dr. İsmail ÇİÇEK for his contributions to this process. I would like to state that he devoted much more to me than a thesis advisor would spare for his student, and I would like to thank him for this. Without his contributions, I would never have achieved the results I was aiming for.

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December 2022 Orhan GÖNEL
(Lecturer)

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ABBREVIATIONS

AIS : Automatic Identification System
AMSA : Australian Maritime Safety Authority
BLR : Binary Logistic Regression
CES : Continuous Event Simulation
DES : Discrete Event Simulation
df : Degree of Freedom
DSC : Digital Selective Calling
ECDIS : Electronic Chart Display and Information System
EMSA : European Maritime Safety Agency
EU : European Union
GLM : General Linear Model
GMDSS : Global Maritime Distress and Safety System
GPS : Global Positioning System
HBMCI : Hellenic Bureau for Marine Casualties Investigation Agency
HK : Hong Kong
IAMSAR : The International Aeronautical and Maritime Search and Rescue
ILO : The International Labor Organization
IMO : The International Maritime Organization
ISM Code : The International Safety Management Code
ISPS Code : The International Ship and Port Facility Security Code
ITU : International Telecommunication Union
LDA : Linear Discriminant Analysis
LR : Logistic Regression
MAIB : Maritime Accident Investigation Branch
MCIB : Marine Casualty Investigation Board
MEI Form : Maritime MOB Events Investigation Form
MGLM : Multivariate General Linear Model
MOB : Man Overboard
MRT : Marine Technology Company
MSC : Maritime Safety Committee
MSLS : Maritime Survivor Locating Systems
PLB : Personal Locator Beacons
PPE : Personnel Protective Equipment
RGB : Red, Green, And Blue
SAR : Search and Rescue
SE : Standard Error
SMS : Safety Management System
SOLAS : The International Convention for the Safety of Life at Sea
SPSS : Statistical Package for the Social Sciences
STCW : The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
SVDR : Simplified Voyage Data Recorder
SW : Sea Water
TSB : Transportation Safety Board

UGLM **:** Univariate General Linear Model
UK **:** United Kingdom
USA **:** United States of America
USCG **:** United States Coast Guard
VDR **:** Voyage Data Recorder
VHF **:** Very High Frequency
WHO **:** World Health Organization

SYMBOLS

°C	**:** Celsius
β	**:** Beta
p	**:** Probability Value

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MODELING AND ANALYSIS OF MAN OVERBOARD AND SEARCH AND RESCUE OPERATIONS

SUMMARY

Although progress has been made in many areas such as safety equipment, work rules, and so on, the occupational accidents that seafarers are exposed to and the death rates due to these accidents are very high. The most dangerous of these accidents is man overboard accidents. As the type of occupational accident with the highest death rate, falling overboard accidents pose a great risk for seafarers. Hundreds of seafarers, passengers and boat users die every year as result of man overboard accidents.

Overboard accidents, unlike other types of accidents, consist of multiple stages and there are many factors that determine the outcome of the accident. After the accident is detected, first interventions are made, the search and rescue process begin, if the casualty is found, taken on board and post-rescue responses are made. A problem in any of these stages may adversely affect the absolute outcome of the response process.

There are many factors that affect the outcome of a man overboard accident. A large amount of data has been collected from different sources to better understand these factors and the accident process. Databases were scanned, accident reports, textbooks, company procedures were examined. Expert opinions were received, surveys were conducted and even a small workshop was organized. The obtained data were examined, analyzes were made with different statistical methods, time modeling was established and simulation models were made. A detailed examination of the data and analysis results revealed that some there are procedural deficiencies and some common information about overboard accidents were incorrect. In addition, many procedures, equipment and training issues that are open to improvement have been identified and even some suggestions have been made. As a result of bringing together all these studies and data, an important source has been created about the man overboard accident.

In addition to all the data obtained within the thesis study, a procedural proposal and an autonomous emergency response system proposal were made at the end of the study. The procedural proposal concerns another seafarer entering the water to save a man overboard casualty. Equipment proposal, on the other hand, is an emergency response system that automatically performs some of the response actions that must be performed after the overboard accident and assists in other stages of the response.

In summary, this thesis study, besides providing detailed information about overboard accidents, makes an equipment proposal and a procedure proposal as the main output of the study. These recommendations aim to optimize the outcome of overboard accidents.

DENİZE ADAM DÜŞMESİ VE ARAMA KURTARMA OPERASYONLARININ MODELLEME VE ANALİZ ÇALIŞMASI

ÖZET

Her ne kadar emniyet ekipmanları, iş kuralları ve benzeri birçok konuda ilerlemeler kat edilmiştir. Dünya çapında birçok işçi kuruluşu kurulmuş, iş güvenliği ile ilgili birçok mevzuat geliştirilmiştir. Zaman içerisinde iş güvenliği ile ilgili birçok yeni kavram oluşmuştur. 'Emniyet kültürü', gibi kavramlar, 'olası kaza', gibi raporlama prosedürleri gelişmiş ve hatta iş güvenlik uzmanı gibi meslekler oluşmuştur. Muhakkak ki genel kaza oranlarında ve kazalara bağlı ölüm oranlarında azalmalar olmuştur. Ancak bu gelişmeler genel iş gücüne olduğu oran ile gemiadamlarına aynı oranda yansımamıştır. Her ne kadar gemilerdeki çalışma koşulları genel iş koşullarına oranla daha zor olsa da gemiadamlarının maruz kaldıkları iş kazaları ve bu kazalara bağlı olarak oluşan ölüm oranları genel iş gücüne kıyasla çok daha yüksektir. Bu kazalar içerisinde gemiadamlarına en büyük tehlike oluşturan iş kazası çeşidi denize düşme kazasıdır. Denize düşme kazaları en yüksek ölüm oranına sahip iş kazası türü olarak gemiadamları için halen çok büyük risk oluşturmaktadır. Her yıl yüzlerce gemiadamı, yolcu ve tekne kullanıcısı denize düşmekte ve büyük bir oranı ise hayatını kaybetmektedir.

Denize düşme kazaları, diğer kaza türlerinden farklı olarak birden fazla aşamadan oluşur ve kazanın sonucunu belirleyen çok fazla etmen vardır. Müdahale, denize düşme kazasının oluşumu ile başlar ise, ilk önce öncül müdahaleler yapılır, arama ve kurtarma süreci başlar, eğer kazazede bulunur ise gemiye alınma süreci başlar ve en sonunda kazazedeye kurtarma sonrası müdahaleler yapılır. Bu aşamalardan en önemlisi, kazanın ilk oluştuğu esnada icra edilen eylemlerden oluşan öncül müdahale aşamasıdır. Öncül müdahale aşaması kazaya yapılan müdahalenin sonucunu en çok etkileyen aşamadır. Örneğin kazazedenin denize düşme kazası olay anında ya da olaydan çok kısa süre sonra, kazazede denizde iken görülerek tespit edildi ise kazazede sürekli olarak deniz yüzeyinde takip edilebilir. Ancak herhangi bir sebepten dolayı kazazede ile göz teması kesilir ise, tekrar göz teması kurulması ya da ilk başta sağlanamayan göz temasının daha sonra sağlanması oldukça zordur.

Söz konusu müdahale aşamaların herhangi bir tanesinde oluşacak bir sorun kurtarma sürecinin mutlak sonucunu olumsuz olarak etkileyebilir. Eğer denize düşme kazası olayın en başında tespit edilemez ve kazazedenin gemiden düştüğü öngörüsü ile müdahale başlar ise, müdahale arama ve kurtarma süreci ile başlar. Bu durumda geminin izleyeceği yol iki yol vardır. Eğer kazazedenin denize düşmesi çok muhtemel bir süreç içerisinde olduğu biliniyor ise, bu olayın zamanı ve bu zamanda geminin bulunduğu konum merkez alınarak arama ver kurtarma süreci başlatılır. Eğer kazazedenin denize düşmesi muhtemel bir eylemde bulunduğu değerlendirilmiyor ise gemi farklı metotlar ile seyir güzergahını tersten takip eder. Tahmini düşme zamanı gerçeğe ne kadar yakın ise ve akıntı ne kadar doğru hesaplandı ise kazazedenin tespit edilme olasılığı o kadar artacaktır.

Denize düşme kazasının sonucunu etkileyen çok fazla etmen vardır ve bu kazaya karşı yapılan müdahale çok aşamalı bir müdahaledir. Müdahale süresi çok uzayabilir. Bu etmenleri ve kaza sürecini daha iyi anlamak için kaza süreci sadece sayısal olarak incelenmemiş, farklı kaynaklardan büyük miktarda veri toplanmıştır. Veri tabanları taranmış, denize düşme kazalarına ait kaza inceleme raporları, denizcilik eğitiminde kullanılan ders kitapları, denize düşme kazalarında ve talimlerinde kullanılan şirket prosedürleri incelenmiştir. Uzman görüşleri alınmış, anketler yapılmış ve hatta küçük çaplı bir çalıştay düzenlenmiştir. Elde edilen veriler farklı metotlar kullanılarak incelenmiştir. Sayısal sonuçlar farklı istatistik metotları ile analiz edilmiştir ve veriler kontrol edildiğinde yüksek tutarlılık oranına sahip olduğu görülmüştür. Denize düşme kazası sonra yapılan müdahale ile ilgili zaman modellemesi oluşturulmuştur. Modellemedeki zaman değerlerini elde etmek için deneysel bir çalışma yapılmıştır. Deneysel çalışma ile denize düşme kazası oluşması durumunda köprüüstünde yapılan öncül müdahale eylemlerinin zaman verisi elde edilmiştir. Zaman modellemesi, elde edilen değerlerle birleştirilerek simülasyon modelleri hazırlanmıştır.

Elde edilen veriler incelendiğinde kaynaklarda birçok sorun olduğu, yapılan müdahalelerde eksiklikler ve yanlışlıklar olduğu tespit edilmiştir. Gemiadamı eğitiminde kullanılan ders kaynaklarında, gemi prosedürlerinde yanlışlıklar olduğu tespit edilmiştir. Denize adam düşmesi ile ilgili kaza raporları incelendiğinde, birçok hata yapıldığı ve iyileştirilmesi gereken nokta olduğu tespit edilmiştir. Çalışma kapsamında yapılan deneysel çalışmada dahi bazı hatalar yapıldığı tespit edilmiştir. Çalışma kapsamında elde edilen tüm bulgular tez kapsamında paylaşılmış ve önemli bulgular ayrıca tartışmaya açılmıştır. Bütün bu çalışmaların ve verilerin bir araya getirilmesi sonucunda denize düşme kazaları ile ilgili önemli bir kaynak oluşturulmuştur.

Elde edilen veriler incelendiğinde, denize düşme kazasından sonra yapılan müdahalede, özellikle müdahalenin ilk aşamalarında zaman faktörünün çok önemli olduğu ve müdahalenin nihai sonucu üzerinde çok etkilediği olduğu tespit edilmiştir. Ayrıca yapılan acil durum müdahalelerinde zabitlerin deneyim, bilgi ve benzeri durumlarına göre müdahalede bazı müdahale eylemlerini yanlış yapabildikleri ve hatta bazılarını yapmayı tamamen unuttukları tespit edilmiştir. Zaman kayıplarını ve ilgili yanlışlıkları engellemek için otonom bir acil durum müdahale asistanı önerilmiştir. Bu önerinin sebepleri, özellikleri ve sağlayacağı olası faydalar detaylı olarak açıklanmıştır. Otonom acil durum müdahale sistemi ile yapılacak olan müdahalenin de zaman modellemesi ve simülasyonu hazırlanmıştır. Simülasyon üzerinde hem konvansiyonel müdahale hem de önerilen sistem ile yapılan müdahale kıyaslanmıştır. Kıyaslama sonuçları ile otonom müdahale sisteminin amaçladığı zaman tasarrufunu gerçekten sağladığı ispat edilmiştir. Söz konusu zaman tasarrufu oran olarak yüksek bir değere sahip olmakla beraber, süre olarak kısa bir değere sahip olduğu düşünülebilir. Ancak önerilen otonom müdahale sisteminin kazanın ilk ve en önemli aşamasında sağladığı zaman tasarrufunun müdahalede çok büyük etkisi olacaktır.

Kaza inceleme raporları üzerinde araştırmalar yapılırken, bazı olaylarda denize düşen kazazedeyi kurtarmak için başka gemiadamlarının denize girdikleri tespit edilmiştir. Ancak bu konu ile ilgili hiçbir mevzuata ya da geçmiş çalışmaya rastlanmamıştır. Söz konusu kaza örnekleri daha detaylı olarak incelendiğinde böyle bir karar vermesi gereken gemiadamlarının hiçbir prosedür, risk değerlendirmesi, emniyet ekipmanı, olmadan duygusal sebepler ile anlık karar verdikleri tespit edilmiştir. Böyle önemli sonuçları olacak bir konuda duygusal karar yerine rasyonel karar verilmesi için çalışmalar yapılmıştır. Çok aşamalı bir çalışmadan sonra böyle bir kararın verilip verilemeyeceği, eğer verilecek ise hangi koşullarda verilebileceği, hangi önlemlerin alınması gerektiği gibi konularda tespitler yapılmıştır. Çalışma bulguları ile hem eğitimde kullanılacak hem de acil durumda olay anında kullanılacak iki tane prosedür oluşturulmuştur. Bu çalışmanın ana çıktısı olan prosedüre ilave olarak, bir gemi kazasında verilmesi gereken acil durum kararlarından bir tanesini için karar mekanizması modellenmiş ve sayısal olarak çözümlenmiştir.

Özet olarak, bu tez çalışması, denize düşme kazaları ile ilgili sunduğu detaylı bilgilerin yanında, önemli tespitler ve çözüm önerileri sunmuştur. Son olarak da otonom acil durum müdahale sistemi ve acil durum karar verme prosedürü önermiştir. Bu öneriler ile denize düşme kazalarına yapılan müdahalenin optimize edilmesi amaçlanmıştır.

1. INTRODUCTION

'Falling' or 'Accidental Falling' is a common type of accident that can occur in any workplace. This type of accident can also happen onboard ships. The casualty may fall from a higher place on the ship to a lower location, e.g. from the deck into the cargo hold. If the casualty falls into the water, this type of falling accident it is called 'Man Overboard' (MOB). MOB is a different type of accident than general 'Falling' accidents and needs to be studied in more detail.

Selmy and Mahdaly (2018) defines MOB as '*a person who has fallen to the sea from a boat or a vessel in the water and needing to rescue; this person may be crew member of coast gourd, merchant ship or fisher*'. Macmillan online dictionary (URL-1) makes MOB definition as '*used for telling people that someone has fallen into the water*'. MOB definition of Wikipedia (URL-2) is '*is an exclamation given aboard a vessel to indicate that a member of the crew or a passenger has fallen off of the ship into the water and is in need of immediate rescue*'. Among many sources, the online database Wikipedia makes the closest definition to the MOB definition made in this study. This study makes the definition of MOB as 'accidental fall from a marine craft to water, the rescue operation and all other processes that occurred as a result of this event'. Intentional enter to water and falling into the water from any coastal structure are not considered as MOB.

1.1 Need of MOB Response Improvement

With the industrial age, concepts such as 'job safety' and 'security policy' began to emerge and spread. Different national and international organizations have been formed in this regard and their activities have increased over time. Such, ILO and WHO had their first joint Committee on Occupational Health in 1950 (Alli, B, O., 2008) which was a major step in regard to international standardization of work safety. In year 1986 the term 'Safety Culture' was first used after Chernoby accident (Arslan, et. al., 2016). Later, many concepts such as 'Risk Assessment', 'Accident Report', 'Work Permit' emerged and these concepts took their place in work life over time.

Similarly, the very near future work safety did not have the importance it should have in the maritime sector and every sea voyage was seen as an adventure. Then same safety culture started to take part in maritime sector as well. National and international rule makers, maritime companies, academia and private sector companies have contributed to the reduction of occupational accidents and increase in life safety in the maritime sector in many different fields.

As approaching the 21st century, IMO decided to take effective measures in maritime safety in year 1999 as the leading international maritime safety standard maker (Li, K, Jun., 2001). As a result of this decision, IMO created ISM Code with the goal to gradually create a new safety culture in the maritime industry (Nævestad, et. al., 2019). ISM Code also brought another safety standard which had positive impact on safety culture at sea; Safety Management System (SMS). This code requires all procedures to be in a written format and to be carried out in a standard way. Safety procedures and emergency response procedures are also a part of these written standard procedure. Shipping companies developed their safety procedures, work forms and developed their safety culture.

Technology companies have also developed products that will increase the safety of seafarers in many different subjects, which may or may not be mandatory on ships. The technology company 'SICK', which specializes in sensor technologies in particular, aims to reduce the accidents of falling overboard with the 3D scanner systems it has developed (URL-3). A marine technology company ‘MRT’ makes Personal Locator Beacon (PLB) devices. But unlike other companies, their PLBs are not standard and are compatible with their base units that is planned to be used in man overboard Search and Rescue (SAR) operations (URL-4).

Academia has also carried out many studies to increase the job security of seafarers. Existing studies have been applied to the maritime sector or even new studies have been developed in order to increase safety standards. Some academic studies have also been turned into projects, and instead of staying in theory, they have been put into practice and moved to the stage of active contribution. As an example, SAFEMODE (URL-5) brought 29 different partners from 16 countries together and made a joint contribution to the maritime field.

Although many studies are carried out to increase the occupational safety of seafarers, high numbers of seafarer occupational accidents are still seen today. 3000 shipping incidents were encountered in 2021 globally (Allianz, 2022). From 2014 to 2020, 550 seafarers died and 6921 injured only in EU region. Reported marine casualties and incidents over the same period is 22532 (EMSA, 2021). Annual death, injury and casualty-incident numbers are 78.6, 988.7 and 3218.9 respectively. It is not possible to acquire reliable global marine accident and incidents figures especially related to MOB accidents. But considering the facts that 24% of deaths as a result of maritime accident are related to MOB events and annual MOB number is approximately 1000, maritime accidents and especially MOB accident still poses a great risk to seafarers.

Although many improvements in different aspects regarding the occupational safety of seafarers have been mentioned above, the numerical results show that still more improvements are needed. Considering 24% of maritime accidents with deaths are the result of MOB events (Gonel and Cicek, 2022) improvements especially needed on different aspects of MOB accidents.

1.2 Background of MOB Accidents

In order to analyze the importance of MOB accidents and their effects on seafarers, maritime accidents and MOB accidents data were analyzed collectively. This data will also provide simple statistical correlations for maritime accidents and MOB accidents. Other benefits of this data:

• Find the threat that MOB accidents pose to seafarers,

• Compare MOB with other accident types,

• Find fatality rates of different accidents and compare them with MOB accidents.

In order to make the comparison, statistical data must both include overall maritime accidents data and MOB accidents data.

Unfortunately, reliable data on maritime accidents and incidents, especially MOB accidents cannot be obtained on global scales. Reliable data can only be obtained from national and regional sources. There are studies that provide MOB statistics, but many of them are limited to regional MOB figures (Hansen et. al., 2008) or global figures for limited historic dates (Huang et. al., 2016). There are some studies that provides global MOB statistics but these studies are limited with assumptions (Selmy, 2016). Some of the reasons that global maritime accident and incident statistics especially MOB statistics can’t be acquired are:

• All marine areas of the world are not covered by reporting agencies,

• A substantial proportion of accidents are not being reported,

• There is no central reporting agency that collects maritime accident data for all parts of the world,

• Many accidents are also included in different reports. For example, the same accident can be recorded in the accident statistics of its flag state and accident statistics of coastal state that the accident took place in its territorial waters.

For these reasons, statistics on general maritime accidents and MOB accidents were obtained from national sources.

1.2.1 Acquisition of national maritime accident and MOB accident statistic data

Maritime events and MOB statistics data of each country is provided by authorized national reporting agency. Data is acquired from their annual reports and webpages. The data are obtained from different sources and there are many issues to be considered about these data. Some of these issues are:

• Terms such as 'event', 'incident' and 'accident' may be used with different meanings by the reporting authorities of different countries,

• The types of accidents are not categorized in a common way and differ from country to country,

• Different reporting authorities provide different levels of detail on accident statistics. Some sources only share the number of events, while other sources share the number of deaths or the number of deaths and rescues,

• Reporting agencies may change event figures in time. For example, accident figures for the same year may differ in two different annual reports. This may be due to better understanding of events or acquisition of new knowledge,

• Event and relative figures may seem inconsistent at first. For example, as a result of 10 MOB accidents, 11 people may have died. Factors such as the falling of more than one person into the sea in the same accident or the involvement of more than one ship in the accident may cause such misconceptions.

As an example, to change of event figures in time: Transportation Safety Board (TSB) of Canada expresses number of 'Serious Injuries of 2017' as:

• '46' in 2017 report (TSB, 2018),

• '47' in 2018 report (TSB, 2019),

• '47' in 2019 report (TSB, 2020),

• '47' in 2020 report (TSB, 2021),

• '49' in 2021 report (TSB, 2022).

National maritime events and MOB event statistic data are driven from:

Turkey: Maritime event and MOB data of Turkey from 2004 to 2016 is acquired from Main Search and Rescue Coordination Center of Turkey (URL-6). Total event number involves maritime events within and outside of Turkish Waters but MOB figures are only for Turkish Waters. Ministry of Transport and Infrastructure of Turkey (URL-7) provides MOB figure for only 2017 but does not include, death, lost and rescued numbers.

Hong Kong Special Administrative Region: Events and MOB data of Hong Kong (HK) Special Administrative Region is acquired from Marine Department of Government of the Hong Kong Special Administrative Region (URL-8). Total event numbers within and outside of HK Waters are from 1984 to 2021. But MOB event statistics are from 1990 to 2000 only.

Greece: Maritime event and MOB figures of Greece waters are acquired from annual reports of Hellenic Bureau for Marine Casualties Investigation Agency (HBMCI) (HBMCI, 2016, 2017, 2018, 2019, 2020 and 2021). Maritime events include: marine incidents, (less serious) marine accidents, serious marine accidents and very serious marine accidents. Since HBMCI categorizes MOB as (less serious) maritime accident, (less serious) maritime accident figures are also given in details. Data is driven from annual reports of the reporting agency.

Ireland: Maritime events numbers such as death, injury, vessel involvement, MOB and death due MOB in Ireland Waters is acquired from annual reports of Marine Casualty

Investigation Board (MCIB) of Ireland (MCIB, 2004, 2005, … 2021). Data is from 2004 to 2021.

Canada: Accident, incident, fatality, injury and MOB statistics occurred in Canadian waters are recorded and shared by Transportation Safety Board (TSB) of Canada (TSB, 2007, 2013, 2014, 2017, 2018, 2019, 2020, 2021). Statistical data is available from 1998 to 2021. But due to change in data format, results are shared in two different periods:

• From 1998 to 2007, shares only MOB results with fatality and injury,

• From 2008 to 2021, shares only MOB event numbers without survival status.

United States of America (USA): Maritime events and MOB events statistics occurring in USA data are published annually by U.S Department of Homeland Security U.S. Coast Guard Office of Auxiliary and Boating Safety. Annual reports are named as 'Recreational Boating Statistics' and gives very detailed statistical information of all types of maritime accidents and MOB accidents. Data is acquired from 18 of these reports from 2004 to 2021 (USCG 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021) but data is from 1991 to 2021.

These reports do not contain the term 'incident' but US Coast Guard is the only reporting agency that gives information on coast of MOB accidents. 'Death Rate' term has been used to describe three different ratios:

• Death Rate (1): Ratio of deaths occurring as result of MOB accident over deaths occurring as result of all accident types.

• Death Rate (2): Ratio of MOB accidents resulting with death over all MOB accidents.

• Death Rate (3): Ratio of all accidents (accident of all kinds) resulting with death.

United Kingdom (UK): Maritime events in UK Waters are recorded and reported Maritime Accident Investigation Branch (MAIB) of UK. Annual reports dating back to 1973 are available in MAIB's web page. Due to change in data format, main maritime events and MOB events data from 1994 to 2012 are used (MAIB, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012). For additional statistics data from 1994 to 2016 are used additionally (1994-2016) These annual share statistical data mainly in two groups:

• UK merchant vessels 100 gross tones and over,

• UK fishing vessels.

All data used in tables are not available for merchant vessels less than 100 gross tones, but MAIB shares the most detailed maritime event and MOB data for fishing vessels.

1.2.2 National maritime events and MOB accidents data

In this section, general maritime accidents and MOB accident figures of specific countries are given.

1.2.2.1 Maritime events and mob accidents data reported by Turkish maritime authorities

From 2004 to 2016, 2114 incidents were reported to Turkish Main Search and Rescue Coordination Center and 56 of these events were categorized as MOB accident occurred in Turkish waters (See Table 1.1 for details). 12 of the 56 MOB casualties were saved with an average of 21.4%. During this 13-year period, the annual number of MOB accidents ranged from 0 to 10, with an average of 4.3 accidents reported. Unfortunately, Main Search and Rescue Coordination Center and Ministry of Transport, Maritime Affairs and Communication of Turkey does not share detailed MOB statistics.

Table 1.1 MOB events in Turkish waters.

Years	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Number of MOB Events	2	1	1	0	3	4	10	7	9	6	8	2	3	56
Number of Lost	0	1	1	0	0	2	3	2	2	3	6	1	1	22
Number of Death	2	0	0	0	1	2	6	3	3	3	1	0	1	22
Number of Rescued	0	0	0	0	2	0	1	2	4	0	1	1	1	12

1.2.2.2 Maritime events and mob accidents data reported by the Government of the Hong Kong Special Administrative Region maritime authorities

Table 1.2 shows the accident statistics data provided by The Government of Hong Kong (HK) Special Administrative Region for the years 1984-2021 (URL-8). In 38 years, 297 deaths, 2120 injuries and 30 losses occurred as a result of 12164 events in HK waters. At the same time, 240 deaths, 698 injuries, and 260 disappearances occurred as a result of 2441 events outside HK waters.

Table 1.2 Maritime events within and outside of HK waters.

	Within Hong Kong Waters				Outside Hong Kong Waters			
Year	Events	Deaths	Injuries	Missing	Events	Deaths	Injuries	Missing
2021	431	10	189	8	171	7	63	17
2020	281	9	22	0	103	2	1	15
2019	321	6	28	0	138	3	6	31
2018	335	2	18	0	129	3	1	31
2017	368	1	29	0	130	15	2	23
2016	319	2	32	0	121	9	7	9
2015	319	2	171	0	106	2	6	5
2014	358	1	55	0	96	3	80	28
2013	302	7	157	0	103	1	6	0
2012	312	43	136	0	111	6	47	19
2011	351	2	104	0	80	1	11	2
2010	329	8	58	0	95	0	12	8
2009	332	3	49	0	104	12	3	18
2008	323	18	46	0	93	5	147	1
2007	278	5	33	-	55	11	5	8
2006	361	1	15	1	63	0	4	0
2005	368	9	179	0	43	1	2	0
2004	388	2	38	2	42	5	2	11
2003	358	5	65	1	43	2	2	2
2002	336	17	37	1	23	0	36	25
2001	378	3	47	4	38	5	8	3
2000	420	2	55	0	53	13	21	3
1999	407	23	64	12	34	2	8	1
1998	330	8	22	1	34	1	28	0
1997	327	7	41	\	22	0	7	\
1996	373	9	39	\	22	2	2	\
1995	410	10	31	\	29	27	0	\
1994	324	4	18	\	25	20	1	\
1993	378	8	48	\	30	11	50	\
1992	284	2	37	\	29	2	9	\
1991	216	4	17	\	18	2	5	\
1990	232	10	68	\	28	6	2	\
1989	255	15	50	\	33	26	0	\
1989	231	14	21	\	39	13	93	\
1987	220	6	59	\	36	1	1	\
1986	229	11	22	\	60	9	11	\
1985	186	2	20	\	34	4	9	\
1984	194	6	\	\	28	8	\	\
Total	12164	297	2120	30	2441	240	698	260

However, MOB accident statistics were shared by HK authorities only for the years 1990-2000. As can be seen in Table 1.3, 37 MOB accidents occurred within and outside of the HK waters over a period of 11 years. As result of these accidents 14 people died 4 people assumed lost.

Table 1.3 MOB events within and outside of HK waters.

	Within the Hong Kong Waters				Outside of the Hong Kong Waters			
Years	Events	Deaths	Injuries	Missing	Events	Deaths	Injuries	Missing
2000	0	0	0	0	0	0	0	0
1999	10	2	3	3	1	0	0	1
1998	6	2	0	0	1	0	0	0
1997	2	0	0	0	0	0	0	0
1996	8	5	5	0	1	1	0	0
1995	7	4	4	0	1	0	0	0
1994	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0
Total	33	13	12	3	4	1	0	1

1.2.2.3 Maritime events and mob accidents data reported by Greece maritime authorities

Between 2013 and 2020, a total of 2988 incidents and accidents in different severities were reported by the Hellenic Bureau for Marine Casualties Investigation Agency (HBMCI). See Table 1.4. for annual distribution of these events.

Table 1.4 Maritime events in Greece waters.

Event Type	2013	2014	2015	2016	2017	2018	2019	2020	Total
Marine Incidents	19	106	142	166	176	120	294	165	1188
Marine Accidents (Less Serious)	110	151	152	168	173	154	157	106	1171
Serious Marine Accidents	60	37	62	55	93	74	68	32	481
Very Serious Marine Accidents	27	20	28	13	16	23	12	9	148

HBMCI places MOB accidents in the less serious maritime accident category. Table 1.5 shows the annual distribution of less serious maritime accidents between 2013 and 2020, including MOB accidents. A total of 19 MOB accidents occurred in 8 years, and no information was shared about the survival status of the casualties.

1.2.2.4 Maritime events and mob accidents data reported by Ireland maritime authorities

From 2004 to 2021, 151 fatalities and 31 injuries occurred in the maritime events with the involvement of 191 marine crafts as reported by Marine Casualty Investigation Board of Ireland (See Table 1.6).

Table 1.5 Maritime accidents (less serious) events and in Greece waters.

Event Category	2013	2014	2015	2016	2017	2018	2019	2020	Total
Collision	7	14	19	28	20	15	8	4	115
Grounding	9	11	3	9	9	14	13	10	78
Pollution	-	6	7	9	-	-	2	9	33
Explosion	-	2	-	-	-	-	-	-	2
Water Ingress	1	4	5	3	8	9	3	5	38
Lost/Material Damage	3	10	4	4	8	13	9	9	60
Mechanical Failure	-	-	-	-	-	-	-	12	12
Grounding and Towed	1	-	-	-	-	-	-	-	1
Adrift and Towed	-	-	-	-	-	-	1	-	1
Man Overboard	-	1	3	-	5	7	1	2	19
Injury	57	71	86	80	92	66	90	44	586
Fire	6	10	7	5	5	1	4	1	39
Impact/Contact	26	20	18	27	25	22	25	10	173
Other	-	2	-	2	1	7	1	-	13

Table 1.6 Maritime event statistics in Ireland waters.

Years	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Fatalities	14	8	10	17	9	6	18	7	13	6	5	5	9	6	8	6	4	0	151
Injuries	2	0	1	2	Nil	-	2	Nil	4	Nil	1	0	14	Nil	Nil	1	2	2	31
Vessels Involved	17	11	12	20	10	6	18	12	17	6	7	7	15	5	5	7	8	8	191

In the same time period, 77 MOB events were reported with 75 fatalities (See Table 1.7). Considering the fact there are total of 151 fatalities and 75 are result of MOB accidents in the same period, 49.7% of the fatalities occurred as result of MOB accidents.

Table 1.7 MOB event statistics in Ireland waters.

Years	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
No of MOB Event	7	8	5	9	5	4	5	3	5	1	1	1	8	5	3	4	1	2	77
No of Death	7	7	5	8	5	4	5	3	6	1	1	1	7	5	3	5	1	1	75

1.2.2.5 Maritime events and mob accidents data reported by Canada maritime authorities

From 1998 to 2007, 17.6% of the fatalities occurred as result of MOB accidents. While 47 MOB events resulted with fatality, 36 resulted with injury (See Table 1.8).

Table 1.8 Maritime events and MOB statistics in Canada waters (From 1998, To:2007).

Years	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Shipping Accidents	491	536	450	459	448	481	442	444	422	393
Accidents Aboard Ships	59	69	77	59	36	66	50	45	50	60
Incidents	165	178	248	239	175	224	248	227	216	222
Fatalities	48	29	31	34	28	17	28	20	18	14
Injuries	80	84	94	70	78	95	82	66	85	80
MOB Result with Fatality	4	6	8	10	3	5	2	3	2	4
MOB Result with Injury	4	5	5	5	4	3	3	4	0	3

From 2008 to 2021 average 8.6 person felt overboard as seen in Table 1.9. Unfortunately, there is no information about survival rates of MOB accidents in these periods.

Table 1.9 Maritime events and MOB statistics in Canada waters (From 2008, To:2021).

Years	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Shipping Accidents	313	301	273	254	216	238	249	213	264	233	233	207	221	177
Accidents Aboard Ships	69	57	63	41	52	61	52	35	43	46	49	64	43	43
Incidents	285	249	224	216	270	734	747	707	768	885	937	945	925	885
Persons Overboard	9	7	9	4	5	10	7	13	10	10	12	14	5	5
Fatalities	30	15	18	16	14	18	12	19	7	11	20	17	18	11
Injuries	60	54	75	32	48	49	46	42	48	47	50	57	41	45

1.2.2.6 Maritime events and MOB accidents data reported by USA maritime authorities

From 2000 to 2021, 107614 maritime accidents were resulted with 14985 deaths, as reported in US Waters (Table 1.10). 8484 of these accidents are MOB accident and resulted with 4043 deaths. 13.9% of all accidents were resulted with death and 47.7% of the MOB accidents were resulted with death. In the same period, 27% of all deaths are result of MOB accidents. Average cost of a MOB accident is 565.7$.

Table 1.10 Maritime events and MOB statistics in USA waters.

Year	Total Accident	Total Deaths	Total Injuries	MOB Events	Deaths by Drowning	Other Deaths	Total MOB Deaths	Total MOB Injuries	Total MOB Cost ($)	Average MOB Cost ($)	Death Rate (1)	Death Rate (2)	Death Rate (3)
2021	4439	658	2641	273	137	33	170	98	164331	601.9	25.8%	62.3%	14.8%
2020	5265	767	3191	335	148	33	181	161	284771	850.1	23.6%	54.0%	14.6%
2019	4168	613	2559	299	148	41	189	122	110101	368.2	30.8%	63.2%	14.7%
2018	4145	663	2511	274	122	37	159	120	138338	504.9	24.0%	58.0%	16.0%
2017	4291	658	2629	306	135	44	179	126	104320	340.9	27.2%	58.5%	15.3%
2016	4463	701	2903	284	126	35	161	125	103495	364.4	23.0%	56.7%	15.7%
2015	4158	626	2613	259	125	30	155	107	78750	304.1	24.8%	59.8%	15.1%
2014	4064	610	2678	281	117	43	160	138	85440	304.1	26.2%	56.9%	15.0%
2013	4062	560	2620	281	120	29	149	131	83350	296.6	26.6%	53.0%	13.8%
2012	4515	651	3000	331	153	44	197	157	79885	241.3	30.3%	59.5%	14.4%
2011	4588	758	3081	359	148	57	205	157	117424	327.1	27.0%	57.1%	16.5%
2010	4604	672	3153	291	130	31	161	144	107585	369.7	24.0%	55.3%	14.6%
2009	4730	736	3358	349	152	36	188	173	57745	165.5	25.5%	53.9%	15.6%
2008	4789	709	3331	431	157	31	188	257	502615	1166.2	26.5%	43.6%	14.8%
2007	5191	685	3673	485	169	39	208	312	257181	530.3	30.4%	42.9%	13.2%
2006	4967	710	3474	485	161	41	202	306	363915	750.3	28.5%	41.6%	14.3%
2005	4969	697	3451	498	185	28	213	305	487895	979.7	30.6%	42.8%	14.0%
2004	4904	676	3363	488	163	36	199	339	288205	590.6	29.4%	40.8%	13.8%
2003	5438	703	-	509	-	-	201	354	141018	277	28.6%	39.5%	12.9%
2002	5705	750	-	542	-	-	189	389	627960	1158.6	25.2%	34.9%	13.1%
2001	6419	681	-	514	-	-	176	367	313789	610.5	25.8%	34.2%	10.6%
2000	7740	701	-	610	-	-	213	434	300918	493.3	30.4%	34.9%	9.1%
Total	107614	14985	-	8484	-	-	4043	4822	4799031	565.7	27.0%	47.7%	13.9%

From 2004 to 2021, 6309 MOB events were reported with 3264 deaths. 2596 of these deaths were result of drowning and 668 of these deaths were due to other reasons. 79.5% of MOB deaths are result of drowning. In the same period, 6.0% of all injuries are result of MOB accidents and also total injury number is 4.5 times of death number.

1.2.2.7 Maritime events and mob accidents data mob events data reported by UK maritime authorities

From 1994 to 2016, 5915 ship crew and 2382 passenger injured, resulting with 82 and 18 deaths respectively (See Table 1.11). 1.4% ship crew injuries, 0.8% passenger injuries and 1.2% total injuries resulted with death.

As can been seen in Table 1.12, 'Other Crew' has suffered highest injury rate followed by 'Deck Ratings'.

From 1994 to 2012, 3126 maritime accidents occurred in UK merchant vessels (100 gross tones or more) and 6937 in UK fishing vessels, 170 and 192 of these accidents are MOB accidents respectively (See Table 1.13 and Table 1.14).

Table 1.11 Deaths and injuries in UK merchant vessels >= 100 gross tons.

	Crew Members		Passengers	
Year	Injuries	Resulted in Death	Injuries	Resulted in Death
2016	133	2	51	1
2015	141	2	55	1
2014	142	0	56	1
2013	134	1	46	0
2012	186	3	50	0
2011	185	5	109	1
2010	222	3	92	2
2009	199	6	115	1
2008	224	5	170	2
2007	243	12	106	0
2006	233	3	114	1
2005	246	2	110	1
2004	310	4	147	0
2003	289	3	186	0
2002	302	5	134	0
2001	296	3	137	1
2000	301	3	137	1
1999	288	4	80	1
1998	330	2	120	2
1997	327	5	94	0
1996	403	3	97	2
1995	345	4	97	0
1994	436	2	79	0
Total	5915	82	2382	18

Table 1.12 Injuries to crew in UK merchant vessels >= 100 gross tons by rank.

Rank/Position	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	Total
Master/Skipper	4	3	1	1	4	3	2	8	1	5	8	40
Chief Engineer	1	4	4	5	10	9	9	6	5	6	4	63
Officer	-	-	-	-	2	1	4	8	-	11	16	42
Officer, Deck	16	9	19	22	22	16	7	13	13	8	8	153
Officer, Electrical	6	5	2	3	2	3	2	1	1	7	1	33
Officer, Engineering	17	26	17	17	19	15	15	28	18	23	7	202
Rating	13	6	7	20	5	7	11	22	16	23	-	130
Rating, Deck	50	70	62	58	68	59	72	64	66	55	67	691
Rating, Engineering	21	25	17	18	26	21	18	20	23	19	37	245
Rating, General Purpose	12	23	15	17	15	18	14	28	33	34	75	284
Other Crew	45	52	54	64	70	79	93	109	114	106	70	856
Worker (non-crew)	-	-	5	-	-	-	-	-	-	-	-	5
Total	185	223	203	225	243	231	247	307	290	297	293	2744

Table 1.13 Maritime events and MOB statistics of UK merchant vessel >= 100 gross tons.

Years	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Capsize/Listing	-	-	5	-	-	1	-	1	-	-	2	1	-	2	-	-	-	-	-
Cargo Handling	9	7	2	2	2	1	8	1	1	3	1	2	2	1	4	3	2	1	1
Collision	25	23	26	30	23	10	25	16	16	12	16	37	25	14	21	24	28	20	22
Contact	26	22	31	24	23	18	14	13	24	38	29	34	20	29	27	31	38	24	27
Escape of Harmful Substance	24	26	20	15	27	15	4	11	-	-	4	2	1	2	1	-	-	1	-
Fire/Explosion	24	25	22	26	24	19	18	21	26	21	22	19	6	8	8	3	6	13	14
Flooding/Foundering	5	3	3	4	3	3	2	3	1	3	3	6	4	2	4	4	3	3	1
Grounding	9	19	18	21	20	16	7	18	13	13	15	27	21	11	26	19	24	18	18
Heavy Weather	4	4	12	2	4	2	5	1	4	3	4	1	5	4	4	5	3	3	3
Machinery/ Equipment Failure	62	37	41	50	55	48	50	39	28	41	42	51	31	36	23	24	25	21	38
Person Overboard	6	6	14	15	7	10	5	9	7	9	5	13	12	7	11	10	7	10	7
Other	55	64		48	29	16	3	-	2	3	1	4	3	-	2	5	5	1	2

Table 1.14 Maritime events and MOB statistics of UK fishing vessels.

Years	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Capsize/Listing	9	7	9	8	11	15	4	3	5	4	2	6	5	2	2	2	6	7	5
Collision	23	29	25	22	20	15	25	17	15	17	12	23	12	18	17	10	15	11	16
Contact	8	9	6	3		7	2	6	1	7	3	2	3	4	2	6	4	4	4
Escape of Harmful Substance	21	17	19	17	11	15	16	10	12	13	19	16	15	9	11	7	10	15	11
Fire/Explosion	91	74	68	51	62	54	59	46	41	50	40	54	34	33	34	31	25	26	23
Flooding/Foundering	56	58	64	44	40	31	40	29	26	38	29	20	24	24	28	26	16	25	21
Grounding	4	5	2	1	2	4	4		2	1	2	3	1	5	-	3	1	1	1
Heavy Weather	322	385	327	316	247	232	174	212	181	221	202	232	240	213	156	140	184	195	174
Machinery/ Equipment Failure		1			1		1			1	1	-	1	-	-	-	-	-	-
Person Overboard	14	19	8	15	9	8	11	11	2	7	6	11	14	8	7	13	9	15	5
Other				1	1		2			1	1	1	-	1	-	-	2	-	-

5.4% and 2.8% of the maritime events are MOB accident related UK merchant vessels (100 gross tones or more) and UK fishing vessels respectively.

1.2.3 Comparative marine accidents data

The accident statistics obtained from the reporting authorities of the countries include only the number of accidents. However, it is not possible to determine the probability of accidents and make comparisons from these data.

Data in Table 1.15 gives total seafarer years at risk and mortality rates of different causes according to countries (Diestel, H. H., 2005). Data cover five years period from 1990 to 1994. Mortality rates are expressed in terms as per 10000 seafarer years. In the given time period, Hong Kong has the highest fatality rate of all accidents with

17.30 fatalities per every 10000 seafarer years. In the same period, Bangladesh has the highest fatality rate of illness with 16.05 fatalities per every 10000 seafarer years.

Table 1.15 Total seafarers' years at risk mortality rate.

Country	Total seafarer - years at risk (5-year period)	Mortality Rate (maritime casualties)	Mortality Rate (occupational accidents)	Mortality Rate (illnesses)	Mortality rate (all accidental fatalities)
Hong Kong	22,536	15.09	2.21	3.99	17.30
Chile	6,192	9.68	No info	No info	No info
Singapore	78,455	7.39	2.68	4.08	10.07
Israel	5,449	7.34	No info	No info	No info
Poland	39,300	5.85	1.53	3.05	7.38
Japan	209,308	5.78	No info	No info	No info
Greece	126,510	5.53	10.67	No info	16.20
Norway	153,406	4.51	5.68	9.54	10.17
Denmark	60,000	2.67	4.67	5.17	7.33
The Netherlands	50,842	1.77	2.16	No info	3.93
Bangladesh	14,954	1.34	No info	16.05	No info
Spain	44,955	0.67	0.89	No info	1.56
Great Britain	85,000	0.35	1.06	4.70	1.40
France	30,067	0.33	1.66	No info	1.99
Germany	90,992	0.22	3.63	No info	3.85
Australia	0,023	0.00	1.00	0.67	1.00
Sweden	94,682	0.00	0.95	1.48	0.95

1.3 Purpose of the Thesis

In the German merchant navy, personal accidents at sea for 100 insured crew members from 1988 to 1991, 1992 to 1995 and 1996 to 1999 are 4.9, 3.4 and 3.2 respectively (Diestel, H. H., 2005). Numbers show that improvements can be made and positive results on maritime accidents can be obtained. Mbong and Bygvraa (2021) claims that ISM Code increase safety standards at sea and participants of their study stated that SMS has prevented accidents from occurring. Results shows that even procedural developments can increase safety at sea.

This study does not aim only to find the problems causing MOB accidents or root causes. But instead aims to optimize 'Response to MOB Accidents'. Purpose of this optimization is to increase the survival rate of MOB accidents and this study aims to achieve this goal by making improvements in different aspects such as developments of new 'equipment' and 'procedure'.

1.4 Scope of the Study

This thesis has been prepared as result of a very detailed study. It includes detailed research on MOB accidents, researches made with different academic methods.

In section two, detailed statistical accidents about maritime accidents and MOB accidents are given. Statistics acquired from different national reporting agencies covering different time intervals. But more importantly, very detailed investigation data about MOB accidents are also shared in this section. These data were obtained as a result of the detailed examination of 100 MOB accidents with the 113-item 'MOB Accidents Investigation Form' created within the scope of the thesis study.

Since several analyzes were made in the study, different analysis methods were used. Information about these analysis methods used is shared in the methodology section.

In section 4, a procedure proposal for regulating another person entering the water to save a MOB casualty is made. Although the final decision will be made by the captain, details such as under which conditions this decision can be made and which factors should be considered are shared.

In section 5, an equipment proposal for assisting the responder or responders during a MOB person entering the water to save a MOB casualty is made. This pre-programmed response assistant carries out most of the response actions in the name of the responder and then switches to reminder mode and reminds the other actions to be carried out and provides some additional information such as drift predictions and contact information of nearest coast authorities.

After all the data obtained in the study and the equipment and procedure recommendations, which are the main outputs of the study, were presented, all data and results were evaluated. Discussions made as a result of the evaluations are included in Section 6 Discussions. Critical conclusions and discussions about each stage of the study are included in this section. After the discussions, the whole study was concluded and final results shared in Section 7 Conclusion. In addition, suggestions for future studies are also included in this section.

1.5 Contribution of the Thesis Study

This study has made many contributions to the maritime and academic community. First of all, within the scope of the study, a form has been created to examine a marine accident type in a more detailed way than it has been examined before. With this form, detailed accident investigations were made and very important results were found. If similar forms are formed for other maritime accidents, all maritime accidents can be examined in much more detail and much more important results can be obtained.

While reviewing MOB accident investigation reports, it was determined that other seafarers entered into the water to save the casualty in some MOB accidents. However, there is no previous study, rule or regulation suggesting or opposing such an action. This study is the first study on whether such a decision will be made, and if so, under what conditions such a response can be made. The study results in question were also transformed into an exemplary procedure.

During the thesis studies, many problems experienced while responding to the MOB accident and the negative consequences caused by these problems were determined. In order to eliminate these problems, a detailed study has been made and a response aid proposal has been made to use when responding to MOB accidents.

This study including all the publications prepared within the scope of the study is the most detailed study prepared for the MOB accident. If this study becomes a reference for other accident types, similar studies for other accident types will result in much more detailed data on maritime accidents. Thus, much more successful procedures and equipment will be developed.

2. MOB ACCIDENTS

In the first part of the study, statistical information about maritime accidents and MOB accidents is given. In this section, processed MOB accident data are given. Data from accident investigation reports, textbooks and company procedures have been studied in great detail.

2.1 Detailed MOB Accident Statistics Data

General maritime accident and MOB accident statistical data include only basic statistical information such as ‘total number of accidents’, ‘MOB accidents number’, ‘deaths numbers’ and some similar and very limited additional information. These statistics do not provide enough data to drive out important conclusions. To better understand MOB accidents, more detailed statistical information related to MOB accidents required. This data is required in order to:

• Obtain detailed statistical data that is exclusive to MOB accidents,

• To cross examine variables and to find if there is any correlation,

• Driving out root causes easily.

Optimum source to drive detailed statistical information was found as maritime accident investigation reports.

2.1.1 Need of a data acquisition form for MOB accident investigation reports

Maritime accident investigation forms are prepared according to ‘Code of International Standards and Recommended Practices for a Safety Investigation into a Marine Casualty or Marine Incident (Casualty Investigation Code) (MSC, 2008). Standard parts required to be included in this accident investigation reports are clearly stated in this code. Unfortunately, examination of many different MOB accident investigation reports relieved that most of the reports do not include necessary parts and/or information. Problems with existing reports and need of a data acquisition for MOB accident investigation reports are already explained in detail (Gonel and Cicek, 2019).

2.1.2 Maritime MOB events investigation form (MEI Form)

It has been determined that a format is needed to examine MOB accidents and to obtain detailed data. The preparation of this format was the result of a detailed study consisting of many stages. MOB accident investigation reports were obtained from many different sources. These reports were examined in detail and all the factors affecting the occurrence of MOB accidents and the outcome of the accident were determined. Identified factors were grouped under appropriate categories. MEI Form consisting of 113 items under a total of 10 categories was created (Gonel and Cicek, 2019 ; Gonel and Cicek, 2020). These 10 categories are:

• Vessel Information,

• Navigation Conditions,

• Casualty Status/Information,

• Meteorological Conditions,

• Work Type and Conditions,

• Managerial/Procedural Conditions,

• Initial Events and Timings,

• Response Actions and Times,

• SAR Operation (SAR) and Event Timings,

• Health Status of the Casualty.

Information items under 'Managerial/Procedural Conditions' category:

• P01 : Is there an applicable checklist? (Is there any kind of a specific document such as a checklist or a form to be filled prior to commence the work of which the event occurred?)

• P01.1: Is the checklist filled?

• P01.2: Is the checklist filled properly?

• P02 : Is there any applicable general work procedure? (Is there a special work procedure for the work being done? General procedures are not included.)

• P02.1: Is the general work procedure implemented properly?

• P03 : Fatigue condition (Not applicable for passengers and other non-crew casualties)

• P04 : Implementation of MOB drills

• P05 : Existence of a SAR procedure?

• P05.1: Appropriate implementation of SAR procedure.

Among 10 categories, information items under ‘Managerial/Procedural Conditions’ category is given as an example. All items are included in the appendix.

2.1.3 Detailed MOB accident information and statistics

In this section, detailed information obtained from 100 MOB accident investigation reports using the above-mentioned MEI Form is shared. This information includes statistical information, timing information about accident and response, and general inferences. Since results are already shared in detail (Cicek and Gonel, 2020) , here only important results are shared. In sub section 2.1.3.7, section 2.1.3.8 and section 2.1.3.9: all times are given in minute and timing start with the MOB accident. Response actions, SAR actions and health related issues are given with a short name (field name). Details of these response actions, possible answers and how the timing information is acquired is explained in previous studies prepared within scope of the thesis study (Gonel and Cicek, 2020; Cicek and Gonel, 2020). In order to avoid repetition, details of the form is not given in the thesis study.

2.1.3.1 Vessel information

This category gives information about the ships where the accidents occurred. 26% of the ships are in 0-4 years age group and the average ship age is 18.9 years. Average ship tonnage, length and number of crew member are: 19879.2 gross tones, 121 meters and 15.3 crew respectively. Majority of the ships are cargo vessels and among cargo vessels the subcategory with the highest rate is bulk carrier. 65% of the ships were classed by a classification society by the time of the MOB event.

2.1.3.2 Navigation conditions

This category gives information about navigational status of the ships. 62% of the ships were underway and the rest 38% of the ships were not underway. 40 of the ships that were underway were navigating, 13 of the ships that were not underway were at anchorage and 19 were at port by the time of the accident. Ships speed, draft and distance to nearest land are: 9.3 knots, 6.4 meters and 58.4 nautical miles respectively.

In some events no one was in command of the ship for reasons such as being at port and in some events, there was no information to determine who was in command of the ships. The captain was in command of the ship in 67.9% of the events other than these.

2.1.3.3 Casualty status/information

This category gives information about casualty' status. 60% of the casualties were deck ratings bosun comes first. It must be noted that in one case, captain was the casualty, in two cases port crew and in 10 cases the passengers were the casualties. Average age, total ship experience, work experience on the ship that the accident has occurred are: 40.3 years, 8 years and 8.6 months respectively. In the accidents that have information about alcohol and drug use, 33.3% of the casualties were found to have these substances in their blood or know to have consumed them.

2.1.3.4 Meteorological conditions

In 36 accidents weather conditions were adverse, in 58 accidents weather conditions were not adverse and in remaining 6 of the 100 accidents there is no information. Average sea and weather conditions were both scaled as 4. Average water temperature, air temperature and water depth are 12.1°C, 13.6°C and 427.1 meters respectively.

2.1.3.5 Work type and conditions

In 10 cases casualty was not carrying out a ship duty and in four cases there is no information about the activity that the casualty was engaging. In rest 86 cases, casualty was carrying out a work related to ship duty or was travelling as passenger. In majority of the cases, casualty was not working according to safety rules and was not wearing a lifejacket. In 56% casualty was accompanied by someone rather than being alone.

2.1.3.6 Managerial/Procedural conditions

In the majority of the accidents fatigue was not considered as a cause, MOB drills were not carried out and the ship procedures did include SAR procedure. However, these procedures were not applied properly. In 30 of the accidents, there was an applicable checklist but only 10 of these checklists were filled. Unfortunately, detailed examination of accident investigation reports relieved that only one of this form was filled appropriately. In 64.9% of the accident investigation reports that are the subject of the study, there was an applicable general work procedure. But these procedures were properly implemented only in 94.7% of the accidents.

2.1.3.7 Initial events and timings

MOB accidents mostly occurred during 08:00-11:59 period while working overboard. Mostly fall of the casualty is witnessed by a ship crew. In 51 accidents, casualty was momentarily seen while falling. In 28 accidents casualty was seen on water after the fall. The average time that casualty was seen on water in these 28 accidents after fall is 3.3 minutes. In 16 of the accidents, casualty was neither seen on water nor their fall was witnessed by someone and therefore assumed lost.

2.1.3.8 Response actions and times

In this section execution of some response actions and key events as well as their timing information are given. Table 2.1 shows response actions and their execution times.

Table 2.1. Response actions and timing.

Action	Carried Out	Not Carried Out/NI	Cases with Timings	Min. Time	Max Time	Avg. Time
Notification	65	35	40	0	53	4.1
Alarm	41	59	16	1	30	8
Announcement	17	83	7	0	50.5	15.2
Whistle	3	97	2	3	9.5	6.3
Buoy	48	52	33	1	150	12.4
Maneuvering	57	43	31	1	184	14.2
Captain	85	15	50	0	53	5.2
GPS MOB	11	89	10	1	25	10.2
Notification to close by ships	50	50	30	1	47	10.9
Notification to SAR stations	71	29	42	1	74	16.7
Other notifications	27	63	13	1.5	70	26.5
Rescue boat is ready	27	63	20	0	8	7.5

Average time of notification to the bridge, rising ship alarm, making an announcement via public addresser, blasting ship whistle and throwing life buoy are 4.1, 8, 15.2 6.3 and 12.4 minutes respectively. 62 of the ships were underway and 57 of these ships carry out MOB maneuvers. Timing information is available only in 31 events. Average time for maneuvering is 14.2 minutes. Average time for informing the captain, activating MOB function of GPS, notifying ships in proximity, notifying SAR stations, making other notifications i.e. company are 5.2, 10.2, 10.9, 16.7, 26.5 minutes respectively. Rescue boat was prepared only in 27 events and only 20 events had timing information. Average time for readying rescue boat is 7.5 minutes.

2.1.3.9 SAR operation and times

In this section execution of SAR actions and their timing information are given. Table 2.2. shows these SAR actions and their execution times.

Table 2.2. SAR actions and execution times.

Action	Carried Out	Not Carried Out/NI	Cases with Timings	Min. Time	Max Time	Avg. Time
Rescue Boat	24	46	18	0	46	10.1
Other Ships	49	51	24	0	500	51.3
SAR Ships	47	53	29	2.5	184	51.1
Air Operation	47	53	29	14	255	87.2
Shore Assistance	22	78	13	3.5	32.5	21.1
Removed from Water	65	35	35	0	3667	214.2
Cancellation of SAR	33	67	19	27.5	5135	986.2
Limited Sighting	24	76	14	1.5	23.5	7.9

Rescue boat was used in 24 accidents and timing information is available in 18 accidents. Average time that rescue boat participates in the SAR operation is 10.1 minutes. Other ships such as passing cargo ships participated in SAR operation in 49 accidents. Timing information is available in 24 accidents with an average of 51.3 minutes. Both SAR ships and SAR air crafts participated in SAR operation in 47 accidents and their average arrival times are 51.1 and 87.2 minutes respectively. Ship crew received assistance from shore such as ambulance and paramedic in 22 accidents and average arrival time of these assistance is 21.1 minute.

Casualty was removed from the water in 65 accidents regardless of survival status. Longest duration that it took to remove the casualty from water is 3667 minutes and the average time for that is 214.2 minutes. In 24 cases, casualty was sighted for a limited duration varying from 1.5 minutes to 23.5 minutes. SAR operation was cancelled in 33 accidents and the earliest cancelation was 27.5 minutes after the accident.

2.1.3.10 Health status of the casualty

In 41 accidents casualty received first aid and in 35 accidents casualty received professional medical treatment in a medical facility. Yet 88 of the 100 accidents resulted with death. In 34 accidents casualty is assumed death. In 18 accidents casualty has already died before rescue, in 31 accidents casualty died after rescue and in the rest 5 accidents casualty' death is unclear whether if it is before or after rescue.

2.1.4 Important findings driven from statistical analysis

In this section, important findings driven from examination of statistical results acquired with above mentioned MEI Form is shared. Refer to previous studies (Cicek and Gonel, 2020) for more details. Some important findings:

• MOB accidents occur more frequently when there are no adverse weather conditions.

• MOB accidents mostly occur at 08:00-12:00 interval and when casualty is being accompanied by another crew.

• Crew that are more experienced both as a seafarer in general and as the crew of the ship that accident occurs is more likely to fall overboard than the less experienced crew.

• In the majority of the accidents, safety rules and work procedures are not implemented correctly. Safety checklists are often completely ignored or not properly filled.

• An important number of the casualties that are rescued alive lost their lives after the rescue.

• 38% of the ships that MOB accidents occurred were not underway.

2.2 Findings Driven Out from MOB Accident Investigation Reports

• While examining the accident investigation reports related to MOB accidents, only statistical data were not obtained. Many important findings have been drawn from the accident reports. Some of these findings are:

• The inflatable life jacket can be punctured as a result of the impact. In this case, the life jacket may lose its buoyancy completely or to a large extent. In the accident that occurred on the Ernest Bevin ship, the casualty fell overboard both unconscious and with a punctured life jacket (MAIB, 2012). To mitigate the impact of such an event, a life jacket should have more than one inflatable sub component.

• In the event of a MOB accident that occurs on an underway ship, the first and only thing to be done is expressed as the casualty avoidance maneuvers. However, there is no information, procedure or any assistance for the actions to be carried out in cases where such maneuvers cannot be performed. In the accident that occurred on the MSC Sienna ship, there were factors affecting maneuverability of the ship and the ship was unable to perform the mentioned maneuvers (ATSB, 2013). Additional procedures should be developed for the type of maneuver and action to be taken in such situations.

• In some MOB accidents, it has been determined that more than one lifebuoy and even life jackets are thrown into the sea at intervals. In such a case, the number of things that the casualty can hold onto and help him swim increases. On the other hand, a confusing situation can occur with multiple rescue reference points for both the casualty and the ship. The casualty and the ship's rescue team can go to different life buoys. As a solution, two life buoys with a rope tied between them can be thrown, one from the port quarter and the other from the starboard quarter. In this way, the area where the casualty can gain initial grip will be increased and the life buoys will move together.

• Combinations and locations of lifeboats and fast rescue crafts on ships vary. The ship may be moored to the port facility on the side, on which the only rescue vehicle that can be used in case of MOB accident is located. In the MOB event occurred onboard M/V Joanna, the fast rescue craft was on the inboard side of the vessel so that it couldn't been launched (MAIB, 2011). Therefore, this possibility should be taken into account in ship design.

These important findings mentioned above were determined during the reading of the MOB accident investigation reports, unlike the findings determined by academic analysis methods. Many similar important factors have been identified and the above-mentioned findings are only given as an example. Before making a final comment, detailed studies should be conducted for each of these findings instead of evaluating them on a single event.

2.3 MOB Response in Merchant Maritime Education

MOB accidents are examined in detail in maritime education books, especially in maritime safety textbooks. 10 randomly selected books from the examined books are shared in Table 2.3 as an example. In the books, the maneuvers and emergency actions that should be done in the MOB situation are generally mentioned. Risks waiting for a MOB casualty were defined as propeller of the ship and sharks.

Table 2.3. MOB accident response in maritime course books.

No	Name of Book	Publication	Writer	Types of Maneuvers (Turns)	Risks
1	Temel Denizcilik ve Denizde Güvenlik	Istanbul, 1997	Barış Tozar	-	-
2	Manual of Seamanship	Southampton, 2007	Tom Cunliffe	-	-
3	Seamanship Techniques	Burlington, 2004	D.J. House	Williamson, Delayed, Double	Propeller
4	Denizciler İçin Sağlık Rehberi	Istanbul, 2004	Seçil Aksayan	Williamson, Elliptic	Propeller
5	The Theory and Practice of Seamanship	London, 1996	Graham Danton	Williamson, Single Delayed, Double	Propeller and Sharks
6	Nicholls's Seamanship and Nautical Knowledge	Glasgow, 2004	A.N. Cockcroft	Double, Single Turn, Williamson Turn	Propeller
7	Denizde Güvenlik	Istanbul, 2001	Yusuf Sertkaya	Williamson, Elliptic, Scharnow	Propeller
8	Ticaret Gemilerinde Olağanüstü Haller		Güven Tuncer	Williamson, Anderson, Scharnow	Propeller
9	Denizde Emniyet ve Canlı Kalabilme	İstanbul, 2010	Ercüment Şahin, Fethi Yağız	Williamson, Anderson, Scharnow	Propeller
10	Solas Training Manual		Yusuf Sertkaya	Williamson, Elliptic, Scharnow	Propeller and Sharks

In the books, maneuvers to be done in the event of a MOB accident were mentioned, and mostly 'Williamson Turn', 'Anderson Turn' (Single Turn is another name for Anderson Turn and they are same maneuvers) and 'Scharnow Turn' maneuvers were mentioned. These three maneuvers are also referenced in the International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual (IAMSAR, 2016) (See section 3.1.3 for details) and these maneuvers are referenced in almost all of the books. Unfortunately, according to the ship types (single propeller-single rudder, double propeller-double rudder), which maneuver type would be more appropriate was not mentioned enough and even in some books this subject was not mentioned at all. In addition, which maneuver types would be more appropriate when the accident is seen immediately or if it is noticed later, has not been discussed in detail.

One of the dangers that MOB casualties are facing is considered as propeller of the ship and in most course books, it is advised to turn the wheel opposite side that the accident occurred in order to avoid the casualty from the propeller. This possibility exists in theory but is very unlikely in practice. Modeling of the positive and negative pressures created by the ship and experiments on the modeling are required in order to make a complete determination on the subject. However, in the accident investigation reports examined in detail with the MEI Form or accessed from the databases, no example of an accident in which the casualty was caught by the propeller of a merchant ship was identified.

Another danger that MOB casualties are facing is considered as shark attack according to course books. International Shark Attack File of the Florida Museum is considered as the authority that keeps track of global shark attacks from 1990. Institution reports global annual unprovoked fatality as only five (URL-9). In 2021, 137 total shark attacks (either fatal or non-fatal) were reported and only four of these attacks were categorized as ‘Boat Bites’ which involves motorized or non-motorized marine vessels. There is no direct data to suggest that sharks attack to a MOB casualty is not possible, but figures suggest that it is very unlikely.

2.4 Response Procedures of Ships

MOB drill procedures of eight different ships were collected. A total of 25 response items were recorded from these procedures. Table 2.4 shows the cumulative list of actions to be carried during MOB drills. Response actions that are included only in a single company procedure were not included in the list.

Table 2.5 shows which emergency actions are included in different companies MOB drill procedures. The letters in the table code the company to which the procedure belongs. However, due to the requirement of the International Ship and Port Facility Security Code (ISPS), the companies did not want their names to be mentioned and their procedures to be disclosed. Eight response actions are included in all companies’ actions and only one response action included only in two company procedures. The average for response actions to be included in company procedures is six.

Table 2.4. MOB drill emergency actions list.

No	Emergency Action
1	Switch to hand steering
2	Commence turn / maneuver (Williamson Turn)
3	Release lifebuoy with light and smoke signal
4	Activate GPS MOB function
5	Note position of the accident, mark it on chart/ECDIS
6	Call master to bridge
7	Inform engine room
8	Sound “Man Overboard Alarm”
9	Use ship whistle
10	Hoist signal flag ‘O’
11	Post lookouts
12	Muster crew / Position crew according emergency duties
13	Prepare rescue craft for launching
14	Launch rescue craft
15	Complete Williamson turn / Complete maneuver
16	Sen appropriate message to all stations
17	Alert ships in vicinity
18	Keep GMDSS watch
19	Prepare for post rescue treatment
20	Rescue the casualty
21	Recover rescue craft
22	Treat the casualty
23	Notify the rescue to all parties
24	Inform the company
25	Preserve VDR (or SVDR) recordings and all notes

Table 2.5. MOB drill emergency actions of different ships.

No	A	B	C	D	E	F	G	H
1			√	√		√		√
2	√	√	√	√	√	√	√	√
3	√	√	√	√	√	√	√	√
4	√	√		√	√	√	√	
5	√	√	√	√	√	√	√	√
6	√	√	√	√	√	√	√	
7	√	√	√	√	√	√	√	√
8	√	√	√	√	√	√	√	√
9				√		√		√
10	√		√	√		√	√	√
11	√	√	√	√	√	√	√	√
12	√	√		√	√		√	
13	√	√					√	√
14			√					√
15	√	√		√	√		√	√
16	√	√	√	√	√	√	√	√
17	√			√	√		√	√
18	√	√		√	√		√	
19	√	√		√	√		√	
20	√	√		√	√	√	√	√
21		√			√			√
22	√	√			√		√	√
23	√	√			√		√	√
24	√	√	√	√	√	√	√	√
25	√		√	√	√	√	√	√

Emergency procedures were also examined along with MOB drill procedures. Emergency procedures are largely similar and all require a quarterly MOB drill. Emergency procedures of different companies do not differ significantly. Findings of the reviewed checklists:

• The same response actions were defined differently in different forms. For example, in one form suggests to use of 'Pan Pan' expression which means broadcasting an urgency message but other form suggest to broadcast 'Distress' message. In addition, in both forms, there is no statement that the type of message to be sent may vary depending on the severity of the situation. Sending a distress message in one of the forms and an urgency message in the other is clearly stated.

• In the forms prepared both in English and in Turkish, the translations of the response actions do not have the same meaning.

• Two very different response actions can be written in the same article such as: ‘pan pan message establish search’. When the Turkish equivalent of the same article is evaluated, the meaning of this article is: broadcast pan pan message and commence search.

• Response actions in some company procedures are prone to misunderstanding. In a form one response action is as follow: ‘Other shipos contacted’ (spelling error is intentionally left uncorrected). It is unclear that if the response action is to contact other ships or not. Reason of contact such as requesting assistance or informing them in order to keep clear is not expressed. Also, there is no explanation that mention way of communication.

• Some response actions are unclear such as: ‘Emergency station issued’ and ‘Recording communications’.

As a result, the MOB emergency procedures of different ships were examined. It has been determined that there are many deficiencies, translation errors, spelling errors and many other problems in these procedures

3. DATA ACQUISITION AND METHODOLOGY

In this section, it is explained how the data used in the study was obtained and with which methods it was analyzed.

3.1 Literature Survey

In this part, the information about which written sources are researched and for what purpose is given. In addition, the data obtained as a result of the literature review are shared in this section.

3.1.1 Legal legislation

There are some international organizations and treaties that aims to increase safety at sea. The International Maritime Organization (IMO) is the first international organization that comes to mind in this regard, and the International Convention for the Safety of Life at Sea (SOLAS) is the first agreement that comes to mind. These and other relevant international rules require that emergency procedures be written on ships, taking precautions by identifying risks, and establishing drill procedures. Seafarer training is determined according to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW). According to the curriculum prepared on the basis of this legislation, seafarers should be trained against the dangers that await them, and MOB is among these dangers. According to the 'Seaman Training and Examination Directive' in Turkish legislation, MOB accident takes place in seafarer trainings of different seaman ranks. As a result, when the national and international legislations are examined, it is seen that there is no special legislation for MOB accidents such as ‘law to protect seafarers from MOB accidents’, ‘legislation to prevent MOB accidents from occurring’ or any similar. Matters related to MOB accidents are included in the general legislation. For example, identifying the risks that await seafarers and putting them in writing.

However, it is seen that there are special provisions regarding MOB accident in the national legislation of some countries. In United States (US) Cruise Vessel Security and Safety Act was accepted in 2010. However, this national legislation has sanctions only on passenger ships of certain standards and International Cruise Victims Association is claimed to have effect on acceptance of this regulation (URL-10). French laws also have a similar equipment legislation (URL-11).

International Telecommunication Union (ITU) is an institution that is affiliated with the United Nations that has headquarter in Geneva and sets many standards in the field of telecommunications. Although it has not been published as a rule, there is a report published by ITU as a recommendation on Maritime Survivor Locating Systems (MSLS) and devices (ITU, 2014). Although this report is published as a recommendation, it is included in the written legislation of some countries. For example, in the GMDSS handbook published by the Australian Maritime Safety Authority (AMSA, 2018), these devices are included by specifying the frequencies they can use.

3.1.2 Publication in national directories and Theses Center of Turkey

The Thesis Center database of the Council of Higher Education, where all master's and doctoral theses published in Turkey are shared, has been scanned. As of 27.11.2022, the following search words were searched in both Turkish and English under ‘Title’ and ‘Subject’ categories:

• man overboard

• denize düşme

• denize adam düşmesi

No results were found for related searches.

The database of DergiPark, which is an electronic hosting and editorial process management service for academic refereed journals published in Turkey under TÜBİTAK ULAKBİM. As of 2021 December, there are 2076 journals and 536832 articles registered to the system. Database scanned with the following keywords:

• man overboard (searched as: ‘man AND overboard)

• denize düşme (searched as: ‘denize AND düşme)

In the search made on 27.11.2022, four results were obtained and two of them were directly related to MOB accidents. These studies are:

• An article study prepared within the scope of this thesis (Gonel and Cicek, 2019)

• A man-overboard discovery system article (Sevin, et. al., 2016).

The search results show that as of 27.11.2022 detailed studies were not carried out in Turkish publication indexes and theses that can lead to better understand MOB accidents.

3.1.3 Academic studies

Academic studies on MOB accidents are generally grouped under the following titles:

• Detection systems

• MOB maneuvers

• Search and rescue path planning

• MOB accidents on fishing boats

• MSLS devices

• Other MOB related academic studies

There are many academic articles about the MOB accident detection system. In these studies, many different systems were used to detect the accident. Selmy (2016) explains why a MOB detection system is required on ships. Katsamenis et. al. (2020) used RGB and thermal imagery, Bakolas et. al. (2021) used thermal imagery and spatiotemporal autoencoders and Sevin et. al. (2016) used wireless sensor network to detect MOB accidents. Study by Tsekenis et. al. (2021) is more complex and proposes machine learning-assisted man overboard detection using radar. Commonly expressed point in these studies is a constant monitoring equipment needs to be installed in order to detect MOB accident and alert the ship. In these studies, different systems are used for detection. However, the key point of all studies is the necessity of installing additional complex systems on the ship's sides. It has already been clearly stated in these studies that the system they propose will work under which conditions. For all systems, it is necessary to have the optimum conditions for the system to work. In addition, the systems do not work properly or cannot work at all if the required conditions are not provided. As a result, the positive side of these systems is that they detect the MOB accident immediately and report it to the ship, the negative sides are the necessity of adding extra gear to the ship's hull and the systems not working if the necessary conditions are not met.

Formela et. al. (2015) compared two different MOB maneuvers (Williamson Turn, Anderson Turn) on simulator and shared results. Kulbiej and Rosik (2018) compared the most commonly defined three MOB maneuvers (Williamson Turn, Anderson Turn, and Scharnow Turn) on the simulator. Su et. al. (2021) compared same maneuvers with full-scale sea trials by using a 12494 tonnes oil/chemical tanker and carried out MOB maneuver trails at Tasman Sea near the Australian coast. Academic studies on this subject are generally concerned with testing the suitability of customary MOB maneuvers. Most commonly mentioned of these maneuvers are Williamson Turn, Anderson Turn and Scharnow Turn. These maneuvers are also referenced in the IAMSAR Manual (2016), which is considered the most important resource in its field. The results of academic studies, both with the simulator and in real time sea trails, show that the said maneuvers do not give the same results in topics such as completion time, turning diagram and similar. In a real time MOB accident, maneuver may be carried out by less experienced watchkeeping officer in a very tense situation. But results acquired by experts from sea trails and simulators are used in these studies. Involvement of factors such as experience level of watch officer, psychological impact of the actual accident event and other similar factors may provide more realistic results. Also, in these studies it has not been determined which maneuvers are suitable for which type of ships and according to the awareness time of the accident. As an example, no study suggest which MOB maneuver is the optimum for a loaded oil tanker if the accident is momentarily reported to bridge.

A search and rescue path planning must be carried out to locate a MOB casualty. There are also academic studies on this subject. Academic studies on search and rescue generally focus on two different subjects. The first is about the determination of search and rescue paths, and the second is about the use of unmanned vehicles in search and rescue operations. Ai et. al. (2021) proposed an autonomous coverage path planning model. Ma et. al. (2022) proposed a new maritime emergency resources allocation optimization model. Academic studies on search and rescue that propose use of unmanned vehicles suggest use of both air and water vehicles. Mou et. al. (2021) proposed path planning for a fleet of cooperative maritime autonomous surface ships. Cho et. al. (2021) proposed coverage path planning for multiple unmanned aerial vehicles. There is not a noticeable difference between the planning methods suggested by the studies on the determination of search and rescue route. In addition, the different methods in question have not been sufficiently compared with each other. Also, some studies on this subject do not suggest methods for determining a search and rescue route, but makes drifting trajectories (Zhang, et. al., 2017).

Although some of the academic studies on MOB accidents are prepared in general to include all marine vessels, some academic studies are prepared specifically for fishing vessels. McGuiness et. al. (2013) studied fatalities in Norwegian fishing fleet from 1990 to 2011 and provided some statistical analysis. Similarly, Lucas and Lincoln (2007) studied fatal falls overboard on commercial fishing vessels in Alaska and Case et. al. (2018) studied fatal falls overboard on commercial fishing vessels in United States. Domeh et. al. (2021) studied risk analysis of MOB scenario in small fishing vessels. The model they proposed in their study would estimate the percentage likelihood of MOB occurrence aboard a vessel and also could assist in decision-making about the vulnerable factors requiring control to prevent a possible MOB occurrence. Academic studies on MOB accidents on fishing vessels usually present statistical data or make risk assessments. A common result of these studies is that when evaluated as a ratio, MOB accidents result in more deaths in fishing vessels than in commercial vessels.

As explained in the previous parts of the study (See section 3.1.1), an advisory document on the use of MSLS devices has been published by ITU. Some devices have been developed to meet the requirements of the said legislation and academic studies have been prepared on these devices. Sheu et. al. (2020) proposed a real-time alarm, dynamic tracking and monitoring system for MOB accidents. Their system used Global Positioning System (GPS) in order to provide dynamic tracking. A similar study proposed an alternative alarm and tracking system (Mao et. al., 2014). But their system uses BeiDou satellite navigation system. In a different study, proposed system used automatic identification system instead of satellite use (Li et. al., 2018). These studies are important for the instant detection of the MOB accident and the location of the casualty. However, these systems only work if the user physically carries the equipment in the recommended system and the battery of the device is full.

Above, the most prepared academic study titles related to MOB accidents have been shared. Of course, academic studies have been prepared on many different subjects related to MOB accidents. However, not all of the topics that are not widely studied are referenced. In a study, human reliability during emergency response drill for man overboard on ships was assed (Ahn, et. al., 2022). In addition, there are academic studies whose main subject is not MOB, but which also includes MOB accidents. As an example of such studies, in a study on the effect of life jacket use, environmental factors and casualty activity on maritime accident survival, MOB accidents are also widely covered (Pitman et. al., 2019). Some academic publications on MOB aim to adapt new technologies to MOB accident response. Ferura et. al. (2020) proposed use of autonomous aerial vehicles in MOB search and rescue operations. A very similar study made by (Cafarelli et. al., 2022) proposes use of a drone to provide video dataset for MOB rescue. Academic studies are being prepared on the use of current technologies in MOB accidents. However, these studies do not provide solutions to all of the problems that may be encountered in the active use of the technological developments they propose, or do not offer suggestions on this issue. There are many problems to be encountered in the use of related technologies in MOB accidents on ships. For example, the unmanned aerial vehicles in question must withstand adverse weather conditions in the open sea, be able to stay in the air for a long time at a distance from the ship and transmit data from a very long distance. It will also be necessary to have personnel on board who have the technical competence and training to maintain and operate these aircraft. Finally, in order to use these devices in the event of a sudden MOB, these aircraft and the personnel who will use these vehicles must be ready in all respects at the time of the accident.

3.1.4 Technological equipment

In this section, the technological equipment currently available in the market regarding the MOB accident is mentioned. These devices are:

• MOB detection systems

• Personal Locator Beacons (PLB)

• MOB devices

The technology company MARSS claims that the systems they have developed for MOB accident detection have accuracy detection with 95% probability. In addition, each of its sensors has a detection distance of 80 meters (URL-12). PureTech Systems Inc. is in 2004 and specialized in developing detection systems especially with their patented location-based AI video analytics and detection sensor integration software (URL-13). Their detection system is video-based and compatible with drone integration. The MOB detection system of the technology company SICK works with the scanners, not the video image capturing (URL-14). MOB accident detection systems work with different principles. The downside of all systems is that they give false alarms due to a litter thrown from the ship, a passing seagull, sea waves, and so on. In addition, each type of detection system has positive and negative aspects depending on its working principle. For example, for video detection systems to work properly, vision must be sufficient. A passenger travelling with MSC Bellissima was assumed lost and the event was considered as MOB accident (URL-15; URL-16) and the exact nature of the accident couldn’t be identified. MSC Bellissima was know to be the first MSC ship that was equipped with MOB detection system. By the time of the incident, the video data received from the detection system was being monitored and analyzed in the ship’s central security center by two independent image processing systems. However, the MOB detection system was not activated during the probable time of the event (URL-17).

PLB description made by Australian Maritime Safety Authority is: ‘PLBs are smaller and easier to transport than other beacons, and are designed to be worn or carried by individuals rather than vehicles.’ (URL-18). PLB devices communicate with COSPAS SARSAT satellites over 406 MHz frequency and give an emergency signal. The working logic of the device is explained in great detail prepared by the COSPAS SARSAT Secretariat (Cospas Sarsat Secretariat, 2021). PLB devices are developed for land, maritime and air use. MT610G GPS PLB is produced by Australian-based GME. The product has built in GPS and compatible with both marine and land use (URL-19). The time it takes for PLB devices to connect to COSPAS SARSAT satellites and send the distress message varies depending on many factors. Two PLB devices of McMurdo company 'McMurdo FastFind Ranger' and 'McMurdo FastFind 220' were examined (URL-20). There is a difference in the time of sending distress messages between these devices, and the reason for this difference is due to the technology they use. The 'McMurdo FastFind 220' model can also send distress messages earlier as it connects to Galileo and GPS satellites.

Unlike PLB devices, MOB devices are produced specially for MOB accidents and to be used in maritime sector. Another difference of these devices from PLBs is that they notify both the surrounding ships and the ship they are connected to, seconds after they are activated. Personal locating AIS MOB device produced by Ocean Signal Ltd. is only 92 grams and can easily be integrated to life jackets (URL-21). The model has both GPS receiver and integrated Digital Selective Calling (DSC) transmitter. ‘AISLink MOB’ is the name of the AIS MOB beacon produced by ACR Electronics Inc. (URL-22). Product features integrated DSC and GPS technology. Another product of the company is named ‘ACR OLAS Tag’. This product is identical to a wrist watch and weighs only 30 grams even with straps. The working logic of the product is simply as follows: The product is connected to any smartphone or tablet. If the connection is lost for eight seconds or longer, the system will consider that the user has fallen overboard and rises the alarm.

Some of these MOB devices are categorized as wearable and are generally preferred in small boats and fishing boats. BoatU.S. Magazine tested five MOB wearables and drove out important conclusions (URL-23). While four of these devices have the feature of giving an alarm only to the marine vehicle they are connected to, only one of them has the feature of giving an automatic alarm to the emergency services.

3.2 Statistical Analysis

Statistics is a set of methods used to analyze data (Sarmaneto and Costa, 2019). Heumann et. al. (2016) made definition of statistics as: ‘statistics is a collection of methods which help us to describe, summarize, interpret, and analyze data’. Lavenberg (1983) made definition of statistical analysis as: ‘the purpose of the statistical analysis is to produce a meaningful statement about the accuracy of the estimate’. With a very simple explanation, analyzing data is called ‘statistics’ and analyzing statistical data is ‘statistical analysis’. One of the major statistical analysis software company SAS considers statistical analysis as a science. Statistical analysis science is collecting, exploring and presenting large amount of data in order to discover underlying patterns and trends (URL-24).

The data set created to use in the procedural part of the study was created by asking 100 questions to 29 experts (ship captain). Statistical analysis was needed to examine the data set in detail, to determine the correlation between the data and to draw conclusions. However, statistical analysis is a general concept and not a method per se. There are many mathematical models and software for statistical analysis and these models are considered as method. The method to be used varies according to the type of data available, the purpose of use of the data and many other factors. Al-jabery, et. al. (2020) determined the questions to select an appropriate statistical analysis are:

• What is the main research question the study?

• List variables that are being investigated to answer this question?

• How many variables are there in the model?

• What relationships are being investigated?

• What is the independent variable or variables in the model?

• What is the dependent variable or variables in the model?

• Are the dependent and independent variables being quantitative or categorical?

The primary method used to prepare the procedural proposal in Section 4 was selected as BLR and criteria of this choice is explained in Section 3.2.1. The GLM method was also used in the relevant procedural proposal. The reasons GLM method is used and according to which criteria it is selected is explained in Section 3.2.2.

Choosing the wrong method to be used will result in erroneous results. However, there are many control methods to determine the accuracy of the analysis results. The said control methods are also determined according to the selected analysis method. If there is an inconsistency in the results due to the wrong method selection, it will be determined by consistency analysis. Appropriate analyzes were made for both methods used in the procedural proposal and it was seen that the data had high consistency rates.

Today, the calculation methods of statistical analyzes have changed radically with the change of computer technologies (Smith, 2018). Statistical analyses made in this study were also made using computer-based programs. Statistical Package for the Social Sciences (SPSS) software is the software program that is used in this study.

3.2.1 Binary logistic

Linear regression is an attempt to model the relationship between two variables by fitting a linear equation to observed data, where one variable is considered to be an explanatory variable and the other as a dependent variable (Shobha and Rangaswamy, 2018). Basically, logistic regression is an extension of regular linear regression. Logistic regression is used when the dependent variable is a categorical type. If the dependent variable of the model is a 'Yes/No' type variable that is expressed by 1s and 0s, the model is called binary logistic regression (Gonel and Cicek, 2022). But a categorical type dependent variable may not always be expressed by only 1s and 0s.

BLR isn't the only type of logistic regression. If categorical type dependent variable has more than two possible outcomes, the model is also a logistic regression model and called as 'multinomial logistic regression'. The model that has more than two possible outcomes is also called 'ordinal logistic regression' if the dependent variable is ordinal type variable. There are different types of logistic regression models as explained, but the model that is suitable for the data set to be analyzed is the BLR.

In simplest terms, BLR is the analysis method used to detect the relationship between one or more explanatory variables and the outcome variable. In addition to a binary dependent variable, a binary logistic regression has at least one independent variable that is used to explain or predict values of the dependent variable (Primer on binary logistic regression). Like regular regression models, BLR provides assessment on how well variables in the model predicts categorical dependent variable. But more importantly, it provides a summary of the accuracy of the classification of cases that determines the percent of predictions made from this model that will be correct (Fritz and Berger, 2015).

Scientist Verhust published some papers which were related to population growth in period 1838 to 1847. In year 1845 he explained his function and named it as 'logistic'. In 1920, logistic function was discovered again by Pearl and Reed. The study was again related to population growth and the two scientists were unaware of Verhust's study. The basic idea of logistic growth is simple and effective, and it uses to this day to model population growth and market penetration of new products and technologies (Cramer, 2002). From the first use of the word logistics to the present day, of course, numerous studies have been carried out on the model in question. With these studies, different models and methods of logistics were identified. Different control functions have also been developed to detect the consistency of the new models.

Over time, not only logistic functions have improved. With the computer age, logistic functions also began to be digitized. 'IBM SPSS Statistics', which is shortly refereed as 'SPPS' was initially introduced in 1968 (Frey, 2017). 'SAS' was originally developed at North Carolina State University starting in 1966 and initially released in

1972. In August 2020, 34th version was released (URL-25). ‘Stata 1.0’ was released by StataCorp LLC in 1985 (Pinzon, 2015). In April 2021, 17th version of STATA was released. With 17 versions and 21 sub versions a total of 38 versions are released in 37 years period from 1985 to 2021 (URL-26). The referenced statistics software programs are the most widely known in their field. However, there are some other statistical programs currently available in the market and under development process.

The BLR method is widely used today by both academia and many different sectors. Bera et. al. (2020) used BLR method to analyzes the relation of variables and deforestation probability in Silabati. By using data from 1998 to 2019, they resolved the relation of deforestation probability and the variables with very consistent results. Szeto et. al. (2019) used BLR method to model guiding vacant taxi drivers to demand locations. With the results they acquired from BLR analysis, they developed a simulation and prepared a solution procedure in order to increase efficiency of taxi calling signals. In another academic study, it was tried to detect the heavy metal/metalloids in the groundwater by examining nail and hair samples taken from the subjects. BLR revealed that the factors associated with the concentrations of these substances in the hair samples were source of the drinking water, water consumption rate, gender, water source used for bathing, education, smoking and underlying disease (Wongsasuluk, et. al., 2018). BLR is used in many disciplines like medicine (Mesa, et. al., 2018; Hanson, et. al., 2013; Yemane, et. al., 2022), engineering (Peeters, et. al., 2012), psychology (Das, 2022) and used in many other fields. The BLR method is also used as the main method when preparing master's (Yılmaz, 2016; Mahmood, 2017) and doctoral thesis (Yenipınar, 2019).

3.2.1.1 Choosing the BLR method as the primary analysis method of the procedural proposal

This section explains why BLR was chosen as the main method in the procedural proposal. However, some preliminary concepts need to be explained before the relevant explanation is made.

Bivariate and Multivariate Data: The word bivariate is explained as ‘of, relating to, or involving two variables’ (URL-27) and multivariate is explained as ‘having or involving a number of independent mathematical or statistical variables’ (URL-28). In statistical analyze, if data involve two variable it is called as bivariate data and if data involve three or more variable it is called as multivariate data.

Dependent and Independent Variable: In a model, variables have effect on each other, which is usually the focus of the research. The input variable which causes a particular outcome is called independent variable. The outcome variable, which is affected by the input variable is called the dependent variable (Jaiyeoba, et. al., 2017). Since dependent and independent variables are explained in detail (See Section 4.5.1), so no further explanation or examples are required.

Quantitative and Categorical Variable: If a variable is represented by number with a mathematical meaning, this type of variable is called a quantitative variable. If the number associated with the variable, is not equivalent to a mathematical relation, this type of variable is not a quantitative variable. All of the variables other than the quantitative variables, regardless of whether they contain numerical values or not, are defined as categorical variables (Hernandez, 2021).

Al-jabery, et. al. (2020) explained statistical analysis methods in great detail in their book. They also explained which data type should be analyzed by which statistical analysis method. Figure 3.1 is taken from this study and guides the selection of the method to be used according to the data type and the characteristics. In procedural proposal part of the data used can be categorized as:

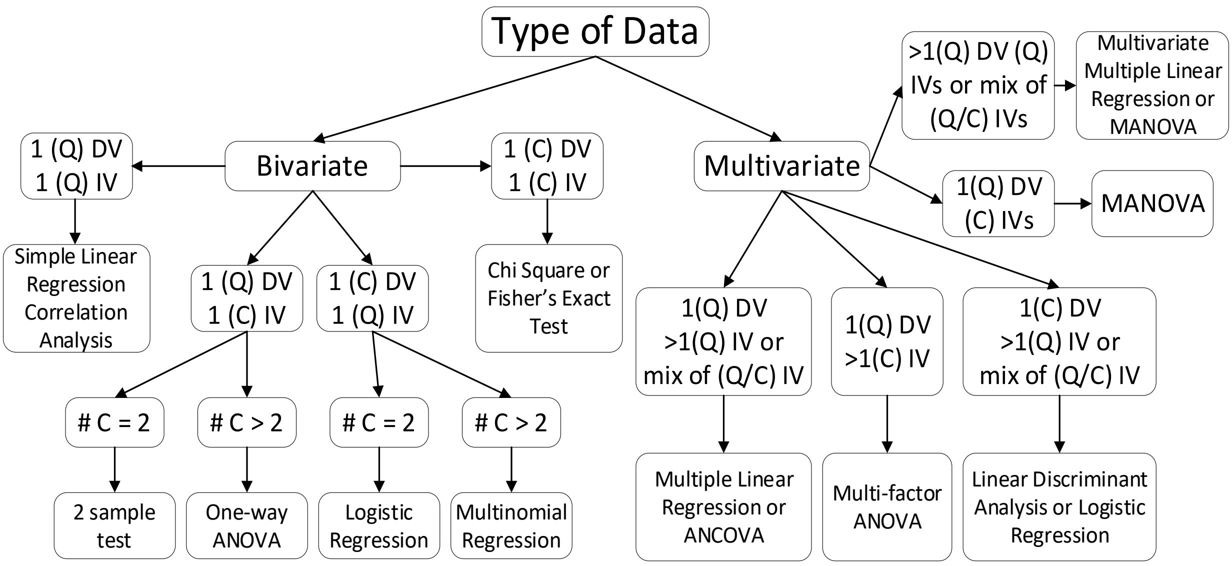

Figure 3.1 : Statistical Analysis Flowchart for Different Parametric Statistical Methods Al-jabery, et. al. (2020)

1st option is a choice over number of variables as 'Bivariate' and 'Multivariate'. Because there are 11 variables at the first stages and seven variables at the final stage of the analyze process (See Section 4.5.1 and 4.5.3). First option is 'Multivariate'.

2nd option is a choice over type of dependent and independent variables. Dependent variable is 'Categorical Dependent Variable' and independent variables are 'Mix of Quantitative and Categorical Independent Variables'. Dependent variable is a 'yes/no' type variable expressed by 1 and 0, which is an identical example to a categorical dependent variable. And the seven final variables are a combination of quantitative and categorical type variables as can be seen in Section 4.5.1.

3rd option is choosing the analyze method between 'Linear Discriminant Analysis' and 'Logistic Regression'. LDA method is explained and compared with BLR in Section 3.2.1.2. According to comparison results, BLR method is chosen as the primary method for data analyze for data set.

3.2.1.2 Linear discriminant analysis and comparison with binary logistic regression

How the main analysis method used in the procedural proposal was chosen was explained in the previous section (Section 3.2.1.1). In some PhD thesis, all the methods that can be used as in the study are listed, explained and most appropriate method is chosen according to criteria of the study (Kececi, 2015). In this studty, the method selection was not carried out by personal evaluation, but according to the categorical and other characteristics of the available data set. Reference source required a choice between LDA and BLR methods. For this reason, apart from the BLR method used, only the LDA method has been explained and the comparison has only been made between these two methods.

Zhu et. get. (2022) explains the Linear Discriminant Analysis (LDA) method simply as a widely used supervised dimensionality reduction method. Deepika et. al (2022) describes the principle of LDA as optimization of the separability between the two classes to identify them in the best way that can be done. Wang et. al. (2022) claims that LDA is one of the most representative supervised robust dimensionality reduction method which can be used for handling high-dimensional data.

Wei et. al. (2022) used LDA method to positioning method for maize seed laser-cutting slice. Maize seeds sliced with laser cutter in order to analyze breeding genotype. With

LDA method, researches gave up the conventional idea and proposed a new method. LDA method is usually preferred in face recognition studies (Chelali et. al., 2009; Bhattacharyya and Rahul, 2013; Zhao and Yuen, 2008)

LDA is an important method accepted in statistics which is used for modelling differences in groups. Jiang and Leung (2021) states that LDA is generally used as a dimensionality reduction technique. Since there are no groups for modelling, data set to be used is not dimensional and no dimensionality reduction is required, LDA is not the proper method to be used to analyze the data set. Also, the BLR method is a much more suitable method for examining the dataset, and the relevant justifications are explained in Section 3.2.1. As a result, one of the LDA or BLR methods should be used when the relevant options for the properties of the current data set are evaluated one by one. However, when the diversity and other characteristics of the data were examined, it was determined that the most appropriate method for data analysis was BLR.

3.2.1.3 Benefits and negatives of BLR method

This section describes not the general benefits of the BLR method, but the benefits it provides to this study. By using the BLR method, all the objectives aimed in the study were fulfilled and it was determined that the results had a very high consistency in the controls. Benefits of using the BLR method in the study:

- Removal of variables that have no effect on the model,
- Identifying the most effective correlation,
- Determining the order of importance of the variables,

Removal of variables that have no effect on the model: An analysis study is started before the results of the study are known. All the variables that are likely to have an effect on the result are included in the equation, and the variables that are found to have no effect as a result of the analysis are removed from the equation. Wang et al. (2021) started with 72 variables in his crash prediction model, according to BLR analyze results they removed 59 variables and thirteen significant variables were left. Similarly, Abdulqader (2017), however, used the BLR method for real medical data on hepatitis and removed the insignificant variables.

At the first stages of the study, there were 11 variables at the initial stages of the study and only five variables were left in the model at the final stage of the variable. Variables that have no effect on the model were removed as explained in Section 4.8.2.

Identifying the most effective correlation: Removal of variable which has no effect on the model and identifying the most effective correlation may be considered as the same thing or very similar things but there is a very big difference. If the independent variable negatively affects the explanation of the model, it is removed from the model. However, in some cases, the independent variable does not negatively affect the explanation of the model, but it cannot explain the model to a significant degree. These variables can also be removed from the model to find the most meaningful correlation. Similarly, in this study, the variables that had no effect on the explanation of the model were excluded from the model and the most significant correlation was found as explained in Section 4.8.2.

Determining the order of importance of the variables: BLR method allows prioritizion the variables according to their beta coefficients. Many other studies have already used BLR method for prioritization of variables (Dascalu, et al., 2007; Abdulqader, 2017; Aksu and Keceoglu, 2019). Aksu and Keceoglu (2019) used BLR, Chi Squared Automatic Interaction Detection (CHAID), and decision tree methods for the same data set and all three methods provided the same order of importance for the variables. In order to better understand the independent variables in the model, the order of importance has been determined. In addition, some evaluations were made according to this order.

In this study, no negative features of the BLR method or a negative result reflected in the study were observed. However, some negative features of the BLR method can also be mentioned. In such statistical analysis studies, the possibility of 'multicollinearity problem', 'uncertainty' and similar problems can be mentioned. The evaluation results of the analysis data show that the study is highly consistent (See Section 4.7).

3.2.2 General linear model

The main method used to analyze the data set used for the procedural proposal of the study is the BLR method. The BLR analysis helped determine both the effect of the variables to the model and the order of importance of the variables. However, the BLR method does not have the ability to detect the interaction within each variable. The GLM method was used as an additional method in this study in order to determine the interaction of attributes within each variable. Employment of the GLM method also provided additional analysis, cross checking the results obtained with the BLR method and increasing the reliability of the presented results.

With a simple explanation, the GLM method helps characterizing the statistical properties of the estimator (Tian and Takane, 2008). General Linear Model (GLM) consists of three words. The term ‘general’ is used to name this method because it is not a necessity that regressors are measured data. But they can code for the belonging to either a group or to a condition. Since the model is linear, the word ‘linear’ is used to name this method. GLM is basically a multiple regression and a series of numbers are approximated by weighting the sum of other numbers (Poline and Brett, 2012). By using the data set, a number of statistical assumptions are made. Model is the sum of the assumptions and the generated data. By combining these three words, GLM method uncovers the linear relation between the response and the predictors regardless of the data set being measured or generalized. Although the GLM method establishes a linear relationship, the relationship between the variables does not have to be linear.

The GLM method also has some sub-varieties such as Multivariate General Linear Model (MGLM) and Univariate General Linear Model (UGLM). According to statement made by Tian and Wang (2017), MGLM is generalization of UGLM. In addition to the sub-varieties there are even extensions of the GLM method (Lünmann, et. al., 2020).

Adad et. al. (2007) used GLM model to detect functional activation in the brain by using diffuse optical imaging. The GLM method is used in many different fields, especially in medicine. Campell (2004) used GLM to asses annual indices of stock abundance in fishery. Ochwada et. al. (2008) used GLM method to predict the age of fish.

3.2.2.1 Use of GLM in the study

In the procedural proposal part of the study, BLR was used as the main method and this choice was explained in detail with the reasons. However, the GLM method was chosen to determine the interactions of their attributes within the variable they are connected to. This additional statistical review was performed to better assimilate variables and attributes rather than preparation of the proposed procedure as a result of the study.

The GLM method results and the findings of the analysis are explained in detail in Section 4.7 and Section 4.8.3. For two different reasons, very detailed information about the GLM method has not been given in this study. First, the GLM method is not the main analysis method of the study. Second, Poline and Bret (2012) mentioned the GLM method in detail in their study and no additional explanation was needed in this study.

3.2.3 Combined use of binary logistics regression and general linear model

BLR method is used to determine which variables are to be included in the model and also to identify their order of importance. GLM method is used to asses the effects of attributes to their own variables. For both methods, analyzes are made with Statistical Package for the Social Sciences (SPSS) Version 22. The same two methods were used before by Lee et. al (2018) and results of their study proved that that these two methods can be used in a very compatible way with each other and will give very successful results.

3.3 Experimental Study and Simulation

As explained in great detail in Chapter 5.1, 'time' is a very important factor in the SAR operation occurred as a result of the MOB accident. An emergency response equipment proposal was made in order to shorten the response time after the MOB accident. The features of the response aid and the other benefits it will provide are explained in Section 5.9. A time model was required to identify the problems in more detail. Since it is not possible to acquire timing data from previous real accidents, an experimental study was carried out. Timing data acquired from experimental study was used to prepare time model and a discrete event simulation was made accordingly. The serviceability of the response aid device was also determined by simulation. As a result, 'experimental study' and 'discreet event simulation' methods were used to obtain data and determine the serviceability of the proposed system in the equipment proposal part of the study.

3.3.1 Experimental study

In order to better analyze the response at the bridge to man overboard accidents, a time modeling was required. Also, time to carry out each emergency action and total response time were needed. ‘Experimental Study’ has been chosen as the method to obtain these data (See Section 3.3.1.1). 'Experimental Study' is a data collection method in its simplest form. It is the collection of data directly by fieldwork instead of models, formulas, assumptions and similar assumptions to obtain the needed data. Sorkun and Ozpeynirci (2022) explains experimental study as ‘a quantitative research method that allows to see the effects of changes in the variables of interest by keeping other relevant variables under control’. Kim et. al., (2019) used a quasi-experimental study to find effects of a patient safety course using a flipped classroom approach among undergraduate nursing students. Human is the test subject in above two studies but that is not the only case. Zhang and Li (2020) used experimental study on high-performance rubber bearings to find their temperature dependence of mechanical properties. Favero et. al. (2021) used experimental study for finding human thermal comfort under dynamic conditions. The main aim of this study was to determine dynamics of human thermal comfort. Rather than making a simulation or carrying out a survey study, researches directly collected the data from office-like climate chambers from 38 participants.

3.3.1.1 Choosing the experimental study method for the purpose of data collection for the procedural proposal

At this stage three possible source were determined to collet this data:

• Investigation or court documents (decoded versions of VDR recordings)

• Accident investigation reports

• Sea trails

• Experimental study

Investigation or Court Documents: Depending on each country's legislation, there will be an investigation and perhaps a court process after the MOB accident. When the VDR records examined in this process are analyzed, they will be able to obtain the most sensitive data on the subject. However, access to these records has not been obtained. Due to lack of access, this option has been completely eliminated.

Accident Investigation Reports: These reports were mentioned in detail and were used extensively in the previous parts of the study (See Section 2.2 and 2.3). 100 accident investigation reports were examined in detail but these reports do not include all required timing information. More importantly time data does not include seconds but only minutes. Also, most of the time information is not very accurate and involves time information such as ‘in a couple minutes’, ‘during this period’ and similar. Precise time information could not be obtained from this source. However, even if it is obtained, it will not be possible to use the data in combination, as the ships and conditions will be different. Also, accident investigation reports do not include decoded VDR records.

Sea Trails: Sea trials are the most realistic method of obtaining relevant data. However, it is quite difficult, if not impossible, to perform these operations on a large ship. The study in the bridge simulator was carried out with 10 different participants. For such a large number of different participants to be on board, they must be formally aboard the ship. In addition, there must be sufficient space and safety equipment for additional participants on board and in survival craft. For these trials, the ship will have to go off course, lose time and consume fuel. Due to the costs incurred due to all these reasons, this opportunity was excluded from the evaluation.

Experimental Study: It is the creation of the desired environment and data collection with different participants on the bridge of a ship or in a simulator. If this work is performed in the simulator, the biggest advantages it provides are easy access and environmental conditions can be created as desired.

Also, criteria to choose the optimum method were determined. These criteria are for obtaining the data needed in the study. Criteria are:

• Time information

• Precision in time measurement

• Include all response actions

Time Information: Regardless of which operation method is chosen, the data to be obtained is the duration of the actions performed during the MOB emergency response. For example, how long an emergency announcement with VHF will take.

Precision in Time Management: Times need to be measured precisely. In addition, times should be measured in seconds, not minutes. Also, a study done only to obtain time data will contain much more precise results.

Include All Response Actions: Time data of all response actions is needed to create the simulation.

A limited number of possible methods and selection criteria have been identified as can be seen in Table 3.1. Ship trials and experimental study options were identified as two possible options. However, the ship trials option was excluded due to financial reasons and other difficulties. As a result, the experimental study option was chosen as the data collection method in the equipment proposal part of the study.

Table 3.1. Comparison of timing data acquisition methods and criteria.

Criteria	Investigation or court documents	Accident investigation reports	Sea trails	Experimental study
Time information	NI	√	√	√
Precision in time measurement	NI	X	√	√
Include all response actions	NI	X	√	√

3.3.1.2 Positive attributes of experimental study

If the experimental study is to be used as a method in a study, acceptance, assumptions and similar binding conditions may not be required. This is the strongest feature of the experimental study. In fact, the data can be obtained directly from the desired environment itself, not from the closest (created) environment to the desired environment. The main aim of this study by Favero et. al (2021) was to determine dynamics of human thermal comfort. Rather than making a simulation or carrying out a survey study, researches directly collected the data from office-like climate chambers from 38 participants. In such a study, it cannot be questioned how close the environment in which the data is collected is to a real environment. Because the data were obtained directly from a real environment where the data was intended to be collected.

3.3.1.3 Negative attributes of experimental study

However, in order for an experimental study to be used, the environment in question must actually exist or be created. Experimental study is not always applicable due to reasons such as ethics, cost, physical space and most importantly ability to create the environment. Also, the results to be obtained are directly limited by the reality of the created environment. The reference study by Favero et. al (2021) has also negative attributes. Most of the participants were between age 23 and 31 years old. Gender distribution of the participants were unbalanced and the study suggests that there are significant differences between males and females in terms of thermal discomfort. Also difference in clothing of the participants was also a limitation to the study. As can be understood from the examples given, some negative features of the experimental study have been determined in the reference study. However, if these negative factors are correctly identified and reported as limiting factors in the study, they will not affect the objectivity of the study.

3.3.2 Discrete event simulation

This study proposes an autonomous system that performs some of the emergency response actions that must be carried out in MOB emergencies (Section 5.9). In order to determine if the proposed MOB response system would be beneficial, it is necessary to compare the 'response with the proposed MOB system' and the 'standard response'. Additionally, the main purpose of the proposed system is reducing the response time. In order to make this proposal, it is necessary to determine if the system reduces response time. It is very unlikely to test the proposed system in a real MOB accident on board. Even if such an option is in question, comparison will not be possible since there is no example of a response made without using the proposed system under exactly the same conditions.

Also, it is not impossible but very unlikely to carry out numerous MOB response exercises on a real ship and acquire the required data for this study as already explained in Section 3.3.1.1. In addition, since the proposed system has not yet come to an operational level, testing the response with the proposed system on a ship is not an option. Discrete Event Simulation (DES) is chosen as the main method to acquire this data.

3.3.2.1 What is simulation

Aksoy (2017) describes the simulation as the construction of a model of a real system and performing experiments on the model designed to observe the results of different situations and makes detailed explanation in his thesis. Simulation allows to perform operations that are impossible, very difficult or not practical for any reason in reality. In addition, the number of times the operation will be performed can be selected by the user. Simulation has a wide range of uses in many fields of study such as airport security, haulage systems, nursery and many other fields. Researchers tried to find answers to a wide variety of questions. Even if there is no question or a problem, simulations are still used. Yuknis and others (2022) carried out a simulation based interventional study in order to improve emergency preparedness in pediatric primary care offices.

3.3.2.2 Advantages and disadvantages of simulation

The advantages and disadvantages of simulation are explained in detail by Aksoy (2017). For this reason, no additional explanation was made in this study. Some examples of the advantages of simulation:

It can be applied more easily than mathematical methods.

Performance of a real operating system under different conditions assessable.

Some examples of the disadvantages of simulation:

Collecting data for the establishment of the simulation model and obtaining the results by running the model requires time and intensive work.

At the stage of data collection, situations such as system administrators not sharing realistic data due to various prejudices are frequently experienced.

Only a few of the advantages and disadvantages of simulation are given as examples, and all examples are from doctoral thesis of Aksoy (2017).

3.3.2.3 What is discrete event simulation

Depending on the change of a system's variables over time, a simulation is either called a Discrete Event Simulation (DES) or a Continuous Event Simulation (CES). Kettenis (1997) describes the difference of these two models as: discrete event simulations are used to study queueing problems and continuous models are applied are used to study dynamic behavior of technical systems. Queueing theory is basically the mathematical study of waiting lines and it is used to predict queue lengths and waiting times (URL-29). Wang et. al. (2018) proposed a practical approach to approximate time-dependent queuing model in their study. Study by Wang et. al. (2018) and the many other studies referenced in their study, prove the relation between queuing model and time modeling and prediction. DES was chosen as the appropriate method since the data needed in the equipment proposal part of the study includes time modeling and time prediction.

First introduction of DES dates back to October 1961 by Geoffrey Gordon who is an IBM engineer (Sumari et. al., 2013). Babulak and Wang (2010) describe DES as: 'Discrete-event simulation represents modeling, simulating, and analyzing systems utilizing the computational and mathematical techniques, while creating a model construct of a conceptual framework that describes a system'.

3.3.2.4 Advantages of discrete event simulation

Some of the advantages of using the DES method:

• Testing a number of different scenarios without any restriction,

• User can increase or decrease the speed of the simulation. Which allows to acquire data can be acquired in years or slowly monitor the process (Forbus and Berleant, 2022).

• DES uses animations and graphics that represents the entities and the occurring events which provides better understanding (Sumari et. al., 2013).

• Competing risks can be applied properly in DES model (Caro and Müller, 2016)

The usage area of the DES method is unlimited as well as its benefits. Many complex operations can be performed with the method, but in this study, it was used only for time modeling and the additional advantages of the model were not utilized.

3.3.2.5 Disadvantages of discrete event simulation

Some of the negative aspects of using the DES method:

• A simulation model output is only as good as the data input that drives it, and without taking the time to ensure quality input data, the output may not yield usable results (Forbus and Berleant, 2022).

• DES does not represent the true variability but represent central tendency measurement (Sumari et. al., 2013).

• If the model becomes complex and level of details increase. On the other hand, the model may reduce transparency and became harder to understand (Caro and Müller, 2016).

They mentioned the negative features of the DES method in reference studies. However, when these negative features are examined, it is seen that these features cannot be effective on all DES models. For example, the data inputs used in this study were also measured very precisely within the scope of this study. Therefore, the output cannot be expected to be unusable results. In addition, since the model used is a very simple model, it cannot be expected to have reduced transparency and hard to understand.

4. OPTIMIZATION BY PROCEDURE PROPOSAL

In this part of the study, detailed studies have been made on whether a seafarers can enter the sea to rescue a MOB casualty, and if so, under what conditions this decision can be made. All results of the study and a procedural proposal for this decision were shared.

4.1 Identification of the Problem

First of all, helping a casualty at sea under appropriate conditions is a requirement under some international legislation (United Nations, 1982). However, the exact limits of the appropriate conditions and the rescue that should be made are not specified. As ships are subject to these rules, each ship that meets the requirements has its own written procedure. In some cases, MOB casualties could not be retrieved from the sea when standard procedures were followed (MAIB, 2011; MAIB, 2012). Although no such requirement nor prohibition is mentioned in the rules or procedures, in some cases seafarers enter a position where they have to decide whether to enter the water to save a MOB casualty. Detailed review of accident investigation reports of MOB accidents reveals that seafarers sometimes make this decision and enter the water to save a MOB casualty (MAIB, 2011; MAIB, 2012; ATSB, 2016).

At 1429 on 14 October 2013, a 3-year-old girl, who is a commuter passenger in passenger ferry ship Snowdrop fell overboard. Mate of the ship momentarily considered that the three years old girl couldn't swim and entered the water to save the casualty. The investigation report of this accident clearly stated that 'The mate ignored his personal safety and responded instinctively by entering the water to rescue the girl' (MAIB, 2014).

At 1755 on 13 December 2010, a crew of the ship felt overboard from cargo ship Joanna. Cook of the ship entered the water to save the casualty. But when doing so, he entered the water with his casual clothing and shoes he had at the moment. After a few minutes he began to lose the feeling in his hands and legs, so he climbed back the ladders at shore (MAIB, 2011). An important point to be considered in this case is that the cook was holding the casualty before climbing back the ladder. If the cook had the appropriate safety equipment and thermal protective clothing, he would have stayed at sea longer. In this way, the chance of survival of the casualty would increase and he could keep himself at a lower risk level.

The accident investigation reports of these two case studies were examined in detail. In both these cases, the responders:

• Both responders made the decision entirely based on psychological factors,

• Continued the rescue operation they started according to their own instant decisions, not according to a procedure

• Not used any safety equipment

• Didn't use thermal protector

The risks to which the responders will be exposed, both by themselves and by other ship personnel, were not predetermined and precautions were not taken for these risks.

It has been found that there are no rules, studies or procedures for a seafarer enter the water to rescue a MOB casualty. Also, there is no rule, study or procedure that prohibits this response. Although there is no legislation on the subject, it has been determined that the seafarers made this decision as mentioned above and referenced by the accident investigation reports. Zhang et al. (2018) states that under risk and uncertainty conditions decision makers usually make their decisions with bounded rationality. Also, the psychological state of the decision makers is effective in the decision process. As a result, the lack of a procedure or recommendation for entering the water to save a MOB casualty puts the decision makers in a difficult situation and causes them to make emotional decisions.

4.2 Purpose of the Proposed Procedure

This part of the study is not intended to suggest or justify any of the following views:

• The responder enters the water to save the MOB casualty under any circumstance,

• Under no circumstances should the responder enter the water to save the MOB casualty,

• If suitable conditions occur, the rescuer enters the sea to save the MOB casualty.

Purposes of the proposed procedure:

• To determine whether such a decision can be made,

• If such a decision can be made, to determine the circumstances of this decision,

• Ensuring that the decision-making process is rational,

• Establishing a procedure that includes the safety issues and precautions to be remembered before entering the water

The procedural proposal prepared in this study is aimed to be a resource to be used in maritime education. In addition, this procedural proposal may be added to the ship's procedures in the future after going through the necessary regulatory stages.

4.3 Framework of the Procedure Proposal

The following equation is the main framework of the procedural proposal study.

$$D = C + c_1 * V_1 + c_2 * V_2 + c_3 * V_3 + c_4 * V_4 + \cdots c_i * V_i \qquad (4.1)$$

In this equation:

D: is the dependent variable with {1,0} possible values. 1 corresponds to ‘enter the water’ and 0 corresponds to ‘not to enter the water decisions’.

C: is the constant of the equation.

C: $\{c_1, c_2, c_3, \dots, c_n\}$: Is the specific coefficient value for each variable.

V: $\{V_1, V_2, V_3, \dots, V_i\}$: V values are different independent variables of the equation. 'i' determines the specific variable according to values it takes such as: i =1;2;3;4;…;n

V_{ij}: $\{V_{i1}, V_{i2}, V_{i3}, \dots, V_{im}\}$: ‘$j$’ values are attributes of the variables. ‘V_{im}’ is the m-th attribute of ‘Variable i’ (V_i). m = 1; 2; 3; 4; …; j as they are determined in Section 4.5.1.

4.4 Outline of the Procedure Proposal Study

Figure 4.1 shows the outline of procedure proposal study section of this study. Except for parts such as methodology and conclusion, the procedure proposal study basically consists of three parts: preparation of the model, survey and analysis. Each part is explained in details.

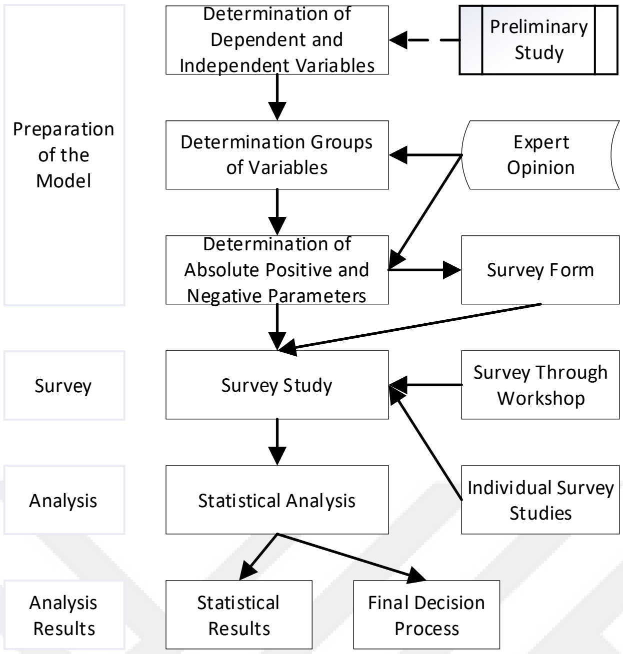

Figure 4.1 : Outline of procedure proposal study.

4.5 Preparation of the Model

This section explains how the model was created. The variables, attributes, contributions and information of the experts who gave their opinions in the model are included in this section.

4.5.1 Determination of variables and attributes

Variables and their attributes were determined from the following sources:

• Academic studies related to MOB accidents within the scope of the thesis study (Gonel and Cicek, 2019; Gonel and Cicek, 2020; Cicek and Gonel, 2020).

• Maritime course books and other educational books (Dodds, 1995; Danton, 1996).

• Academic studies (Domeh et al., 2021; Su et al., 2021).

• Over 300 maritime accident investigation reports (MAIB, 2011; MAIB, 2012; MAIB, 2014; ATSB, 2016)

The data collected from all these different sources, especially previous academic studies, were examined and all the variables that could affect the result of the study were determined. Both these variables and the number of possible values (attributes) can be seen in Table 4.1.

Table 4.1 : Variables and number of attributes.

No	Variables (Var.)	Number of Attributes
1	Training Status	2
2	PPE Status	2
3	Presence of Sharks	2
4	Consciousness State	2
5	Weather State	4
6	Sea State	4
7	SW Temperature	3
8	Surface Current	4
9	Visibility	3
10	Lighting Condition	2
11	Collision Risk	3

Brief descriptions of the variables and their attributes are as follows:

Training Status: Whether the responder who will perform the response has received training for that particular type of response. Attributes of this variable are:

• Obtained training,

• Not obtained trained

Personnel Protective Equipment (PPE) Status: Whether the responder who will perform the intervention is equipped with personal life-saving equipment specifically designated for this type of intervention. Attributes of this variable are:

• Equipped

• Not equipped

Presence of Sharks: Whether the sea area where the response will take place is determined as an 'Active Shark Area' or not. Attributes of this variable are:

• Active shark area

• Inactive shark area

Consciousness State: Whether the MOB casualty is conscious or not. Attributes of this variable are:

• Conscious,

• Unconscious

Weather State: It is the variable that indicates the weather according to the Beaufort Scale. Attributes of this variable given in Beaufort Scale are:

• 0-2

• 3-4

• 5-6

• 7 and Above

Sea State: It is the variable that indicates the weather according to the Beaufort Scale. Attributes of this variable given in Beaufort Scale are:

• 0-2

• 3-4

• 5-6

• 7 and Above

Sea Water (SW) Temperature: It is the sea water temperature at the time of the event. It is given in degrees Celsius. Attributes of this variable are:

• 10°C and Below

• 10°C - 26.7°C

• 26.7°C and Above

Surface Current: This variable is the intensity of the surface runoff at the time of the event. Its unit is 'knots' and 1 knot correspond to a speed of 1 nautical mile in 1 hour. Attributes of this variable are:

• 0-0.5 knots

• 0.6-1.0 knots

• 1-2 knots

• 2 knots and Above

Visibility: It is a variable that indicates how far objects are seen according to the current environmental conditions. The attributes of this variable were determined according to the scale of the 'International Visibility Code' (Bowditch, 2019). Attributes of this variable given in 'International Visibility Code' scale are:

• 1-2

• 3-5

• 6 and Above

Lighting Condition: Light status is: "the medium of illumination that makes sight possible" (URL-30). It is the variable that indicates how bright the environment is. This variable describes how easily the responder can spot the MOB casualty and ship crew can spot the responder and the MOB casualty. Attributes of this variable are:

• Adequate (with daylight or artificial lighting)

• Inadequate

Collision Risk: It is the variable that determines whether the ship is at risk of collision with another ship or ships during the response operation. Attributes of this variable are:

• Collision risk with no ship

• Collision risk with no 1 ship

• Collision risk with no 2 ships

4.5.2 Experts opinions

Experts whose opinions were sought were required to have served as a ship's captain. Opinions of three experts were consulted, two of them have the qualifications of a pilot and one of them has the qualifications of a ship captain. These meetings helped determination of the variables and their attributes. At this stage, there were 11 variables in the study and there was a total of 55296 possible MOB accident scenarios with their attributes. Also, absolute positive and absolute negative parameters were determined at this stage. After the absolute positive and absolute negative parameters were removed from the equation, 854 possible MOB scenarios remained (See Section 4.5.3).

Out of 854 possible MOB scenarios, 100 were randomly selected and a form was prepared. The participants were explained about the variables and their attributes in each scenario and were asked whether they would 'let another seafarer enter the water to save a MOB casualty at sea' in these circumstances. This process was repeated for each of the 100 selected possible scenarios, and a survey form was created.

4.5.3 Determination of absolute positive and negative attributes

Attributes that are always acceptable and never acceptable have been identified. These attributes are named as absolute positive attribute and absolute negative attribute. These attributes were determined at the individual meetings stage. Attributes that are always at an acceptable level are called absolute positive attributes. These attributes do not change the main decision. But they leave the decision to other variables and their attributes. Attributes that are never acceptable are called absolute negative attributes. These attributes change the main decision. No matter how positive the other variables and their attributes, if the scenario has only one absolute negative attribute, the decision is considered negative.

If there is an absolute positive attribute in the scenario, the main decision may be negative or positive and this decision is determined by other variables. If there is an absolute negative attribute in the scenario, the main decision is always negative. An example is, very rough seas that is 7 beaufort and above is always unacceptable and makes the decision as negative.

Absolute positive and negative attributes were excluded from the model. After this removal, some variables were left with one attribute. Since there are no option in these variables, they were excluded from the model also. These variables were only removed from the model, but they were employed in the final decision process.

One other variable 'Presence of Sharks' was also excluded from the model. As stated in Section 2.4, this variable was mentioned in course books and applied in the equation. But further examination of this variable revealed that sharks barely pose hazard or presents a very low level of risk to MOB casualties (URL-31; Midway et al., 2019). After these removals, number of possible MOB scenarios in the model were reduced to 854. Final states of the variables were explained in Section 4.6.2.

4.6 Survey

Survey form consist of 100 possible MOB scenarios. Experts state their decision according to each scenario whether they let another to seafarer to enter the water to save a MOB casualty or not. 100 decisions were made by each expert for 100 different MOB scenarios. For each expert participating in the study, the conditions of being a ship captain and having served as a captain were sought.

The survey form was filled by 29 participants in total and the demographic information of the participants is given in Table 4.2. All the experts are ship captains with an average of 9.1 years of experience as a captain.

Table 4.2 : Demographic information of the participating experts.

Experience of Participants	Mean	Std. Dev.	Min.	Max.
Experience as a ship captain	9.1	8.63	1	27
Total experience in the maritime sector	23.5	8.97	9	40

Workshop: In the second stage, a workshop was held. At this stage, At this stage, experts didn't only fill the survey form, they also expressed their thought about the study.

Surveys: Afterwards, the survey form was given to the individual participants and they were asked to fill in the form after necessary written and verbal explanations were made.

4.6.1 Survey through workshop

At this stage, each scenario was explained to the participants collectively. A total of five experts, one of whom was a seafarer training medical doctor, attended the workshop, but the medical doctor only expressed his opinions but did not actively participate. Other participants were a pilot captain, two ship captains, a vessel traffic service operator. Expert opinions were acquired and initial survey was conducted with the aforementioned survey form. Each scenario was explained to the participants collectively but expert made their own personal decision for each scenario and answered individually. In some circumstances, the medical doctor participant also expressed his opinions. During and after the workshop, the participants expressed their ideas and suggestions about the study.

4.6.2 Individual survey studies

The survey was carried out for the first time in the workshop. In individual survey study stage, each expert completed the survey form individually. Information about the purpose of the study, how to fill out the form and similar issues were explained to the experts in writing and orally. Experts who wanted to express additional opinions added their opinions and suggestions to the form in writing.

4.7 Analysis

Statistical analysis carried out with BLR and GLM models by using SPSS Version 22.

By using the BLR method many possibilities were tried to detect the most significant correlation. According to BLR analysis results, Var. 4, Var. 5 and Var. 9 were removed from the model. Because they both had no effect on the model and reduced the explanatory power of the model. These variables didn’t make a statistical change in the decision of the captain. In other words, these variables do not make any noticeable change or any change at all in the decision process.

Without the Var4, Var 5 and Var 9 in the model, remaining variables had an explanatory power ratio of 78.8%. The final state of the variable had 96% predictive power consistency. Table 4.3 shows the statistical analyze results of the variables according to BLR method.

Table 4.3 : Results of BLR analyze.

Variables	B	S.E.	Wald	df	Sig.	Exp(B)
Constant	-35.269	10.188	11.985	1	.001	.000
Sea State	3.429	1.330	6.649	1	.010	30.852
SW Temp.	3.797	1.188	10.206	1	.001	44.549
Surface Current	1.402	.823	2.904	1	.088	4.062
Lighting Condition	5.579	1.929	8.368	1	.004	264.924
Collision Risk	3.733	1.209	9.536	1	.002	41.796

B: ‘B’ value is basically coefficient of the variables. It specifies how much the multiplicative result of the variable increases the odds. While a positive ‘B’ value increases the odds, a negative ‘B’ value decreases the odds. The increase and decrease of the odds according to ‘B’ value is limited to the variable, not the model.

S.E.: S.E. is short form of ‘Standard Error’ in statistics. It is the average error of the regression model compared to units of the response variable. The smaller this value, the better the result because it indicates that the difference between the observations and the fitted line is relatively small.

Wald: ‘Wald’ is test results of the model. Formula of the Wald test is:

(B/S.E.)2 = Wald

Wald value tests significance of the coefficients and determines statistical significanty of (independent) variables in the model.

df: ‘df’ stands for Degree of Freedom. In statistics, the number of degrees of freedom is the number of values in the final calculation of a statistic that are free to vary (URL 32).

Sig.: ‘Sig.’ value does not determine how significant each variable is. It determines if the (independent) variable has significant effect on the model or not. Similar to S.E. value the smaller this value, the better the result.

Exp(B): In general, change in the (independent) variable changes the results. More specifically, one unit increase in the independent variable, changes the dependent variable in a specific amount. This specific amount is equal to Exp(B) value.

For every variable, a dummy attribute is chosen and GLM analyzes the attributes within their own attribute groups. Analysis results determine the importance of each attribute compared to its own group and its impact on the main decision. Table 4.4 describes the mentioned importance and impact of each variable.

Table 4.4 : Results of GLM analyze.

Variables and Attributes	B	Std. Error	95% Wald Confidence Interval Lower	Upper	Hypothesis Test Wald Chi-Square	df	Sig.
(Intercept)	.264	.0282	.209	.319	87.579	1	.000
[Consciousness State = Conscious]	-.022	.0222	-.066	.021	1.024	1	.312
[Weather State = 0-2]	.029	.0186	-.007	.066	2.467	1	.116
[Sea State = 0-2]	.081	.0214	.039	.123	14.482	1	.000
[SW Temperature = 26.7ºC and above]	.091	.0347	.023	.159	6.827	1	.009
[SW Temperature = 10ºC and below]	-.182	.0201	-.221	-.143	82.338	1	.000
[Surface Current = 0-0.5 knot]	.027	.0211	-.015	.068	1.604	1	.205
[Surface Current = 1-2 knot]	-.088	.0255	-.138	-.038	11.893	1	.001
[Visibility = 6 and Above]	-.018	.0184	-.054	.019	.904	1	.342
[Lighting Condition = Adequate (w/Daylight or Artificial)]	.209	.0171	.175	.242	150.004	1	.000
[Collision Risk = None]	.169	.0193	.131	.207	77.068	1	.000
[Collision Risk = With 2 or More Ships]	-.078	.0202	-.118	-.039	15.075	1	.000
(Scale)	.006[b]	.0009	.005	.008			

Table 4.5 shows the model summary of the statistical analysis. The same data set was analyzed with both BLR and GLM models by using software program SPSS. Unlike BLR model, GLM model does not provide statistical results such R-squared values (URL-33). However, the results in Table 4.5 are also valid for the GLM analysis, as the same data set was examined with both BLR and GLM models. Both Cox & Snell R Square and Nagelkerke R Square are referred as Pseudo-R-squared. R square values measure the usefulness of model in predicting the outcome. In other words, proportion that outcome of the model is predictable by (independent) variables.

Table 4.5 : Model summary for the statistical analysis.

Summary	Cox & Snell R Square	Nagelkerke R Square	BLR Prediction
Constant	.461	.788	.96

Cox & Snell R Square: is an alternative index of goodness of fit related to the R2 value from linear regression (URL 34). And Nagelkerke R Square: provides a correction to the Cox and Snell R2 so that the maximum value is equal to 1 (URL 34). BLR prediction is predictive power consistency of the model. This value for the model in this study is 0.96 which very close to 1. All results showed that the statistical analysis was consistent and reliable.

4.8 Analysis Results

The analyzes made within the scope of the study regarding the decision-making procedure are explained in this section.

4.8.1 Survey results

A data set was created by combining the decisions of all experts participating in the study. Decisions made according to 100 possible MOB scenarios were ‘enter the water' and 'not enter the water'.

'Enter the water' decision was made for 16 MOB scenarios. Average mean value for this decision is 68.75% and all probabilities for this decision is shown in Figure 4.2. The black vertical lines show the percentage of consensus that each 'enter the water' decision was made. The horizontal red line shows the average of the 'enter the water' decision.

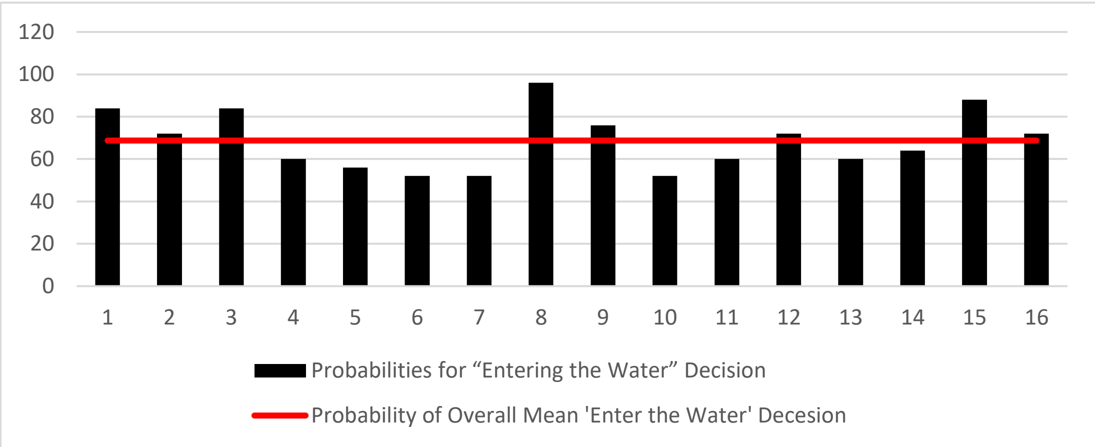

Figure 4.2 : ‘Enter the Water’ decision probabilities and mean overall.

'Not enter the water' decision for 84 MOB scenarios were made. Average mean value for this decision is 76.48% and all probabilities for this decision is shown in Figure 4.3. The black vertical lines show the percentage of consensus that each 'not enter the water' decision was made. The horizontal red line shows the average of the 'not enter the water' decision.

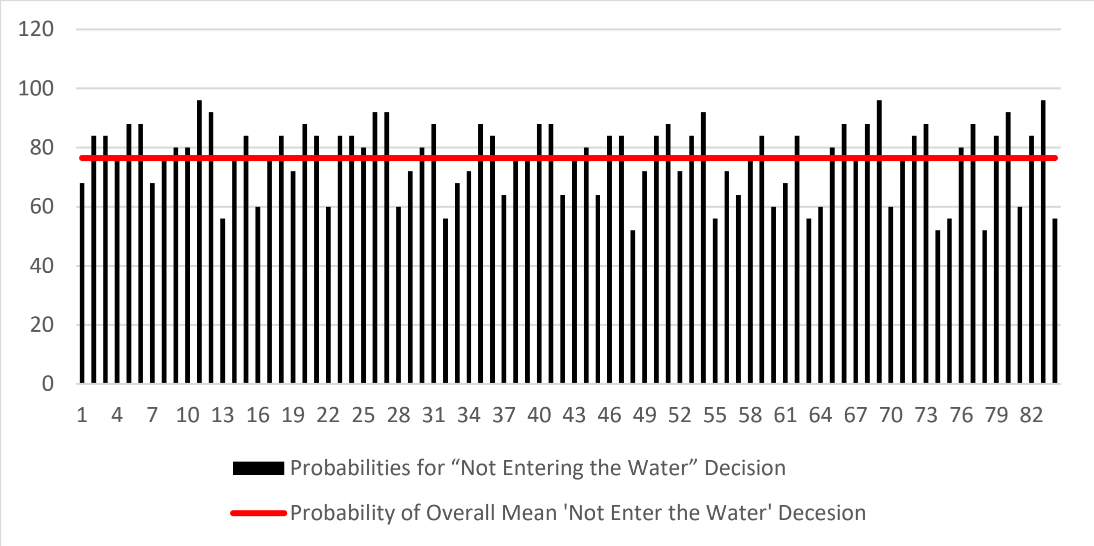

Figure 4.3 : ‘Enter the Water’ decision probabilities and mean overall.

4.8.1.1 Results of BLR analysis

When the model was first established, there were 11 independent variables in the model. Before BLR analysis was performed on the model, there were 8 independent variables in the model. The independent variables available before the BLR analysis are Var. 4, Var. 5, Var. 6, Var. 7, Var. 8, Var. 9, Var. 10 and Var. 11 (See Section 4.5.1). After the BLR analysis, Var. 4, Var. 5 and Var. 9 were removed from the model and 5 independent variables remained in the model. The final version of the variables in the model is shown in Table 4.6.

Table 4.6 : Final state of the independent variables in the model.

Var. No	Variable Description	Effect on the Model	Use of the Model	Ranking of Importance
1	Training Status	Inconsequential	Prerequisite	0
2	PPE Status	Inconsequential	Prerequisite	0
3	Presence of Sharks	Inconsequential	General Reminder	0
4	Consciousness State	Unexpressive	Removed	-
5	Weather State	Insignificant variable	Removed	-
6	Sea State	Significant variable	In Use	4 (β=3.429; $p<0.01$)
7	SW Temperature	Significant variable	In Use	2 (β=3.797; $p<0.01$)
8	Surface Current	Significant variable	In Use	5 (β=1.402; $p\leq0.1$)
9	Visibility	Insignificant variable	Removed	-
10	Lighting Condition	Significant variable	In Use	1 (β=5.579; $p<0.01$)
11	Collision Risk	Significant variable	In Use	3 (β=3.733; $p<0.01$)

According to BLR analyze, final state of the equation is:

$$D = - 35.269 + (3.429*V6) + (3.797*V7) + (1.402*V8) + (5.579*V10) + (3.733*V11)$$

Final decision has two possible values as ‘to enter the water’ and ‘not to enter the water’.

Enter the water decision is given if $D=1$

Not enter the water decision is given if $D<1$

Final states of each independent variable in the model:

Var. 1: ‘Training Status’ variable was removed from the model. This variable had two attributes and when one of the attributes was removed as an absolute negative attribute, the variable was left with only one attribute. The variable was not included in the survey form as it did not constitute an option, but it was included as a prerequisite (obtained training) in the decision-making procedure.

Var. 2: ‘PPE Status’ variable was also removed from the model. This variable had two attributes and when one of the attributes (not equipped) was removed as an absolute negative attribute, the variable was left with only one attribute. The variable was not included in the survey form as it did not constitute an option, but it was included as a prerequisite (equipped) in the decision-making procedure.

Var. 3: ‘Presence of Sharks’ variable was removed from the model. Additional research has revealed that sharks are not a major danger to MOB survivors, as is covered in maritime education resources (See Section 2.4). But unlike Var. 1 and Var 2., this variable was removed from the model but employed in the final decision process as a general reminder.

Var. 4: ‘Consciousness State’ variable was unexpressive, therefore removed from the model and the decision process. This variable didn’t make any change in the experts’ decisions.

Var. 5: ‘Weather State’ variable was both removed from the model and the decision process. Analysis result indicates that this variable has no effect on the model. Weather state describes the wind speed. According to analysis results, experts do not consider the wind speed as factor when making such a decision.

Var. 6: ‘Sea State’ variable significantly effects the decision according to statistical analysis. This variable was both employed in the model and decision process. Sea state variable is the forth variable according to order of importance. Sea state is the description of wave height and its nature. This variable is important because it directly determines the sea condition to which the casualty and responder will be exposed.

Var. 7: ‘SW Temperature’ is the second important variable in the model and employed in the final decision process. The SW Temperature variable is a significant variable because it determines the time that both the victim and rescuer can spend at sea.

Var. 8: ‘Surface Current’ variable has been both employed in the final decision and the model. This variable is significant according to analyze results but ranked fifth in order of importance. The surface current determines how fast the victim will drift and how difficult it will be to swim for the responder.

Var. 9: ‘Visibility’ variable was both removed from the model and the decision process just like weather state variable. This variable didn’t make any change in the experts’ decisions therefore it was removed from both the model and the final decision.

Var. 10: ‘Lighting Condition’ variable is very expressive and ranked one in the order of importance. This variable stayed in the model and took part in the final decision process. This ranking revealed that sighting or to be able to sight the casualty and the responder is a very factor for the captains.

Var. 11: ‘Collision Risk’ variable is the third variable according to order of importance. This variable was both employed in the model and decision process. This variable had an impact on the decision as it determined the maneuvering area and maneuverability of the ship.

4.8.1.2 Results of GLM analysis

First, BLR analysis was performed on the model and the final version of the model was created. After, GLM analysis was also performed in order to determine the effects of individual attributes. The statistical results of the analysis are given in Table 4.4. The same variables analyzed by the BLR method were also analyzed by the GLM method. However, only the variables included in the final decision procedure are explained in detail below.

Var. 6 ‘Sea State’: ‘3-4’ attribute is chosen as dummy. If sea state variable’s attribute changes from ‘3-4’ to ‘1-2’ the odds of making ‘enter the water’ decision by the captains increases. The change is significant ($\beta=0.081$; $p<0.01$) according to statistical results. This change can be interpreted as follows, as the sea conditions become more moderate, the probability of the captains to make decision as ‘enter the water’ increases.

Var. 7 ‘SW Temperature’: ‘10°C to 26.7°C’ temperature interval attribute is chosen as dummy. Increase in the sea water temperature from ‘10°C to 26.7°C’ to ‘26.7°C and Above’ (β=0.091; $p<0.01$) the odds of decision resulting as ‘enter the water’ increases. As the opposite, if the sea water temperature decreases from ‘10°C to 26.7°C’ to ‘10°C and Below’ (β=-0.182; $p<0.01$) the odds of decision resulting as ‘enter the water’ decreases. In addition, the change of this attribute has a considerable effect on the main decision. However, the effect of low seawater temperature on the decision is superior to the effect of high seawater temperature on the decision.

Var. 8 ‘Surface Current’: ‘0.6-1.0 knot’ attribute is chosen as dummy. When this dummy attribute changes to ‘0-0.5 knot’ ($p>0.05$) the probability of decision to ‘enter the water’ increases but the change is not significant. When this dummy attribute changes to ‘1-2 knots’ (β=-0.088; $p<0.01$) the probability of decision to ‘enter the water’ significantly increases. The decision made if the surface current is lower is less dominant than the decision made if the surface current is higher.

Var. 10 ‘Lighting Condition’: 'Inadequate' attribute is chosen as dummy. Change of this attribute from inadequate to 'Adequate (w/Daylight or Artificial)' (β=0.209 and $p<0.01$) increases the odds of making ‘enter the water’ decision of the captains. In addition, this change has a statistically high rate.

Var. 11 ‘Collision Risk’: ‘Collision Risk with 1 Ship’ attribute is chosen as dummy. If collision risk increases from collision risk with 1 ship to collision risk with 2 or more ships (β=-0.078; $p<0.01$), the odds of decision resulting as ‘enter the water’ decreases. If collision risk decreases from collision risk with 1 ship to no collision risk (β=0.169; $p<0.01$), the odds of decision resulting as ‘enter the water’ increases.

With the BLR analysis, variables that are important for the captains in such a decision and their order of importance have been determined. The results of the GLM analysis revealed whether the captain prioritized the casualty or the responder while making a decision and it is the responders that the captains are giving priority.

4.9 Outcomes of the Procedure Proposal Study

A detailed study was conducted on the response model that another seafarer enters the water in order to save a MOB casualty. Expert opinion, statistical analysis results and all other data obtained from the research were examined in detail. By evaluating all study data, the following results were obtained regarding the intervention in question:

• A seafarer may enter the water to save a MOB casualty.

• Variables effecting this decision are determined.

• Effects of attributes within their own groups (variable) are determined.

• There are some absolute negative conditions (attributes of variables) that completely revokes this decision.

• Model of this decision is established and statistically explained.

• A decision proposal is prepared as an educational material is prepared to be used in maritime training for MOB accidents.

• A simpler version of the procedure is prepared and proposed to be used on scene as a reminder.

This proposed procedure and its simpler form are at an early stage. This procedure cannot be used onboard ships as an official ship procedure since it hasn't gone through official approval process. Also, safety equipment to be used in this rescue has to be identified. In final step, seafarers have to go through the specific training in order to be appointed as the responder. Like safety equipment, training procedure has not been established and approved. However, as stated in the previous parts of the study, from time to time, seafarers come to the stage of making this decision. In some cases, they make this decision and enter the water without sufficient safety equipment or any plan. This study is the first study on the subject, and the most important outcome of the study is the procedural proposal.

4.10 Proposed Emergency Decision-Making Procedure

This study is the first study on the subject and its use in maritime education will be beneficial. However, in a real accident, this decision making over a computer program or equation will not be practical. Therefore, the procedure has been transformed into a simple flowchart. The procedure, which has been converted into a flow chart, can be hung like a safety poster on different parts of the ship, especially on the bridge. In this way, the decision maker can evaluate the procedure and make his own decision much more quickly in a real emergency. Variables that are both prerequisite and have effect on the decision are included in the flowchart version of the decision procedure. The order in the flowchart is as follows. The prerequisite variables were first listed, and the variables that had an effect on the decision followed in order of importance. Flowchart also includes countermeasures for the risks that the responder will encounter. Main purpose of this decision-making procedure is to guide the decision maker in a real MOB event, drill or during a training to throughout the decision process. Flowchart version of the proposed procedure can be seen in Figure 4.4.

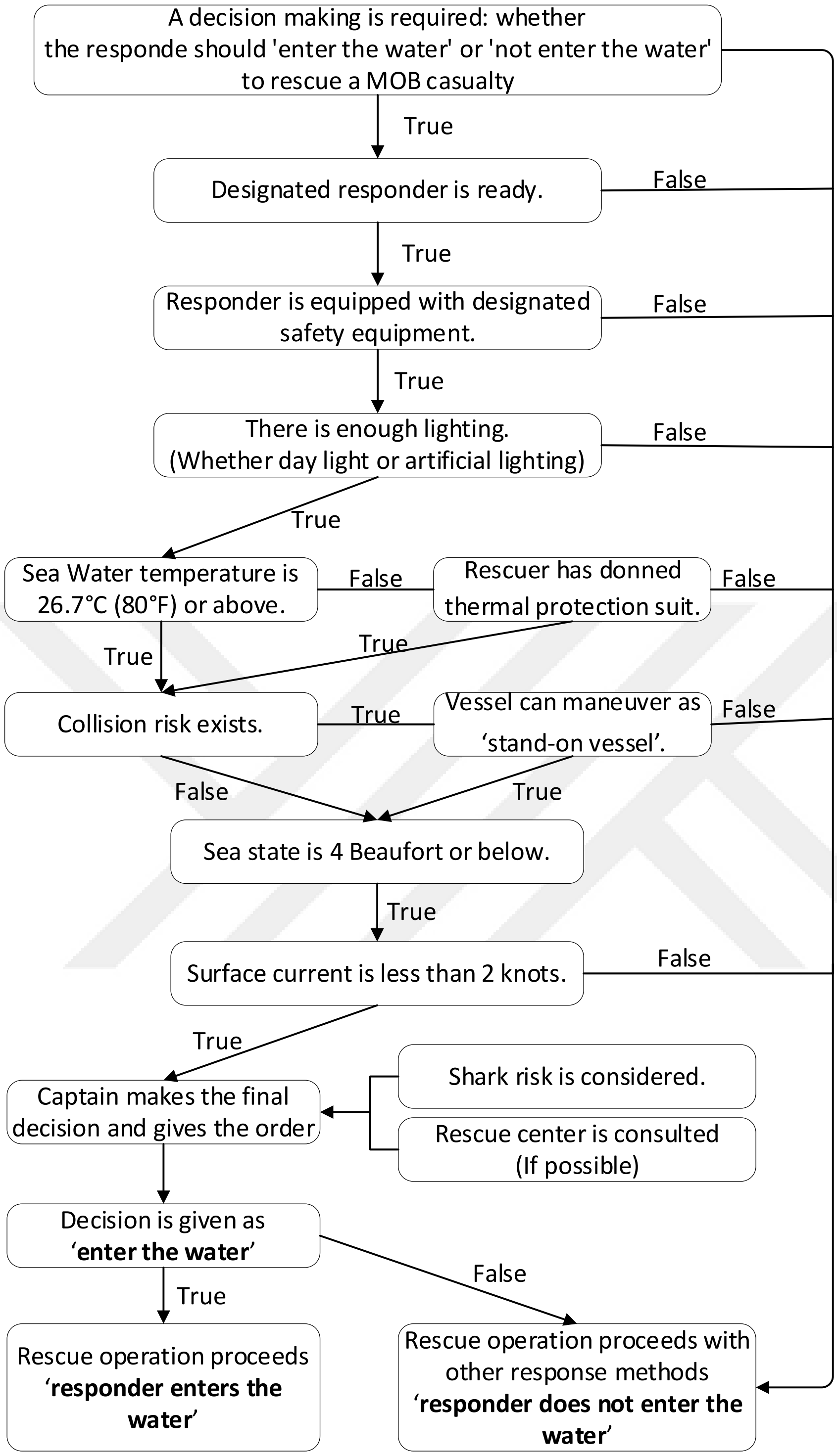

Figure 4.4 : Proposed decision flowchart for training use.

In a challenging MOB response, events can develop very quickly. The captain may need to make a decision in a very short time. Or if the decision has already been made, only important things may need to be reminded before the decision is implemented. For these and similar conditions, a simplified version of the flowchart has been prepared. Figure 4.5 shows simplified version of the decision process which is more applicable for practical use.

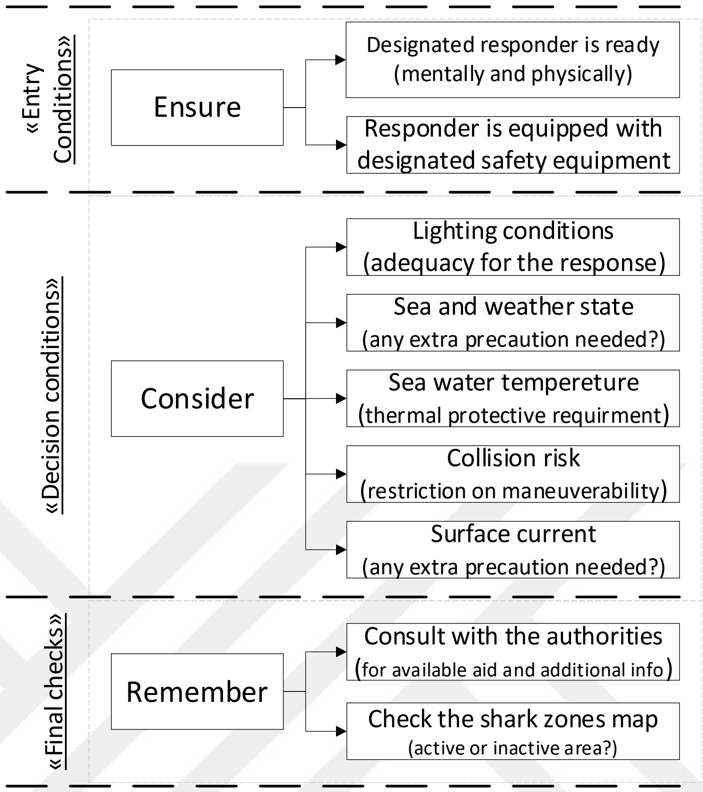

Figure 4.5 : Proposed decision flowchart for practical use.

5. OPTIMIZATION BY EQUIPMENT PROPOSAL

This section includes the recommended equipment optimization study for MOB response. Figure 5.1 shows the outline of the process of the equipment optimization propose.

5.1 Definition of The Problem

Casualty of a MOB accident must be found at sea and rescued from the water. Naturally, one phase of MOB accident response is Search and Rescue (SAR) operation. Many scientific studies emphasize the importance of time in SAR operations (Ali, et al., 2021; Cai, et al., 2020; Benz, et al., 2021; Zhou, et al., 2020). Xiong et. al. (2020) states that shortening the response time in SAR operations reduces the loss of life. Since other factors such as sea water temperature and sea state cannot be changed, this study aims to shorten the response time and thus increase the chance of survival of the casualty.

The aim of the study may be to reduce the response time, but all response actions still have to be carried out. While some of these response actions are carried out by pressing a button, others may take some time and prevent the responder to maintain overall command of the rescue operation. Responders may even failure to maintaining eye contact with the casualty if it is established priorly. Given that survival chance of the casualty is 6.1 times higher if continuous eye contact with the casualty is maintained (Cicek and Gonel, 2020), time used for carrying out response actions should be used for maintaining eye contact and other factors.

As a result, the time factor is very important in the emergency response to be carried out after the MOB accident. The most crucial part of the response is the first stage of the response which is named initial response in this study. It determines the course of the following stages of the response operation and is the most important stage that determines the outcome of the response operation. In summary, the time factor is very important in the initial response phase of the MOB response operation. Since response actions that need to be executed cannot be abandoned, the time allocated to these response actions should be minimized.

5.2 Purpose of the Proposed Equipment

In the previous section, it was mentioned how important time is in MOB response. The main purpose of the proposed response equipment is to shorten the response time. The main function of the emergency response equipment is to automatically perform response actions in the initial response phase. Response equipment not only shortens the response time, but also provides many additional benefits such as proper execution of response actions.

5.3 Outline of The Equipment Proposal Study

Outline of the equipment proposal study is shown in Figure 5.1. Initially, ‘MOB Emergency Checklist’ of different shipping companies were collected. Emergency actions in these checklists were gathered in a cumulative list. The response to a MOB accident was divided into four phases, in which one is 'Initial Response'.

Problems occurring during a MOB response were identified. Optimum solution in order to address these problems were determined and a autonomous MOB response equipment proposal is made.

Data acquired from the experimental study was used in two different simulations in accordance with the proposed response equipment. Simulations were compared and results are shared. This part of the study was carried out in a multi-stage process. For this reason, the subtitles of the study do not proceed in the same order as the flow chart of the study.

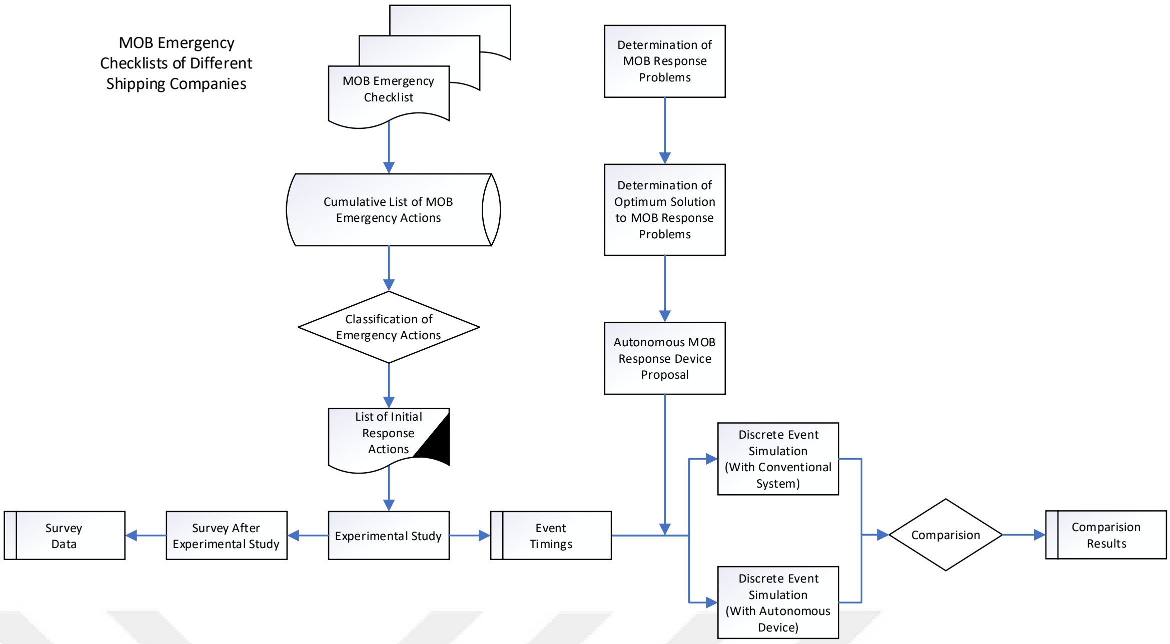

Figure 5.1 : Outline of equipment optimization process.

5.4 Emergency Actions Data

MOB emergency checklist of different shipping companies and different sources were collected. Checklists were chosen randomly without using any method or any requirement. Every response action in these checklists were collected in a cumulative list. The cumulative list can be thought of as the common set of emergency action lists.

The whole process of the response to a MOB accident was divided into four phases:

- Initial Response
- Pre-Rescue Response
- Rescue Operation
- Post Rescue

All response actions in the cumulative list were distributed to these four phases with assistance of an expert (Asmalı, O., 2022). After the distribution, list of 'Initial Response Actions' was created. Initial response actions can be seen in Table 5.1.

Table 5.1 : Initial response actions.

No	Code	Initial Response Action
1	A1	Switch to hand steering
2	A2	Turn the steering wheel on side where the person fell to the sea (commence rescue manoeuvre)
3	A3	Sound general alarm
4	A4	Call master
5	A5	Release lifebuoy with light and smoke
6	A6	Inform engine room and place engines on stand by
7	A7	Record the vessel's position & time of incident
8	A8	Use ship's whistle (three prolonged blasts)
9	A9	Activate MOB position on navigational aids (GPS, DGPS, ECDIS etc.)
10	A10	Use public addresser
11	A11	Broadcast VHF warning (Inform ships and shore stations in range)

5.5 Experimental Study

Experimental study was conducted with the participation of 10 people, in which only the response actions in the 'Initial Response' stage were carried out. At the end of this study, timing data (See Section 5.6.1.2) and response data (See Section 5.6.1.1) were obtained. Timing data was used in preparation of two different discrete event simulation.

5.5.1 Common practice

Common practice is once the initial response commences, responder starts carrying out all actions in random order. There are no rule, regulation or directive were found that puts these response actions into order. But recommended practice is usually expressed as; first 'switching to hand steering' and secondly 'turn the steering wheel on side where the person fell to the sea'. This is basically expressed as first two things to do in order to protect the casualty from the propeller of ship which. But there are no recommendations to be followed after these two actions.

Number of possibilities in which initial response are performed in random order:

RA1 (A1, A2, … A11), RA2 (A1, A2, … A11 except RA1), RA 3 (A1, A2, … A11 except RA1, RA2), … RA11

11 x 10 … x 1 = 11! = 39916800 possible orders

Number of possibilities in which initial response are performed according to recommended practice:

RA1 (A1), RA2 (A2), RA 3 (A1, A2, … A11 except A1, A2), … RA11

1 x 1 x 9 x 8 … x 1= 9! = 362880 possible orders.

An: Action n, in which n = 1 to 11 as indicated in Table 17. (i.e.: ‘A4’ is response action 4 and it is: ‘call master’)

RAm: Response Action m, in which m = 1 to 11 as it is the order of executed initial response action.

Carrying out these 11 actions can be carried out at least in 362880 different orders only if carried out according to recommended practice. There is no study that tries to find the best order to shorten the response time or increase the general effectiveness of the response could be found. Optimizations can be carried out in two different aspects:

• Finding the fastest order to shorten the response time,

• Finding the optimum order that makes the most effective response.

Also, it must be considered that all bridge layouts and equipment are different from each other, optimizations will be not be generic for all ships.

Since optimization of the order of response actions is not very practical and time saving, this study aims to carry out most of the actions simultaneously. This solution both saves time and makes the response more efficient.

5.5.2 Setup for experimental study

All participants were watch keeping officers and no further requirement was asked. Study took place in bridge simulator of Istanbul Technical University Maritime Faculty. Participants of experimental study were firstly given briefing about the aim of the study. The bridge and the equipment were introduced to participants and after they were given free time to get familiarized with bridge. After the training and familiarization of the participants are complete, participants were asked to keep watch as normal practice. In a random time, they were alerted of a MOB accident. Participants responded to accident on their own. At the end of the study, participants were asked to fill a questionnaire. Data was driven from footage in a later time in order to be more precise on timing.

5.6 Experimental Study Data

Two set of data were driven from experimental study; quantitative timing data consisting of execution times of response actions and qualitative data consisting of response effectiveness of responders.

5.6.1 Response data

At the end of the experimental simulation each participant were asked to fill the survey form. Answers to these questions are given in Table 5.2.

Table 5.2 : Survey after experimental study.

No	Question	Yes		No
1.1	While responding to the accident, did you feel you were running out of time?	8	0	2
1.2	If you felt running out of time, do you think that affected your response?			
2	Did you have to check the emergency checklist when responding?	1	4	5
3	Did you perform the actions in an order that you set in your mind?	7		3
4	When executing the actions, did you follow the order in the emergency list?	0	0	10
5	Have you felt that your control of the actual operation has decreased while performing long time-consuming intervention actions (VHF announcement, internal announcement)?	6	2	2
6	Is it possible to do all the actions completely and to have a general command of the intervention?	4	4	2

Also, additional data was driven by observing the performances of participants. As can be seen Table 5.3. completion ratio of emergency actions and checklist usage are presented.

Table 5.3 : Completion ratio and checklist usage.

Participants	1	2	3	4	5	6	7	8	9	10	Ave.
Completion Ratio (%)	81.8	81.8	72.7	63.6	100	81.8	90.9	100	100	72.7	84.5
Checklist Usage	No	No	No	No	Yes	No	No	No	No	No	-
Participants	1	2	3	4	5	6	7	8	9	10	Ave.

5.6.2 Experimental study timing data

The information on how much time it takes to perform each emergency action is shown in Table 5.4. (See Table 5.1 for description of the actions). ‘Lowest’ is the minimum and ‘highest’ is the maximum times that participants performed each action. ‘Mean’ is average time of response actions carried out by all participants.

Table 5.4 : Timing data (all times are given in seconds).

Action	1	2	3	4	5	6	7	8	9	10	11
Lowest	1	1	1	4	4	12	7	2	2	4	17
Highest	5	6	13	23	8	26	17	11	21	21	48
Mean	2.3	2.6	5.2	14	5.7	17	12	7.4	5.7	13	33

5.7 Autonomous MOB Device Proposal

Former studies (Gonel and Cicek, 2019; Gonel and Cicek, 2020; Cicek and Gonel, 2020) and previous sections of the study (Section 5.1 and Section 5.6.1.1) revealed that there is a time constraint that may adversely affect the outcome of the response. Time can be considered as the primary issue in a MOB response. Also, some problems related to MOB accident response were identified by using same sources. Some of these problems:

• Incomplete or incorrect execution of some response actions,

• Failure to carry out some of the response actions entirely,

• Time delays due to thinking response actions or checking emergency action list,

• Incomplete or incorrect broadcasts of VHF call and ship internal announcement due to excitement and other reasons. (Failure to broadcast whole message and make it understood by the receivers),

• If there is eye contact with the casualty, loosing eye contact, if there is no eye contact with the casualty, difficulty to establish eye contact,

In order to intervene more effectively in the MOB accident, the time problem and other problems mentioned above need to be solved. If the existing problems are thought to occur within the current system, an additional system will be needed to solve the problems. If the human resource potential on the bridge is also taken into account, these problems can only be solved with an autonomous system. Only then the responder may mainly focus on casualty.

An autonomous MOB response equipment has been proposed to eliminate the time constraint and improve response outcomes. Details of the autonomous response equipment is explained in Section 5.9.

5.8 Discrete Event Simulation

Timing data acquired from experimental study is processed in two different discrete event simulation models according to standard response method and response with the proposed system. The timing data acquired from experimental study is used in both simulation models. Arena Simulation (Rockwell) version 13 is used as the simulation program.

5.8.1 Discrete event simulation with conventional system

This simulation model has been created in such a way that 11 emergency response actions are performed without exception. No actions such as ‘skip’, ‘delay’ or similar is used. The simulation has processed 1000 individual event (1000 entry resulted with 1000 dispose). With every entry, all 11 actions are carried out. Average time these 11 emergency actions are performed is found as 118 seconds (See Table 5.5). Simulation was programmed only to calculate maximum, minimum and average time to carry out all actions. Order of actions is not taken into account.

5.8.2 Discrete event simulation with proposed system

Autonomous response DES was prepared in accordance with the proposed system. Actions 1 and 2 (Table 5.1) carried out by responder and actions from 3 to 11 are carried out autonomously (See Section 5.9.1). A1 and A2 carried out by responder followed by action of system activation.

RA1: A1, RA2: A2, RA3; activation of proposed system. Total 3 response actions, 3 in fixed order.

The simulation has processed again 1000 individual event (1000 entry resulted with 1000 dispose). With every entry, all three actions are carried out. Average time these three emergency actions are performed is found as 15.6 seconds (See Table 5.5).

5.8.3 Comparison of response times

According to numerical simulations, results indicate that response with the proposed system takes 87.46% less time according to average timings of both models. See Table 5.5 for details.

Table 5.5 : Timing data (all times are given in seconds).

	Lowest	Highest	Average
Conventional Response Times	87.7	159.5	124.1
Autonomous Response Times	5.3	28.7	15.6
Parentage of Response Times	6.01%	17.98%	12.54%
Time Saved	82.4	130.8	108.5
Percentage of Time Saved	93.99%	82.02%	87.46%

5.9 Proposed Response System

In this part of the study, the working principle, features and benefits of the equipment proposal are explained.

5.9.1 Specifications of proposed system

In the simplest terms, the proposed system is a response aid that automatically performs initial response actions that must be performed while responding to a MOB accident. Initial response actions are listed in Table 5.1. According to the expert opinions received, initial response actions 1 and 2 should definitely not be performed by the system as they require human experience and decision. However, other response actions 3, 4, 5, 6, 7, 8, 9, 10 and 11 can be performed by the system. Basically, when the system is activated, system carries out all emergency response actions that can be handled over to system. System also has auxiliary systems that will assist responders during MOB response (See Section 5.9.2).

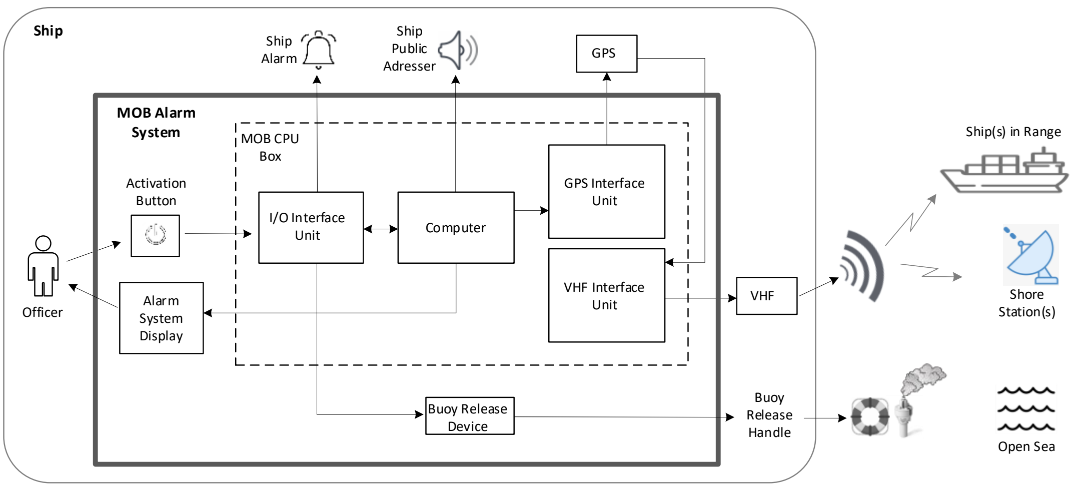

Figure 5.2 : Use-Line diagram of the proposed system.

Proposed system is activated by pressing one of two or both 'Activation Buttons' according to side of the vessel that accident has occurred. Once the system is activated, system commence commanding or interfering with sub-components. For simple tasks such as alarm, relays are used. For standard tasks such as making internal announcement and informing engine room, interference units are used. For more complex tasks that require data transfer such as VHF announcement, interference units with communication protocols are used. See Table 5.6. for details.

Table 5.6 : Activation methods of subsystems.

Resp. Action	3	4	5	6	7	8	9	10	11
	Relay	Int. Unit	Relay	Int. Unit	Int. Unit	Relay	Int. Unit	Int. Unit	Int. Unit
Data Flow	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes
Flow Type	N/A	One Way	N/A	One Way	Two Way	N/A	One Way	One Way	Two Way
Data Process	No	No	No	No	No	No	No	No	Yes

If ‘Port’ activation button is used, port side lifebuoy with light and smoke is released and announcements are made as the accident has occurred from port side. If ‘Starboard’ activation button is used, starboard side lifebuoy with light and smoke is released and announcements are made accordingly. If it is unclear that which side of the ship that accident has occurred or for some other reasons ‘Both’ activation buttons are used simultaneously, announcements are made without referring a side. In this activation type, predesignated choice of lifebuoy with light and smoke is released.

One of the important benefits of the proposed system is that it performs all initial response actions at the same time. In the current system, these actions are performed by the officers one by one, but the proposed system performs these actions simultaneously. Thus, both the total response time is shortened and the actions are carried out earlier. In addition, the proposed system is planned to be customizable according to the characteristics of the ship to which it will be applied.

5.9.2 Extra benefits of the proposed system

Proposed system does not function to assist the responders only during initial response stage. System does not carry out autonomous actions after initial response stage but provides assistance. Also, there are some actions that are not addressed in checklists. Some of these extra benefits:

• Reminding response actions that required to be carried out during ‘Pre-Rescue Response', ‘Rescue Operation’ and 'Post Rescue' phases,

• Proving drift predictions,

• Showing contact details of nearest RCC center (not only GMDSS channels and frequencies but also phone number and mail information),

• Offering search patterns and best approach according to circumstances,

• Making recommendations for the post rescue phase according to the circumstances (sea water temperature, ‘time’ that casualty spent in water),

• Powering search lights and other lights for areas such as gathering stations and rescue craft.

• Displaying time passed after the accident has happened.

This system has an adaptable structure and is proposed to be customized for each ship. Integration can be made into additional detection systems (Section 3.1.4) that may be applied to ships in the future. Since the proposed system has an adaptable and customizable structure, the system can provide additional benefits to future needs.

6. DISCUSSIONS

This part of the study includes important findings obtained within the scope of the study, important issues required to be discussed and contributions of the thesis to academia, maritime education and maritime sector. The findings and discussions in this section are explained in detail and referenced in the thesis study and previous studies prepared within the scope of the thesis study. In order to avoid repetition, detailed explanations and references are not given in this section.

The importance of occupational safety has increased in many sectors, including the maritime sector, and concepts such as 'safety culture' and 'security awareness' have emerged over time. Along with this concept, regulations, academic studies, and newly invented work safety equipment have been created. Although there are reductions in occupational accidents for the general workforce, the decrease in the occupational accidents experienced by seafarers lags far behind the general workforce. In fact, it should also be discussed why seafarers are exposed to more accidents than the general workforce. However, since this discussion is not within the scope of this thesis, this issue has only been mentioned in a few parts of the thesis but mentioned in the future works section of the study (Section 7.3). To be more precise, it can be thought that national and international rules, company procedures and ship equipment developed over the years are optimized to provide the highest level of protection. However, when both general accident statistics and individual accidents are examined in detail, it is seen that there are still deficiencies and improvements are needed in many aspects. MOB accidents are at the forefront of work accidents waiting for seafarers. Occupational accidents and especially MOB accidents still pose a great danger to seafarers. Therefore, MOB accidents should be examined and different solutions should be proposed. But unlike other marine accidents, MOB accidents consist of different stages, the response time can vary greatly, may even extent to days and there are many factors affecting the outcome of the accident. Since the response to the MOB accident is a very complex process, it has been considered that an optimization made from a single aspect will not be sufficient. For this reason, this study aims to examine

MOB accidents in detail to fully understand it and discuss the findings of the study in order to find the optimum response methods.

6.1 Contributions of the Thesis Study

Within the scope of the study, general and MOB accident statistics, hundreds of MOB accident investigation reports, academic studies, regulations and many different sources were examined. As a result of these investigations, it has been determined that there are many deficiencies in the prevention and response stages of MOB accidents. One finding of this thesis study is, there are still many things to be improved regarding the response to MOB accidents. To be clearer, it can be thought that national and international rules, company procedures, ship equipment and every safety related issue developed over the years are optimized to provide the highest level of protection for seafarers. However, there are many aspects of maritime accidents and especially MOB accidents need improvement. In this study, it is aimed to optimize the response to MOB accidents from different aspects and thus to improve the results of the accident.

This thesis study constitutes an example in terms of examining a single maritime accident type in great detail. In addition, the time model of the response to the type of accident examined was prepared. If the impact factor of the outputs of these studies is evaluated, the same studies should be carried out for different maritime accidents using the same methods.

A decision-making procedure that may occur depending on the maritime accident, which is the subject of the study, has been numerically analyzed as a result of very detailed analyzes. Detailed statistical analysis also provided correlation control of the factor affecting the occurrence and the results of the MOB accident. The resolved decision logic was not left as a formula, but transformed into a decision-making procedure. Since the prepared procedure will be difficult to use in a short time and under challenging conditions, the same procedure has been simplified and turned into a reminder poster that will help in the decision-making process. Both outputs of this study are presented as procedural proposals. In addition, a single analysis method was not used to examine the data at the procedure proposal stage. While a single analysis method is generally preferred in variable analysis, both the results were checked and the attributes of the variable were evaluated within themselves by using a second analysis method.

Within the scope of the thesis, not only a procedural suggestion was made regarding the response to the MOB accident, but also an equipment suggestion was made. In the equipment proposal stage, only the need for this equipment and the features of the equipment were not mentioned. In addition, a simulation has been prepared in order to check the benefits of the proposed equipment depending on its purpose.

In this thesis study, it has been tried not only to identify the deficiencies related to its subject, but also to produce different solutions for the deficiencies it has identified. In addition, the contributions of this thesis study are not limited to the outputs provided within the scope of the thesis. Moreover, this study contributes to the academia, maritime sector and maritime education due to the above-mentioned differences such as using different methods, testing the usefulness of the equipment proposal with simulation and many other benefits.

6.2 Findings and Discussions about MOB Accidents

The most important finding regarding the numerical analysis of MOB accident numbers is that MOB accidents have a very high fatality rate. Mortality rate of MOB accidents in Turkey, Ireland, USA and Hong Kong are 78.6%, 97.4%, 47.7% and 54.5% respectively. In Ireland, 49.7% of the maritime accident fatalities are related to MOB and in USA waters, 79.5% of the MOB deaths are result of drowning. USA is the only source, shares the cost of MOB accidents and average cost is calculated as 565.7$. The issue to be discussed regarding maritime accidents and MOB accidents figures is the inconsistency of statistical information and the inaccessibility of these data on a global scale. Accidents terms like, 'accident', 'incident' and 'event' are used differently in most countries and also there are many other differences in data collection and sharing methods. There is no source that shares global accident figures.

The major issue in the statistical analysis of maritime accidents is to examine only the number of accidents and death rates. However, the most important thing is to determine the probability of accident during the working period of the seafarers. During the literature review phase, very rare studies were identified, and the relevant study referenced in this study covers the years 1990-1994. According to this calculation logic, the probability death as of a seafarer working on a ship for 1 year is up to 1 / 0.00173 depending on the nationality.

100 MOB accident investigation reports were examined with 113 item form. The data obtained as a result of this detailed research are very different from those that are customary and sometimes even used in maritime training. Contrary to popular belief, overboard accidents happen when the casualty is accompanied by someone, during the daytime in working hours and when there are no adverse weather conditions.

It can be expected that experienced seafarers are less exposed to MOB accidents. However, experienced seafarers are more exposed to MOB accidents. In all revised MOB drills, captain commands an underway ship. But 38% of the MOB accidents occur when the ship is not underway and, in some cases, captain falls overboard. It may be considered that ship procedures need to be reviewed. Most high-tonnage merchant ships have equipment and procedures to transfer casualties by helicopter. In the reports examined, it was determined that the probability of evacuation of the casualty from the ship to another vessel is higher than evacuation with helicopter. For this and similar cases, in addition to the procedure revision, the safety equipment on board should also be revised.

Also, there are some important findings that are required to be discussed to be included in maritime training. A significant portion of seafarers who die as a result of MOB accident die after rescue. The training curriculum for the treatment of survivors rescued from the water should be revised. In most of the accidents examined in detail, it was determined that the safety procedures were not followed, the forms that had to be filled were either not filled at all or were just filled on paper. These results show that the purpose and seriousness of the occupational safety rules are not fully understood and training curriculum should be revised accordingly.

The most important outcome of examination of the accidents in detail is carrying out correlation analysis. Correlation analysis has many benefits in accident analysis, especially in finding the root cause of accidents. It was found that there was a linear correlation between the rescue of the survivors from the water in favorable and unfavorable weather conditions, but no correlation between the execution of the drills and the rescue and survival of the survivors.

Not only statistical analysis data were driven from accident investigation reports, but also each report was examined in great detail. As a result of these examinations, very important information was obtained and these results were also discussed.

Investigating accidents only statistically is definitely an inadequate process and may cause many important findings to be overlooked. In a MOB event, since the ship had a workboat she had exemption from rescue boat. Due to high freeboard of the rescue craft, casualty couldn’t be recovered. This is a very important finding but it should only be revealed by examining the accident investigation form. Identifying some findings is not enough. These findings should be discussed and the most appropriate solution should be found by studying on them. For example, in some incidents, equipment such as ship cranes and life jackets were tried to be used in rescue operations. Whether the use of such equipment will be beneficial can only be found by after studying and discussing.

MOB accidents are also studied in seafarer training books. Unfortunately, it has been seen that the course resources used in seafarer training contain questionable information at least about MOB accidents. It is seen that some of the information in these sources is based on customary knowledge, not academic or experimental studies. Best example is, in eight of the ten examined maritime safety book, 'being pulled by the propeller' and/or 'cut by the propeller' has been cited as one of the first risks awaiting the MOB survivor. While such a risk is not entirely impossible, it is highly unlikely unless absolute conditions are met. At least, no such event was observed in any of the accident investigation reports examined within the scope of the study.

The procedures prepared for the ships to use both in MOB drills and in a real MOB event are examined. Unfortunately, many problems have been identified with these procedures. Spelling errors, translation errors, incomprehensible articles and other similar problems show that not all of these forms were prepared with care, were not checked and corrected after they were prepared.

6.3 Findings and Discussions about Procedure Proposal

Under certain conditions, responder can enter the water to save a MOB casualty. The factors affecting this decision positively and negatively were determined, the decision-making model is numerically analyzed and presented as a procedural proposal. With the proposed procedure, rational decisions can be made instead of instant emotional decisions.

The difference of this study from many other similar academic studies is that the study outputs are not limited to the academic level. In addition to academic explanations, the study outputs have been converted into a procedure both for use in the maritime education and in a real MOB accident. In addition, the outputs of the study were explained in order to reach wider audiences. With these features, this part of the thesis study set an example and contributed to the academy.

The use of the outputs of this study and the procedural proposal in maritime training will lead to better assimilation of such events by the future to be decision makers. Learning the effects of variables with their attributes in the decision-making process will enable them to think in detail and make more rational decisions when making decisions in other emergency situations. With this benefit, this study also contributes to maritime education (Gonel and Cicek, 2022).

An important issue identified in this study that requires discussion and even updating maritime training curricula is the use of incorrect temperature reference values to determine the survival time of MOB casualties at sea. Data on 'survival time at certain temperature values' are referenced to determine the status of survivors at sea and even plan the rescue. However, evaluations can never be made according to these periods. Because the casualty will not be able to use their hands much sooner, later then casualty will lose consciousness. But during all this time, casualty will not be able to help himself or the responders.

The results of the study show that the most important factor for a captain when making a decision about the proposed rescue operation is lighting conditions. When making a decision in such a risky situation, the captains want to see the casualty and the responder. For this reason, additional searchlights can be placed at different points of the ship, and the use of more reflective tape on seafarers' work safety clothing should be considered. The lighting systems added to the ships can be equipped with a tracking system, allowing the casualties to be followed automatically. However, in order for this tracking system to work efficiently, seafarers must constantly carry a transmitter with them.

The second most important factor is sea water temperature. If it is considered only on the basis of sea water temperature, the probability of the captains to make the decision as enter the water decreases as the sea water temperature decreases. However, since the responder will use thermal protective equipment, he will not be affected by the sea water temperature, but the need for rescue of the casualty at sea will be increased.

When making such a decision, second, third, forth and fifth variables in order of importance are sea water temperature, collision risk, sea state and surface current. On the other hand, statistical analysis results show that, consciousness state, wheather state and visibility state variables have either an indefinite or no effect on the decision.

Collision risk variable also affects the decision of captains as revealed in the results of this study. There are also academic studies on the risk of collision and its effects on the maneuverability of the ships (Uğurlu and Çiçek, 2022). The aforementioned studies related to collision risk and ship maneuverability can be combined with emergency decision making while responding to the MOB accident. The results of the study will reduce the workload and support the decisions of the captain, who must both respond to the emergency and rescue the casualty from the water and make avoidance maneuvers for the ships with collision risk.

After the MOB accident, many different issues may need to be decided. This study is about only one of the decisions that can be made. However, this study shows that a decision to be made in an emergency can be analyzed numerically. The decision-making logic has been resolved and the results can be used in the relevant emergency on the ship as well as in maritime training. In addition, this analysis and resolution sets an example for other accident types.

The results of the analysis revealed that the captains make their decisions by considering the safety of responder more than the safety of the casualty at sea. Responder and casualty are subject to the same risks. However, the responder who is equipped with appropriate safety equipment and thermal protectors and is connected to the ship, it can be considered that the responder is less likely to be affected by the same risks. This decision of the captains should be examined in detail and if there is a misperception, it should be added to the necessary procedures and even the training curriculum.

It could be argued that the decision of entering into water to save a MOB casualty puts the responder at risk. However, in other response procedures for different accident types, seafarers are also involved in the rescue operation by being exposed to different risks with the decision of the captain. For example, in case of fire, the fireman of the ship equipped with the necessary safety equipment enters the comparments unde fire. Similarly, to rescue a seafarer from a confined space, another seafarer enters an area that is too narrow or contains toxic gases to save the casualty with appropriate safety equipment. Likewise, with appropriate safety precautions, a seafarer can enter the water to save a MOB casualty at an acceptable risk level.

The responder may enter the water either from the ship or from the rescue craft for the purpose of rescuing the casualty. But in both cases the responder will be exposed to the same risks. For this reason, the response operation was not divided into two different subcategories: 'entering the water from the ship' and 'entering the water from the rescue craft'. Also, making such a distinction may cause the ‘entering the water from the rescue craft’ option to be perceived as a lower risk level.

This procedure only includes identified variables and should always be considered that unpredictable variables may occur. Before making such a decision, it must be determined if there is any other risk that are not specified in the procedure. This proposed procedure is intended to assist in decision making and regarding to presence of any additional risk, the final decision should always be made by the master.

6.4 Findings and Discussions about Equipment Proposal

'Optimization', 'machine learning', 'automation', 'autonomous' and similar concepts that foresee the use of artificial intelligence and advanced machines are increasingly important concepts today. In many fields of study, new systems have started to replace conventional methods for very different purposes. This study proposes to replace the classical response in an emergency on ships with an autonomous response. With this feature, the study sets an example for the creation of autonomous response systems for different maritime accidents, and with this feature, it sets an example for both the maritime sector and the academy. In addition, if autonomous or semi-autonomous response systems are developed for other emergencies in the future, it will be very beneficial to combine all systems.

The study started with the prediction that an autonomous response system would benefit the officer responding to the MOB accident. However, not only the numerical results of the study, but also the survey results answered by the officers participating in the study that they had difficulties during the intervention and that such a system would be very useful. Similarly, the participants who stated that they felt under pressure during the survey completed the experimental study in a longer time with more deficiency.

Proposed system saves 87.46% of the time compared to conventional response. Considering time is the most important factor during SAR operations, saved time can increase survival chance of the casualty. It might be claimed that time that is saved by proposed system may not be long. But since this time is saved at the very first moments of the accident, saved time is can change the outcome of the whole SAR operation. The 87.46% time savings is the lowest the system can provide. Because as environmental conditions deteriorate, such as adverse weather conditions, heavy marine traffic, the conventional response time will increase, but the autonomous response time will remain constant. As a result, as environmental conditions deteriorate, the time savings provided by the autonomous system will increase.

One other major benefit of the system is making more clear announcements throughout VHF and public addresser. Many factors such as lack of experience and language issues can be easily eliminated.

In the conventional response method to the MOB accident, the responder carries out all the initial response actions one by one. For this reason, responder cannot perform another action without finishing the previous action. However, with this system, all emergency actions can be performed at the same time withou delay. This not only reduces the total response time, but also avoids delays in any of the initial response actions.

10 watch keeping officers participated in the experimental simulation. Only two of them carried out all response actions and average completion rate of all participants were found as 84.5%. While it is very likely that not all response actions will be performed during conventional response, all response actions are carried out by autonomous system. Survey after experimental study clearly states that responders felt stress during response. Proposed system also relieves the pressure on responders.

7. CONCLUSIONS

The last part of the thesis includesfinal conclusions and suggestions for future studies.

7.1 Conclusions of the Thesis Study

Within the scope of the study, very detailed studies were carried out on man overboard accidents. Results of the statistical researches indicate that both occurance and death rate of man overboard accident is very high. Man overboard accidents have also been examined in many aspects apart from statistical data. Maritime education textbooks, training procedures of ships and hundreds of man overboard accident investigation reports were examined in detail and a literature review was made. In all of the examined issues, many major deficiencies or issues that need improvement have been identified. It has also been cleared that these deficiencies can be eliminated Most importantly, solutions have been produced to for some of the identified problems. Finally, this study has been an example for other studies to find problems and produce solutions for man overboard accident and other accidents.

7.2 Suggestions for Future Studies

The statistical information obtained within the scope of the study shows that seafarers suffer more fatal accidents compared to the general workforce, and MOB accidents come first among these accidents. In future studies, first of all, the cause of this problem should be determined and of course, studies should be carried out to eliminate this problem. In this study, MOB accidents were examined in detail and time modeling was done. However, the outputs of the study are only aimed at improving the response after the MOB accident has already occurred. Future studies may aim to prevent the accident from occurring.

Within the scope of the study, very detailed studies were carried out on the MOB accident. Data collection, analysis methods and multi-stage intervention procedures were developed only for this study. It would also be very beneficial to adapt and apply these methods, procedures and all other contributions mentioned in the previous section to other accident types.

REFERENCES

Abdulqader, Q.M., (2017). Applying the Binary Logistic Regression Analysis on The Medical Data. *Journal of University of Zakho*, 5 (4), 330. https://doi.org/10.25271/2017.5.4.388.

Ahn, S. I., Kurt, R. E., & Akyuz, E. (2022). Application of A Spar-H Based Framework To Assess Human Reliability During Emergency Response Drill For Man Overboard On Ships. *Ocean Engineering, 251*, 111089. https://doi.org/10.1016/j.oceaneng.2022.111089.

Ai, B., Jia, M., Xu, H., Xu, J., Wen, Z., Li, B., & Zhang, D. (2021). Coverage Path Planning for Maritime Search And Rescue Using Reinforcement Learning. *Ocean Engineering, 241*, 110098. https://doi.org/10.1016/j.oceaneng.2021.110098.

Aksoy, S. (2017). Liman Topluluk Sistemi, Kara Terminali Demiryolu Bağlantısı Ve Sahil Güç Besleme Sistemi Olanakları İle Çok Amaçlı Bir Limanın Rekabetçiliğinin Geliştirilmesi. (PhD Thesis). İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü. İstanbul.

Aksu, G., Keceoglu, C, R., (2019). Comparison of Results Obtained from Logistic Regression, CHAID Analysis and Decision Tree Methods. *Eurasian Journal of Educational Research*, 84, 115-134.

Ali, S, A., Parvin, F., Pham, Q, B., Vojtek, M., Vojtekova, J., Costache, R., Linh, N, T, T., Nguyen, H, Q., Ahmad, A., Ghorbani, M, A. (2020). GIS-based Comparative Assessment of Flood Susceptibility Mapping Using Hybrid Multi-Criteria Decision-Making Approach, Naïve Bayes Tree, Bivariate Statistics and Logistic Regression: A Case of Topľa Basin, Slovakia. *Ecological Indicators*, 117. https://doi.org/10.1016/j.ecolind.2020.106620.

Al-jabery, K. K., Obafemi-Ajayi, T., Olbricht, G. R., & Wunsch, D. C. (2020). Computational Learning Approaches to Data Analytics in Biomedical Applications. Elsevier, Academic Press.

Alli, B, O., (2008). Fundamental Principles of Occupational Health and Safety. International Labour Office, Genova. Second Edition. Box 9, p.22.

Allianz. (2022). Safety and Shipping Review 2022. Munich: Allianz Global Corporate & Specialty SE.

AMSA. (2018). Australian Global Maritime Distress and Safety System (GMDSS) Handbook 2018. CANBERRA: Australian Maritime Safety Authority.

Arslan, V., Kurt, R, E., Turan, O., Wolff, L, D. (2016). Safety Culture Assessment and Implementation Framework to Enhance Maritime Safety. *Transportation Research Procedia*, 14, 3895-3904. https://doi.org/10.1016/j.trpro.2016.05.477.

Asmalı, O. (2022). Personal Interview. 25 June, Istanbul.

ATSB. (2013). Man Overboard Fatality From Container Ship MSC Siena. Canberra: Australian Transport Safety Bureau.

ATSB. (2016). Man Overboard Fatality from Hyundai Dangjin, Atsb Transport Safety Report. Canberra: Australian Transport Safety Bureau.

Babulak, E., & Wang, M. (2010) Discrete event simulation: State of the art. *Discrete Event Simulations.* https://doi.org/10.5772/9894

Bakalos, N., Katsamenis, I., Karolou, E. E., & Doulamis, N. (2021). Unsupervised Man Overboard Detection Using Thermal Imagery and Spatiotemporal Autoencoders. *Frontiers in Artificial Intelligence and Applications*. https://doi.org/10.3233/faia210103.

Benz, L., Münch, C., & Hartmann, E. (2021). Development of A Search and Rescue Framework for Maritime Freight Shipping in The Arctic. *Transportation Research Part A: Policy and Practice*, *152*, 54–69. https://doi.org/10.1016/j.tra.2021.07.006.

Bera, B., Saha, S., & Bhattacharjee, S. (2020). Forest Cover Dynamics (1998 to 2019) And Prediction of Deforestation Probability Using Binary Logistic Regression (BlR) Model Of Silabati Watershed, India. *Trees, Forests and People*, *2*, 100034. https://doi.org/10.1016/j.tfp.2020.100034.

Bhattacharyya, S. K., Rahul, K. (2014). Face Recognition by Linear Discriminant Analysis. *International Journal of Communication Networks and Security*, 1–5. https://doi.org/10.47893/ijcns.2014.1087.

Bowditch, N. (2019). American Practical Navigator. Springfield, Virginia, National Geospatial - Intelligence Agency.

Cafarelli, D., Ciampi, L., Vadicamo, L., Gennaro, C., Berton, A., Paterni, M., Benvenuti, C., Passera, M., Falchi, F. (2022). MOBDrone: A Drone Video Dataset for Man OverBoard Rescue. *Image Analysis and Processing – ICIAP 2022*, 633–644. https://doi.org/10.1007/978-3-031-06430-2_53.

Cai, L., Wu, Y., Zhu, S., Tan, Z., & Yi, W. (2020). Bi-Level Programming Enabled Design of An Intelligent Maritime Search and Rescue System. *Advanced Engineering Informatics*, *46*, 101194. https://doi.org/10.1016/j.aei.2020.101194

Campbell, R. A. (2004). CPUE Standardisation and The Construction of Indices of Stock Abundance in A Spatially Varying Fishery Using General Linear Models. *Fisheries Research*, *70*(2-3), 209–227. https://doi.org/10.1016/j.fishres.2004.08.026.

Caro, J. J., & Möller, J. (2016). Advantages and Disadvantages of Discrete-Event Simulation for Health Economic Analyses. *Expert Review of Pharmacoeconomics & Outcomes Research*, *16*(3), 327–329. https://doi.org/10.1586/14737167.2016.1165608

Case, S. L., Lincoln, J. M., Lucas, D. L. (2018). Fatal Falls Overboard in Commercial Fishing — United States, 2000–2016. *MMWR. Morbidity and Mortality Weekly Report*, *67*(16), 465–469. https://doi.org/10.15585/mmwr.mm6716a2

Chelali, F. Z., Djeradi, A., Djeradi, R. (2009). Linear Discriminant Analysis for Face Recognition. *2009 International Conference on Multimedia Computing and Systems*. https://doi.org/10.1109/mmcs.2009.5256630.

Cho, S. W., Park, H. J., Lee, H., Shim, D. H., Kim, S.-Y. (2021). Coverage Path Planning for Multiple Unmanned Aerial Vehicles in Maritime Search And Rescue Operations. *Computers & Industrial Engineering*, 161, 107612. https://doi.org/10.1016/j.cie.2021.107612.

Cicek, I., Gonel, O. (2020). Investigation of Man OverBoard (MOB) Incidents: Findings and Discussions. *Engineering and Architecture Sciences. Theory, Current Research and New Trends 2*, 174–189. Cetinje, Montenegro.

Cohen-Adad, J., Chapuisat, S., Doyon, J., Rossignol, S., Lina, J.-M., Benali, H., & Lesage, F. (2007). Activation Detection in Diffuse Optical Imaging by Means of The General Linear Model. *Medical Image Analysis*, 11(6), 616–629. https://doi.org/10.1016/j.media.2007.06.002

Cospas-Sarsat Secretariat. (2021). Specification for Second-Generation Cospas-Sarsat 406-Mhz Distress Beacons. Quebec.

Cramer, J., S. (2002). The Origins of Logistic Regression. Amsterdam

Danton, G. (1996). The Theory and Practice of Seamanship. USA and Canada, Routledge.

Das, K. S. (2022). Child Labour and Its Determinants in India. *Children and Youth Services Review*, 138, 106523. https://doi.org/10.1016/j.childyouth.2022.106523

Dascalu, C, G., Carausu, E, M., Manuc, D. (2007). Methods for Data Selection in Medical Databases: The Binary Logistic Regression - Relations with the Calculated Risks. *International Journal of Biological and Life Sciences*, 3(1). doi.org/10.5281/zenodo.1060693.

Deepika, C., Gnanamalar. R. P., Thangaraj. J., Revathy, N., Karthikeyan. A. (2023). Linear Discriminant Analysis of Grain Quality Traits in Rice (Oryza sativa L.) Using the Digital Imaging Technique. *Journal of Cereal Science*, 109, 103609. https://doi.org/10.1016/j.jcs.2022.103609

Diestel, H. H. (2005). Compendium on Seamanship & Sea Accidents: A Practical Guide to Improve Seamanship and To Prevent Sea Accidents. Hamburg: Seehafen Verlag.

Domeh, V., Obeng, F., Khan, F., Bose, N., Sanli, E. (2021). Risk Analysis of Man Overboard Scenario in A Small Fishing Vessel. *Ocean Engineering*, 229. https://doi.org/10.1016/j.oceaneng.2021.108979

Dodds, D. (1995). Modern Seamanship. New York, United States of America. Lyons & Burford Publishers.

EMSA. (2021). Annual Overview of Marine Casualties And Incidents 2021. Portugal: European Maritime Safety Agency.

Escribano Mesa, J. A., Alonso Morillejo, E., Parrón Carreño, T., Huete Allut, A., Narro Donate, J. M., Méndez Román, P., Contreras Jiménez, A., Pedrero García, F., & Masegosa González, J. (2018). Risk of Recurrence in Operated Parasagittal Meningiomas: A Logistic Binary Regression Model. *World Neurosurgery*, 110. https://doi.org/10.1016/j.wneu.2017.10.087

Favero, M., Sartori, I., Carlucci, S. (2021). Human Thermal Comfort Under Dynamic Conditions: An Experimental Study. *Building and Environment*, 204, 108144. https://doi.org/10.1016/j.buildenv.2021.108144

Feraru, V. A., Andersen, R. E., Boukas, E. (2020). Towards an Autonomous UAV-Based System to Assist Search and Rescue Operations in Man Overboard Incidents. *2020 IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR)*. https://doi.org/10.1109/ssrr50563.2020.9292632

Forbus, J. J., Berleant, D. (2022). Discrete-Event Simulation in Healthcare Settings: A Review. *Modelling*, *3*(4), 417–433. https://doi.org/10.3390/modelling3040027

Formela, K., Gil, M., Sniegocki, H. (2015). Comparison of The Efficiency of Williamson And Anderson Turn Manoeuvre. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, *9*(4), 565–569. https://doi.org/10.12716/1001.09.04.14

Frey, F. (2017). SPSS (Software). *The International Encyclopedia of Communication Research Methods*, 1–2. https://doi.org/10.1002/9781118901731.iecrm0237

Fritz, M., Berger, P. D. (2015). Improving the User Experience Through Practical Data Analytics: Gain Meaningful Insight and Increase Your Bottom Line. Massachusetts Morgan Kaufman, Imprint of Elsevier.

Gonel, O., Cicek, I. (2019). Maritime Investigation Reports Involving Man Overboard (MOB) Casualties: A Methodology for Evaluation Process. *Turkish Journal of Maritime and Marine Sciences*, 5 (2), 141–170.

Gonel, O., Cicek, I. (2020). Statistical Analysis of Man Overboard (MOB) Incidents. *Engineering and Architecture Sciences, Theory, Current Research and New Trends 2*, 146–173. Cetinje, Montenegro.

Hansen, L. H., Laursen, L. H. (2008). Major Differences in Rates of Occupational Accidents Between Different Nationalities of Seafarers. *International Maritime Health* 59 (1-4), 7-18.

Hanson, E. K., Rekab, K., Ballantyne, J. (2013). Binary Logistic Regression Models Enable MIRNA Profiling to Provide Accurate Identification of Forensically Relevant Body Fluids and Tissues. *Forensic Science International: Genetics Supplement Series*, 4(1). https://doi.org/10.1016/j.fsigss.2013.10.065

Hernandez, H. (2021). Quantitative Analysis of Categorical Variables. *ForsChem Research Reports*. 6(4), 1-25

Heumann, C., Schomaker, M., Shalab (2016). Introduction to Statistics and Data Analysis: With Exercises, Solutions and Applications in R. Springer International Publishing AG.

Huang, P. F., Du, Z. X., Cheng, C. F., Chen, J. H. (2016). The Design and Development of Man Overboard Alarm and Rescue Terminal. *Journal of Discrete Mathematical Sciences and Cryptography* 19 (3), 649-661.

IAMSAR. (2016). International Aeronautical And Maritime Search And Rescue Manual.

ITU. (2014). Maritime Survivor Locating Systems and Devices (Man Overboard Systems) – An Overview of Systems and Their Mode of Operation. GENEVA: International Telecomunication Union.

Jaiyeoba, A. O., Ayeni, A. O., Atanda, A. I. (2017). Research Variables: Types, Uses and Definition of Terms.

Jiang, Y., & Leung, F., H., F. (2021). Investigating and Improving the Utility of Probabilistic Linear Discriminant Analysis for Acoustic Signal Classification. *Digital Signal Processing*, 114, 103055. https://doi.org/10.1016/j.dsp.2021.103055

John, D. S. M. (2018). Statistical Analysis Handbook A Comprehensive Handbook of Statistical Concepts, Techniques and Software Tools. Drumlin Publications.

Katsamenis, I., Protopapadakis, E., Voulodimos, A., Dres, D., Drakoulis, D. (2020). Man Overboard Event Detection From RGB and Thermal Imagery. *Proceedings of the 13th ACM International Conference on PErvasive Technologies Related to Assistive Environments*. https://doi.org/10.1145/3389189.3397998

Kececi, T. (2015). Gemi Kazası Kompleks Probleminin İncelenmesi İçin Kök Sebep Analizi Yaklaşımı Önerisi. (PhD Thesis). İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü. İstanbul.

Kettenis, D. L. (1997) Algorithm for Paralel Combined Continious and Discrete-Event Simulation. *Simulation Practice and Summary*, 5, 167-184.

Kim, Y. M., Yoon, Y. S., Hong, H. C., Min, A. (2019). Effects of A Patient Safety Course Using A Flipped Classroom Approach Among Undergraduate Nursing Students: A Quasi-Experimental Study. *Nurse Education Today*, *79*, 180–187. https://doi.org/10.1016/j.nedt.2019.05.033 .

Kulbiej, E., Rosik, J. (2018). Numerical Analysis of MOB Manoeuvres in Regard to A Body Suffering from Hypothermia. *Scientific Journals of the Maritime University of Szczecin*. 54 (126), 120–126. DOI: 10.17402/293.

Lavenberg, S., S. (1983). Computer Performance Modeling Handbook. Academic Press.

Lee, C, C., Liang, C, M., Chen, J, Z., Tung, C, H., (2018). Effects of The Housing Price to Income Ratio on Tenure Choice in Taiwan: Forecasting Performance of The Hierarchical Generalized Linear Model and Traditional Binary Logistic Regression Model. *Journal of Housing and the Built Environment*, 33, 675–694. https://doi.org/10.1007/s10901-017-9572-3.

Li, K, Jun. (2001). Maritime Safety Culture and Development of Ship and Offshore Installations Design Standards in the 21st Century. *Practical Design of Ships and Other Floating Structures*, 1, 3-11. Shanghai, China.

Li, Y., Chung, K. L., Xie, S., Yang, Y., Wang, M., Geng, X. (2018). An Improved Design of Automatic-Identification-System-Based Man Overboard Device: A Multidisciplinary Product. *IEEE Access*, 6, 25220–25229. https://doi.org/10.1109/access.2018.2828399.

Lucas, D. L., & Lincoln, J. M. (2007). Fatal Falls Overboard on Commercial Fishing Vessels in Alaska. *American Journal of Industrial Medicine*, 50(12), 962–968. https://doi.org/10.1002/ajim.20509.

Ma, Q., Zhang, D., Wan, C., Zhang, J., Lyu, N. (2022). Multi-Objective Emergency Resources Allocation Optimization for Maritime Search and Rescue Considering Accident Black-Spots. *Ocean Engineering*, *261*, 112178. https://doi.org/10.1016/j.oceaneng.2022.112178.

Mahmoud, O. M. (2017). Use of Binary Logistic Regression Model in Iraq Patients of Breast Cancer. Master Thesis. Yuzuncu Yil University Institute of Natural and Applied Sciences Statistics Department. Van.

MAIB. (2011). Fatal Man Overboard from Joanna Alongside in Glasgow, Scotland, 13 December 2010. Maritime Accident Investigation Branch.

MAIB. (2012). Report on The Investigation of The Fatal Accident of a Crew Member on The Woolwich Ferry Ernest Bevin on the River Thames, London 3 August 2011. Maritime Accident Investigation Branch

MAIB. (2014). The Falling Overboard and Recovery of a Young Child from The Passenger Ferry SNOWDROP Seacombe Ferry Terminal, River Mersey 14 October 2013. Maritime Accident Investigation Branch.

Mao, X., Liu, X., Feng, T., Chen, K. (2014). A Communication Protocol of Man Overboard System Based on Beidou. *17th International IEEE Conference on Intelligent Transportation Systems (ITSC).* https://doi.org/10.1109/itsc.2014.6957981.

Mbong, T. S. S., Bygvraa, D. A. (2021). Analysis of The Implementation of The International Safety Management Code Using Motivation Theory: The Seafarer's views. *International Maritime Health*, 72(3), 172–178. https://doi.org/10.5603/imh.2021.0033.

McGuinness, E., Aasjord, H. L., Utne, I. B., Holmen, I. M. (2013). Fatalities in the Norwegian fishing fleet 1990–2011. *Safety Science*, 57, 335–351. https://doi.org/10.1016/j.ssci.2013.03.009.

Midway, S, R., Wagner, T., Burgess, G, H., (2019). Trends in Global Shark Attacks. Plos One, 14(2). https://doi.org/10.1371/journal.pone.0211049.

Mou, J., Hu, T., Chen, P., Chen, L. (2021). Cooperative Mass Path Planning for Marine Man Overboard Search. *Ocean Engineering*, 235, 109376. https://doi.org/10.1016/j.oceaneng.2021.109376.

MSC. (2008). Code of International Standards and Recommended Practices for a Safety Investigation into a Marine Casualty or Marine Incident (Casualty Investigation Code). International Maritime Organization, RESOLUTION MSC.255(84). IMO Maritime Safety Committee, 84th session.

Nævestad, T, O., Phillips, R, O., Størkersen, K, V., Laiou, A. (2019). Safety Culture in Maritime Transport in Norway and Greece: Exploring National, Sectorial and Organizational Influences On Unsafe Behaviours And Work Accidents. *Marine Policy*, 99, 1-13. https://doi.org/10.1016/j.marpol.2018.10.001.

Ochwada, F. A., Scandol, J. P., Gray, C. A. (2008). Predicting the Age of Fish Using General and Generalized Linear Models of Biometric Data: A Case Study of Two Estuarine Finfish from New South Wales, Australia. *Fisheries Research*, 90(1-3), 187–197. https://doi.org/10.1016/j.fishres.2007.10.007.

Peeters, B., Dewil, R., Smets, I. Y. (2012). Improved Process Control of An Industrial Sludge Centrifuge-Dryer Installation Through Binary Logistic Regression Modeling of the Fouling Issues. *Journal of Process Control*, 22(7), 1387–1396. https://doi.org/10.1016/j.jprocont.2012.06.010.

Pinzon, E. (2015). Thirty Years with Stata: A Retrospective. Texas: Stata Press.

Pitman, S. J., Wright, M., Hocken, R. (2019). An Analysis of Lifejacket Wear, Environmental Factors, And Casualty Activity on Marine Accident Fatality Rates. *Safety Science*, 111, 234–242. https://doi.org/10.1016/j.ssci.2018.07.016.

Poline, J, P., Bret, M. (2012). The General Linear Model and fMRI: Does Love Last Forever? *Neuroimage*, (62)2, 871-80. doi: https://doi.org/10.1016/j.neuroimage.2012.01.133.

Sarmento, R., Costa, V. (2019). An Overview of Statistical Data Analysis.

Selmy, A. S. (2016). The Need of Man Overboard (MOB) Detecting and Tracking System Descriptive Analyses. Conference: *The 9th China International Rescue & Salvage Conference*, China

Selmy, A. S., Mahdaly, S. (2018). Integrated Man overboard MOB Search and Rescue System (IMOB -SARS) - An Overview.

Sevin, A., Bayılmış, C., Eertürk, İ., Ekiz, H., Karaca, A. (2016). Design and Implementation of a Man-Overboard Emergency Discovery System Based on Wireless Sensor Networks. *Turkish Journal of Electrical Engineering and Computer Sciences*, 24, 762–773. https://doi.org/10.3906/elk-1308-154.

Sheu, B. H., Yang, T. C., Yang, T. M., Huang, C. I., Chen, W. P. (2020). Real-Time Alarm, Dynamic GPS Tracking, And Monitoring System for Man Overboard. *Sensors and Materials*, 32(1), 197. https://doi.org/10.18494/sam.2020.2582.

Shobha, G., Rangaswamy, S. (2018). Machine Learning. *Handbook of Statistics*, 197–228. https://doi.org/10.1016/bs.host.2018.07.004

Sorkun, M. F., Özpeynirci, Ö. (2022). The Effect of Product Modularity on Supplier Integration. *Management Strategies for Sustainability, New Knowledge Innovation, and Personalized Products and Services*, 226–251. https://doi.org/10.4018/978-1-7998-7793-6.ch009

Su, Z., Liu, X., Zheng, G., Zhou, K., Gao, S. (2021). Serviceability of The IAMSAR Standard Man Overboard Recovery Maneuvers: A Case-Study of Full-Scale Sea Trials. *Applied Ocean Research*, 114, 102782. https://doi.org/10.1016/j.apor.2021.102782

Sumari, S., Ibrahim, R., Zakaria, N. H., Ab Hamid, A. H. (2013). Comparing Three Simulation Model Using Taxonomy: System Dynamic Simulation, Discrete Event Simulation and Agent-Based Simulation. *International Journal of Management Excellence*, *1*(3), 54. https://doi.org/10.17722/ijme.v1i3.9

Szeto, W. Y., Wong, R. C. P., Yang, W. H. (2019). Guiding Vacant Taxi Drivers to Demand Locations by Taxi-Calling Signals: A Sequential Binary Logistic Regression Modeling Approach and Policy Implications. *Transport Policy*, 76, 100–110. https://doi.org/10.1016/j.tranpol.2018.06.009

Tian, Y., Takane, Y. (2008). Some Properties of Projectors Associated with The WLSE Under A General Linear Model. *Journal of Multivariate Analysis*, 99(6), 1070 – 1082. https://doi.org/10.1016/j.jmva.2007.07.006.

Tian, Y., Wang, C. (2017). On Simultaneous Prediction in A Multivariate General Linear Model with Future Observations. *Statistics & Probability Letters*, *128*, 52–59. https://doi.org/10.1016/j.spl.2017.04.007

Tsekenis, V., Armeniakos, C. K., Nikolaidis, V., Bithas, P. S., Kanatas, A. G. (2021). Machine Learning-Assisted Man Overboard Detection Using Radars. *Electronics*, 10(11), 1345. https://doi.org/10.3390/electronics10111345

Ugurlu, H., Cicek, I. (2022). Analysis and Assessment of Ship Collision Accidents Using Fault Tree and Multiple Correspondence Analysis. *Ocean Engineering*, 245. https://doi.org/10.1016/j.oceaneng.2021.110514.

United Nations. (1982). United Nations Convention on the Law of the Sea.

URL-1 <*https://www.macmillandictionary.com/dictionary/british/man-overboard*>, date retrieved 02.11.2022.

URL-2 <*https://en.wikipedia.org/wiki/Man_overboard*>, date retrieved 02.11.2022.

URL-3<*https://www.sick.com/il/en/detection-and-ranging-solutions/3d-lidar-sensors/mrs6000/c/g448151*>, date retrieved 01.11.2022.

URL-4 <*https://www.mrtsos.com/commercial/products*>, date retrieved 01.11.2022.

URL-5 <*https://safemodeproject.eu/*>, date retrieved 14.11.2022.

URL-6 <*https://atlantis.udhb.gov.tr/denizkaza/yayin/hepsi.asp*>, date retrieved 01.03.2018.

URL-7 <*https://denizcilikistatistikleri.uab.gov.tr/diger-istatistikler*>, date retrieved 06.11.2022.

URL-8 <*https://www.mardep.gov.hk/en/fact/portstat.html*>, date retrieved 1.03.2018, date updated 03.11.2022

URL-9 <*https://www.floridamuseum.ufl.edu/shark-attacks/yearly-worldwide-summary/*>, date retrieved 26.11.2022.

URL-10<*https://www.lipcon.com/cruise-ship-accident-lawyer/cruise-vessel-security-safety-act/*>, date retrieved 30.11.2022.

URL-11 <*https://www.legifrance.gouv.fr/codes/section_lc/JORFTEXT000000841523/LEGISCTA000021826223/*>, date retrieved 30.11.2022.

URL-12 <*https://marss.com/products/mobtronic/*>, date retrieved 02.12.2022.

URL-13 <*https://www.puretechsystems.com/business-overview*>, date retrieved 02.12.2022.

URL-14<*https://www.sick.com/ag/en/industries/maritime/commercial-and-passenger-ships/intelligent-detection-of-people-beside-and-on-ships/man-overboard-detection/c/p581949*>, date retrieved 02.12.2022.

URL-15 <*https://www.cruisemapper.com/news/11060-search-suspended-passenger-overboard-msc-bellissima*>, date retrieved 02.12.2022.

URL-16<*https://crew-center.com/search-underway-missing-person-believed-have-fallen-overboard-msc-bellissima*>, date retrieved 02.12.2022.

URL-17 <*https://cruise-arabia.com/2019/08/16/ship-review-msc-bellissima/*>, date retrieved 02.12.2022.

URL-18 <*https://beacons.amsa.gov.au/about/beacon-types.asp*>, date retrieved 02.12.2022.

URL-19 <*https://www.gme.net.au/au/emergency-safety/mt610g/*>, date retrieved 02.12.2022.

URL-20 <*https://www.seasofsolutions.com/products/?_sft_technology=plbs*>, date retrieved 02.12.2022.

URL-21 <*https://oceansignal.com/products/mob1/#specifications*>, date retrieved 02.12.2022.

URL-22 <*https://www.acrartex.com/products/aislink-personal-ais-mob-beacon/*>, date retrieved 02.12.2022.

URL-23 <*https://www.boatus.com/expert-advice/expert-advice-archive/2020/april/5-man-overboard-safety-devices-tested*>, date retrieved 02.11.2022.

URL-24 <*https://www.sas.com/ro_ro/insights/analytics/statistical-analysis.html*>, date retrieved 03.12.2022.

URL-25 <*https://en.wikipedia.org/wiki/SAS_(software)#cite_note-Attr76-21*>, date retrieved 05.12.2022.

URL-26 <*https://www.stata.com/support/faqs/resources/history-of-stata/*>, date retrieved 05.12.2022.

URL-27 <*https://www.merriam-webster.com/dictionary/bivariate*>, date retrieved 07.12.2022.

URL-28 <*https://www.merriam-webster.com/dictionary/multivariate*>, date retrieved 07.12.2022.

URL-29 *<https://en.wikipedia.org/wiki/Queueing_theory>*, date retrieved 14.12.2022.

URL-30 *<https://dictionary.reverso.net/english-definition/light+conditions>*, date retrieved 02.02.2022.

URL-31 *<https://www.floridamuseum.ufl.edu/shark-attacks/trends/fatalities/>*, date retrieved 09.03.2022.

URL-32*<https://en.wikipedia.org/wiki/Degrees_of_freedom_(statistics)#cite_note-1>*, date retrieved 18.12.2022.

URL-33*<https://www.ibm.com/support/pages/can-r-squared-be-printed-generalized-linear-models-genlin-results.>*, date retrieved 19.08.2022.

URL-34 *<https://en.wikipedia.org/wiki/Pseudo-R-squared>*, date retrieved 19.12.2022.

Von Lühmann, A., Li, X., Müller, K.-R., Boas, D. A., Yücel, M. A. (2020). Improved Physiological Noise Regression In fNIRS: A Multimodal Extension of The General Linear Model Using Temporally Embedded Canonical Correlation Analysis. *NeuroImage*, *208*, 116472. https://doi.org/10.1016/j.neuroimage.2019.116472

Wang, N., Roongnat, C., Rosenberger, J. M., Menon, P. K., Subbarao, K., Sengupta, P., Tandale, M. D. (2018). Study of Time-Dependent Queuing Models of The National Airspace System. *Computers & Industrial Engineering*, *117*, 108–120. https://doi.org/10.1016/j.cie.2018.01.014

Wang, J., Song, H., Fu, T., Behan, M., Jie, L., He, Y., Shangguan, Q., (2021). Crash Prediction for Freeway Work Zones in Real Time: A Comparison Between Convolutional Neural Network and Binary Logistic Regression Model. *International Journal of Transportation Science and Technology*, 11(3) 484-495. https://doi.org/10.1016/j.ijtst.2021.06.002.

Wang, Z., Hu, H., Wang, R., Zhang, Q., Nie, F., Li, X. (2022). Capped *lp*-Norm Linear Discriminant Analysis for Robust Projections Learning. *Neurocomputing*, 511, 399-409. https://doi.org/10.1016/j.neucom.2022.09.006.

Wei, Y., Gu, K., Tan, L. (2022). A Positioning Method for Maize Seed Laser-Cutting Slice Using Linear Discriminant Analysis Based on Isometric Distance Measurement. *Information Processing in Agriculture*, 9(2), 224–232. https://doi.org/10.1016/j.inpa.2021.05.002

Wongsasuluk, P., Chotpantarat, S., Siriwong, W., Robson, M. (2018). Using Hair and Fingernails in Binary Logistic Regression for Bio-Monitoring of Heavy Metals/Metalloid in Groundwater in Intensively Agricultural Areas, Thailand. *Environmental Research*, 162, 106–118. https://doi.org/10.1016/j.envres.2017.11.024

Xiong, W., van Gelder, P. H. A. J. M., Yang, K. (2020). A Decision Support Method for Design and Operationalization of Search and Rescue in Maritime Emergency. *Ocean Engineering*, 207, 107399. https://doi.org/10.1016/j.oceaneng.2020.107399

Yemane, G. D., Korsa, B. B., Jemal, S. S. (2022). Multilevel Analysis of Factors Associated with Pregnancy Termination in Ethiopia. *Annals of Medicine and Surgery*, 80, 104120. https://doi.org/10.1016/j.amsu.2022.104120

Yenipınar, A. (2019). İkili Lojistik Regresyon Analizinde Örnek Büyüklüğünün Önemi. (PhD Thesis). Kahramanmaraş Sütçü İmam Üniversitesi Fen Bilimleri Enstitüsü. Kahramanmaraş.

Yılmaz, A. (2016). İki Durumlu (Binary) Lojistik Regresyon Modeline Bayesci Bir Yaklaşım: OECD Örneği. (Master Thesis). Yüzüncü Yıl Üniversitesi, Fen Bilimleri Enstitüsü İstatistik Anabilim Dalı, Van.

Yuknis, M. L., Abulebda, K., Whitfill, T., Pearson, K. J., Montgomery, E. E., Auerbach, M. A. (2022). Improving Emergency Preparedness in Pediatric Primary Care Offices: A Simulation-Based Interventional Study. *Academic Pediatrics*, 22(7), 1167–1174. https://doi.org/10.1016/j.acap.2022.03.018.

Zhang, J., Teixeira, Â. P., Guedes Soares, C., Yan, X. (2017). Probabilistic Modelling of The Drifting Trajectory of An Object Under the Effect of Wind and Current for Maritime Search and Rescue. *Ocean Engineering*, 129, 253–264. https://doi.org/10.1016/j.oceaneng.2016.11.002.

Zhang, Z, X., Wang, L., Wang, Y, M., (2018). An Emergency Decision Making Method Based on Prospect Theory for Different Emergency Situations. *International Journal of Disaster Risk Science*, 9, 407-420. https://doi.org/10.1007/s13753-018-0173-x.

Zhang, R.-jun, & Li, A. (2020). Experimental Study on Temperature Dependence of Mechanical Properties of Scaled High-Performance Rubber Bearings. *Composites Part B: Engineering*, *190*, 107932. https://doi.org/10.1016/j.compositesb.2020.107932

Zhao, H., Yuen, P. C. (2008). Incremental Linear Discriminant Analysis for Face Recognition. *IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics)*, 38(1), 210–221. https://doi.org/10.1109/tsmcb.2007.908870

Zhou, X., Cheng, L., Min, K., Zuo, X., Yan, Z., Ruan, X., Chu, S., Li, M. (2020). A Framework for Assessing the Capability of Maritime Search and Rescue in The South China Sea. *International Journal of Disaster Risk Reduction*, *47*, 101568. https://doi.org/10.1016/j.ijdrr.2020.101568.

Zhu, F., Gao, J., Yang, J., Ye, N. (2022). Neighborhood Linear Discriminant Analysis. *Pattern Recognition*, 123, 108422. https://doi.org/10.1016/j.patcog.2021.108422

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- **Gonel, O., Çiçek İ.** 2019. Maritime Investigation Reports Involving Man-Over-Board (MOB) Casualties: A Methodology for Evaluation Process, *Turkish Journal of Maritime and Marine Sciences*, 5(2), 141-170
- **Gonel, O., Çiçek İ.** 2020. Statistical Analysis of Man Over Board (mob) Incidents, *Engineering And Architecture Sciences, Theory, Current Research and New Trends/2*, Cetinje-Montenegro.
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- **Gonel, O., Çiçek İ.** 2021: Maritime Investigation Reports Involving Man-Over-Board (MOB) Casualties: A Methodology for Evaluation Process. *The 10th International Scientific Research Congress Science and Engineering*, April 11, 2021 Ankara, Turkey.
- **Gonel, O., Cicek, I.** 2022. Multicriteria emergency decision for responding to man overboard casualties: A proposed procedure developed using Binary Logistics Regression and General Linear Models, *Ocean Engineering, 265,* 112581. https://doi.org/10.1016/j.oceaneng.2022.112581