

**ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL**

**A PROPOSAL ON A QUANTIFIED SHIP  
NAVIGATIONAL ASSESSMENT AND AUDIT MODEL**



**M.Sc. THESIS**

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**Department of Maritime Transportation Engineering**

**Maritime Transportation Engineering Programme**

**JUNE 2025**



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**İSTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ**

**GEMİLERİN SEYİRDE DENETİMİNE YÖNELİK  
SAYISAL DEĞERLENDİRME MODELİ**

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## **FOREWORD**

Navigational safety in maritime operations, particularly for tanker ships, is paramount to safeguarding both human lives and the marine environment. The complexity of navigating these large vessels through often unpredictable and hazardous waters demands a robust and systematic approach to assessment and audit. This Thesis, "A Proposal on a Quantified Ship Navigational Assessment and Audit Model" addresses this critical need by introducing a structured framework for evaluating and enhancing navigational practices.

June 2025

Nasuh RAZI



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## **ABBREVIATIONS**

<b>EMSA</b>	: European Maritime Safety Agency
<b>EU</b>	: European Union
<b>IMO</b>	: International Maritime Organization
<b>INTERTANKO</b>	: International Association of Independent Tanker Owners
<b>ILO</b>	: International Labour Organization
<b>ISM</b>	: International Safety Management
<b>OCIMF</b>	: Oil Companies International Marine Forum
<b>SIRE</b>	: The Ship Inspection Report Programme
<b>SMS</b>	: Safety Management System
<b>TMSA</b>	: Tanker Management and Self-Assessment



## **SYMBOLS**

<b>I</b>	: Parts
<b>J</b>	: Sub-parts
<b>K</b>	: Sections
<b>w<sub>ijk</sub></b>	: Weights
<b>s<sub>ijk</sub></b>	: Scores
<b>d<sub>i</sub></b>	: Numerical Evaluation
<b>p<sub>i</sub></b>	: Final weights
<b>E</b>	: Final Evaluation



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# **A PROPOSAL ON A QUANTIFIED SHIP NAVIGATIONAL ASSESSMENT AND AUDIT MODEL**

## **SUMMARY**

Navigation errors on board ships have repeatedly led to catastrophic disasters, claiming many lives and causing significant damage to the vessel, cargo and surrounding areas. Furthermore, the increasing complexity of integrated bridge layouts and the introduction of sophisticated navigational equipment have inadvertently increased the risk of navigational errors. This risk is further exacerbated by inadequate training and insufficient familiarity of navigational watchkeeping personnel with the newly introduced technologies and procedures. Despite the implementation of a robust set of navigational and bridge procedures and checklists under the International Safety Management (ISM) Code, a large proportion of navigational incidents are still caused by inefficient procedures, disregard for best bridge watchkeeping practices, poor management of the bridge team and ineffective communication. This highlights the necessity for a deeper exploration of the root causes behind these ongoing challenges. Although, navigation audits and evaluations, mandated by Tanker Management and Self-Assessment (TMSA), would reveal deficiencies in the procedures, bridge team, and equipment, ultimately paving the way for potential advancements and enhancements in onboard navigation practices, to produce thorough, precise, impartial, clear, and succinct navigational assessment and audit reports/results for end users, we present a quantified navigational assessment and audit model.

This thesis introduces an innovative method aimed at improving both the safety and efficiency of maritime navigation through the development of a Quantified Ship Navigational Assessment and Audit Model. Drawing inspiration from established best practices for navigational assessments and audits, this model offers a distinctive analytical perspective. The application of this model yields crucial information for end users, significantly enhancing navigation safety. Historically, the maritime industry has depended on subjective evaluations during navigational audits, resulting in inconsistencies in assessing navigational performance. This thesis responds to the demand for a more uniform and data-centric approach by presenting a model that utilizes quantifiable metrics for a thorough evaluation of ship navigation.



## GEMİLERİN DENİZDE DENETİMİNE YÖNELİK SAYISAL DEĞERLENDİRME MODELİ

### ÖZET

Günümüzde küresel ticaretin dinamosu haline gelen deniz taşımacılığı, dünya ticaret hacminin %80'inden fazlasını oluşturmaktadır. Bu oran, deniz taşımacılığının stratejik önemini açıkça ortaya koyarken, aynı zamanda deniz yolu ile yapılan taşımacılığın güvenliği ve sürekliliği konularının ne kadar kritik hale geldiğini de gözler önüne sermektedir. Artan talep ve yoğun trafik koşulları altında, seyrüsefer faaliyetlerinin emniyetli ve etkin bir şekilde yürütülmesi hayati bir öneme sahiptir. Gemi trafiğindeki artışla birlikte, deniz kazalarının ve olaylarının yaratabileceği etkiler, yalnızca sektör paydaşlarını değil, küresel ekonomiyi ve çevresel sistemi de derinden etkileyebilecek boyutlara ulaşmaktadır.

Bu duruma en çarpıcı örneklerden biri, 2021 yılında Süveyş Kanalı'nda yaşanan Ever Given konteyner gemisi kazasıdır. Dünyanın en önemli su yollarından biri olan Süveyş Kanalı'nda bu geminin karaya oturması sonucu kanal tam altı gün boyunca ulaşıma kapanmıştır. Bu kapanmanın, dünya ticaretine saatte yaklaşık 400 milyon dolar maliyet yarattığı öngörülmektedir. Böyle kısa süreli bir olayın dahi bu denli büyük ekonomik etkilere yol açması, deniz taşımacılığında seyrüsefer hatalarının ne kadar ciddi sonuçlar doğurabileceğini açıkça göstermektedir. Bu örnek olay, denizcilik faaliyetlerinde navigasyonun ne kadar hassas ve kritik olduğunu, yapılan en küçük hatanın bile zincirleme ekonomik, çevresel ve lojistik krizlere neden olabileceğini kanıtlamaktadır.

Ever Given olayının maddi zararları, kanal trafiğinin geçici süreyle durması ve kıyı altyapısında meydana gelen hasarla sınırlı kalmıştır. Ancak bu olay, daha tehlikeli yükler taşıyan tankerlerin benzer bir durumla karşılaşması halinde ortaya çıkabilecek çok daha yıkıcı sonuçlara da dikkat çekmektedir. Örneğin, ham petrol, kimyasallar veya sıvılaştırılmış gaz taşıyan gemilerin karaya oturması ya da çarpışma gibi olaylar neticesinde yalnızca maddi kayıplar değil, aynı zamanda ciddi çevre felaketleri de meydana gelebilmektedir. Bu tür olaylar deniz ekosistemlerini kalıcı şekilde tahrip etmekte ve yıllar süren temizleme çalışmalarına ihtiyaç doğurmaktadır.

Gemi teknolojilerinin ve köprüüstü sistemlerinin giderek daha gelişmiş ve karmaşık hale gelmesi, denizciler için hem fırsatlar hem de yeni riskler yaratmaktadır. Modern seyir sistemleri, doğru ve etkin kullanıldığında seyrüsefer güvenliğini artırmaktadır; ancak bu sistemlerin yanlış kullanımı veya yetersiz bilgiyle işletilmesi, kazaların önünü açabilmektedir. Özellikle köprüüstü personelinin, bu sistemlere yeterince aşina olmaması, eğitimlerinin güncel olmaması veya prosedürlere yeterli hakimiyetlerinin bulunmaması durumunda risk oranı artmaktadır. Bu da gösteriyor ki, teknoloji tek başına çözüm değildir; teknoloji ile insan faktörünün uyum içinde çalışması elzemdir.

Her ne kadar International Safety Management (ISM) Kodu kapsamında güçlü seyir ve köprüüstü prosedürleri ile kontrol listeleri uygulanmakta olsa da, istatistikler seyir kazalarının önemli bir kısmının hâlâ verimsiz uygulamalar, köprüüstü ekibinin zayıf

koordinasyonu ve yetersiz iletişim nedeniyle meydana geldiğini göstermektedir. Bu durum, mevcut sistemlerin yeniden gözden geçirilmesi ve daha etkin denetim ve değerlendirme mekanizmalarının devreye alınması gerektiğini ortaya koymaktadır. Sadece prosedürlerin varlığı değil, bu prosedürlerin gemi personeli tarafından doğru anlaşılması ve etkin şekilde uygulanması da büyük önem taşımaktadır.

Özellikle ham petrol, petrol ürünleri, petrokimyasallar ve doğalgaz gibi tehlikeli yükleri taşıyan tanker gemilerinde, güvenli ve çevreye duyarlı taşımacılığın sağlanması birincil önceliklerden biridir. Bu alanda, Petrol Şirketleri Uluslararası Denizcilik Forumu (OCIMF), denizcilik güvenliğini artırmaya yönelik önemli inisiyatifler geliştirmiştir. Bunlardan biri olan Tanker Management and Self-Assessment (TMSA) sistemi, seyirle ilgili prosedürlerin, köprüüstü ekipmanlarının ve personelin değerlendirilmesini zorunlu kılarak, mevcut eksiklikleri ortaya çıkarmayı ve iyileştirme alanlarını belirlemeyi amaçlamaktadır.

TMSA sistemi, tanker taşımacılığında emniyet kültürünü geliştirmek ve yönetim süreçlerini iyileştirmek amacıyla kapsamlı bir çerçeve sunmaktadır. Bu sistem, gemi işletmecilerinin kendi operasyonlarını değerlendirmeleri ve uluslararası en iyi uygulamalarla uyumlu hale getirmeleri için bir referans noktası sağlamaktadır. Ancak, sistemin genel yapısı ve uygulama biçimi, tüm potansiyel faydalarının tam anlamıyla ortaya çıkmasına her zaman olanak tanımamaktadır. Özellikle seyirle ilgili denetim ve değerlendirme süreçlerinde, kullanıcılar için eksiksiz, nesnel, net ve öz bilgi sağlayan denetim raporlarının hazırlanmasında çeşitli eksiklikler dikkat çekmektedir.

Bu eksikliklerin başında, mevcut uygulamalarda sıklıkla nitel, yani yoruma dayalı değerlendirme yöntemlerinin tercih edilmesi gelmektedir. Denetçilerin kişisel tecrübelerine, yorumlarına ve algılarına dayalı bu nitel analizler, değerlendirme sonuçlarında ciddi farklılıklar doğurabilmekte; aynı gemi, farklı denetçiler tarafından incelendiğinde çok farklı sonuçlar elde edilebilmektedir. Bu durum, hem tutarsızlık yaratmakta hem de alınacak aksiyonların belirlenmesinde kafa karışıklığına yol açmaktadır. Bunun yanı sıra, yapılan değerlendirmelerde eksikliklerin yalnızca varlığı raporlanmakta; bu eksikliklerin operasyonel risk üzerindeki etkisi ya da önem derecesi hakkında yeterli bilgi sunulamamaktadır. Bu da, karar vericilerin hangi eksikliklerin öncelikli olarak giderilmesi gerektiğine dair stratejik bir sıralama yapmalarını zorlaştırmaktadır.

Nitel değerlendirmelerin bu sınırlamaları, özellikle çok paydaşlı ve karmaşık operasyonel yapıya sahip denizcilik sektöründe, daha güvenilir ve karşılaştırılabilir verilere duyulan ihtiyacı daha da belirgin hale getirmektedir. Bu noktada, denetim süreçlerine nicel, yani ölçülebilir ve veriye dayalı bir yaklaşımın entegre edilmesi gerekliliği ortaya çıkmaktadır. Nicel yöntemler, değerlendirme sürecine nesnellik kazandırmakta; elde edilen bulguların sadece “ne” olduğuna değil, “ne kadar ciddi” ve “ne kadar acil” olduğuna dair somut bilgiler sunmaktadır. Bu sayede, risk yönetimi daha etkili hale gelmekte ve kaynakların daha stratejik biçimde kullanılması mümkün olmaktadır.

Ayrıca, nicel verilerin kullanılması sayesinde, zaman içerisinde oluşan değişimlerin ve gelişim trendlerinin takibi de mümkün hale gelmektedir. Bir geminin veya işletmenin belirli aralıklarla aldığı denetim sonuçları, sayısal göstergelerle desteklendiğinde, performanstaki ilerleme veya gerileme net biçimde izlenebilmektedir. Bu durum, sadece bireysel gemiler için değil, filolar, işletmeciler veya tüm sektör için daha geniş çaplı analizlerin yapılmasına da imkân tanımaktadır.

Özetle, TMSA gibi sistemlerin sunduğu çerçeveyi daha işlevsel ve etkili hale getirebilmek için, denetim ve değerlendirme süreçlerinde daha nesnel, sistematik ve ölçülebilir yöntemlerin benimsenmesi elzemdir. Nicel yaklaşım, yalnızca mevcut durumu daha doğru analiz etmeyi sağlamakla kalmaz; aynı zamanda gelecekteki gelişim alanlarını daha açık ve somut biçimde ortaya koyar. Böylece, güvenli ve çevreye duyarlı deniz taşımacılığı hedefi doğrultusunda daha sağlam adımlar atılabilir.

Bu ihtiyaçtan yola çıkarak geliştirilen bu tez çalışması, Nicel Gemi Seyir Değerlendirme ve Denetim Modeli ile denizcilik sektörüne yenilikçi bir katkı sağlamayı amaçlamaktadır. Model, seyir güvenliğini ve verimliliğini artırmak adına, sahada edinilen en iyi uygulamalardan ve mevcut denetim prosedürlerinden esinlenerek oluşturulmuştur. Sunduğu analitik yaklaşım sayesinde, köprüüstü uygulamalarının daha sistematik şekilde analiz edilmesini ve objektif verilere dayalı olarak değerlendirilmesini mümkün kılmaktadır.

Geliştirilen bu modelin uygulanması, gemi işletmecileri, denetçiler ve düzenleyici otoriteler için kritik bilgiler sunmakta ve seyir güvenliğinde gözle görülür bir iyileşme sağlamaktadır. Bu tez, denizcilik sektöründe uzun süredir var olan sübjektif değerlendirme anlayışına alternatif olarak, daha tutarlı, şeffaf ve veri temelli bir yöntemin mümkün olduğunu ortaya koymaktadır. Modelin sunduğu yapı, denetim ve değerlendirme süreçlerinin standardize edilmesine katkı sağlamakta ve sonuçların daha karşılaştırılabilir hale gelmesini mümkün kılmaktadır.

Sonuç olarak, deniz taşımacılığının geleceği, yalnızca gemi teknolojilerindeki ilerlemelere değil, aynı zamanda bu teknolojilerin doğru şekilde değerlendirilmesine ve uygulanmasına bağlıdır. Bu tezde ortaya konan nicel seyir değerlendirme modeli, sektördeki bu kritik ihtiyaca cevap vermekte ve seyrüsefer güvenliğini ileriye taşımayı hedeflemektedir.



# **1. INTRODUCTION**

## **1.1 Overview**

Over 80% of global trade is carried by sea, making maritime transport a cornerstone of international commerce. At the core of this sector's safety is effective and secure navigation. However, despite the integration of advanced technologies into shipping operations, navigational risks continue to pose serious challenges. These issues are often intensified by crew members' insufficient training and limited familiarity with updated technologies and operating procedures.

Although the International Safety Management (ISM) Code enforces the use of comprehensive bridge management checklists and protocols, many navigation-related accidents still occur. Contributing factors include ineffective procedures, weak coordination among bridge team members, and inadequate communication. While navigation audits and assessments under the Tanker Management and Self-Assessment (TMSA) framework help identify procedural flaws, personnel gaps, and equipment issues—offering suggestions for improvement—these measures alone have not eliminated recurring problems.

To address these shortcomings, this study proposes a quantitative navigation assessment and audit model that delivers accurate, concise, unbiased, and thorough reports tailored for stakeholders. A deeper exploration of the root causes behind these persistent safety failures is essential to enhance navigational practices across the industry.

## **1.2 Purpose of Thesis**

This thesis presents a novel approach designed to enhance both the safety and operational efficiency of maritime navigation by developing a Quantified Ship Navigational Assessment and Audit Model. Inspired by widely recognized best practices in navigational evaluations and audits, the model introduces a unique

analytical framework. Its implementation provides valuable insights for end users, contributing significantly to safer navigation.

Traditionally, navigational audits within the maritime sector have relied heavily on subjective judgments, which have led to variability and inconsistency in evaluating navigational performance. To address this challenge, the thesis proposes a standardized, data-driven method that employs measurable indicators for a comprehensive assessment of ship navigation

### **1.3 Objective**

The primary objective of this thesis is to create a comprehensive navigational assessment model specifically tailored for tankers, grounded in the principles outlined in “A Guide to Best Practice for Navigational Assessment and Audit.” This model aims to evaluate critical components including navigational performance, company policies, bridge team structure, operational procedures, and documentation practices.

A key feature of the model is the incorporation of human factors analysis, which will equip companies with valuable, data-driven insights into crew behavior, decision-making, and team interactions. Through a systematic, quantitative auditing approach, the model will produce measurable risk and performance metrics, enabling a thorough evaluation of both operational processes and human elements.

Ultimately, this model is intended to facilitate ongoing advancements in navigation safety and operational compliance with international regulations, while enhancing the company’s ability to assess and optimize crew effectiveness.

### **1.4 Thesis Organization**

The thesis is organized as follows. Chapter One is the introduction chapter which includes an overview of the thesis, objectives, and organization. Chapter Two is composed of literature review of TMSA, SIRE, SIRE 2.0, human factor analysis and navigational audit. In Chapter Three we describe our model. Chapter Four is the case study of implementing our model for a sample company. In Chapter Five, we discuss our results. Finally, Chapter Six includes the conclusions of the thesis and further remarks.

## **2. LITERATURE REVIEW**

This chapter includes a summary of related literature on SIRE, navigational assesment and audit, human factor.

### **2.1 Tanker Management and Self-Assessment (TMSA), The Ship Inspection Report Programme (SIRE) and SIRE 2.0**

Maritime transportation plays a vital role in global commerce, accounting for approximately 90% of worldwide trade (Cicek et al., 2022; UN, 2023). Given this significance, ensuring maritime safety remains a top priority for the shipping industry, which has achieved substantial progress in recent years. Despite the adoption of advanced navigational technologies and sophisticated equipment, the risk of navigation errors persists, leading to occasional maritime accidents (Shi et al., 2021).

Historically, navigation mistakes aboard vessels have caused severe disasters, resulting in considerable loss of life, damage to ships, cargo, and the surrounding environment. During the 1990s, more than 200 vessels were lost annually. However, in the past decade, this number has decreased dramatically—by the end of 2023, it reached an unprecedented low. Specifically, only 26 vessels exceeding 100 gross tonnage were lost in 2023, marking a decline of over one-third from 41 in the previous year. Over the last ten years, shipping losses have diminished by 70%, down from 89 incidents reported in 2014 (Allianz Commercial, 2024).

This downward trend can largely be attributed to the regulatory measures implemented by the International Maritime Organization (IMO), the global authority responsible for overseeing maritime operations. Established with the goal of enhancing maritime safety and reducing risks, the IMO has introduced various conventions and regulations. Among these are the International Convention for the Safety of Life at Sea (SOLAS), the International Convention for the Prevention of Pollution from Ships (MARPOL), the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW), and the International Maritime Solid Bulk Cargoes (IMSBC) Code (Aydin et al., 2021).

In response to the catastrophic capsizing of the ferry *Herald of Free Enterprise* in March 1987, the International Maritime Organization (IMO) introduced the International Safety Management (ISM) Code in 1993 via Resolution A.741 (18). The following year, the ISM Code was incorporated into SOLAS as Chapter IX, entitled "Management of the Safe Operation of Ships," which mandates ship owners or responsible parties to establish and maintain a Safety Management System (SMS) (Chauvin et al., 2013).

Although early research in the 1990s sought to compare the ISM Code's impact with the ISO 9000 series standards, the overarching goal of the Safety Management System is to standardize safety and environmental procedures across the maritime industry (Szwed and Bea, 2000; Pun et al., 2003). Kristiansen (2008) highlights this requirement as a pivotal evolution in the IMO's regulatory framework, shifting focus away from rigid prescriptive regulations on ship design and manning towards fostering a culture of safety awareness both onboard vessels and ashore.

The ISM Code has progressively encouraged the maritime sector to move beyond reliance solely on operator training and checklists, promoting instead a comprehensive safety culture that permeates all organizational levels—from seafarers to senior management. Empirical studies have evaluated the Code's effectiveness; for instance, Tzannatos and Kokotos (2009) analyzed accident records of Greek-flagged ships from 1993 to 2006, comparing periods before and after ISM Code implementation. Similarly, Størkersen et al. (2017) investigated how the Code influenced safety management practices aimed at accident prevention.

Numerous other researchers have examined the ISM Code's impact on maritime safety (Bhattacharya, 2012; Kokotos, 2013; Lee, 2016; Pantouvakis and Karakasnaki, 2016). More recently, Baştuğ et al. (2021) and Esad Demirci et al. (2023) have proposed innovative strategies designed to enhance the effectiveness of ISM Code implementation.

Crude oil and petroleum products make up approximately 65% of all cargo transported by sea, with other major cargo types including dry bulk and containerized goods (Heij et al., 2011). Maritime accidents can have severe consequences, but when tankers carrying hazardous substances are involved, the potential damage escalates significantly (Elidolu et al., 2024; Talley et al., 2001; Talley et al., 2008). In response

to growing concerns about marine pollution, particularly oil spills, the Oil Companies International Marine Forum (OCIMF) was founded in April 1970. Over the past five decades, OCIMF has become a leading authority on marine safety worldwide, boasting more than 100 member companies and holding consultative status with the International Maritime Organization (IMO) (OCIMF, 2024).

OCIMF is dedicated to its vision of “a global marine industry that causes no harm to people or the environment,” focusing on the promotion of best practices in the design, construction, and operation of tankers, barges, and offshore vessels. Additionally, the organization unites companies engaged in offshore marine services that support oil and gas exploration, development, and production (Kartsimadakis, 2013). This collaboration takes place on an independent platform where members and external stakeholders pool their expertise to develop guidelines and initiatives aimed at elevating safety and environmental standards throughout the maritime sector.

In 1993, OCIMF introduced the Ship Inspection Report Programme (SIRE), a key initiative designed to enhance safety and environmental performance within the tanker industry. Although SIRE was launched shortly after the ISM Code, its development was influenced by the safety and operational management objectives promoted by the Code. Based on feedback from the SIRE program, OCIMF established the Tanker Management and Self-Assessment (TMSA) program in 2004. TMSA draws upon international regulatory frameworks, including the IMO’s STCW-95 and the ISM Code, to address limitations in shore-based maritime company operations that SIRE did not cover (Siali and Bertnsson, 2023).

Originally conceived as an internal audit tool to assess and improve operational efficiency, by 2006, TMSA became mandatory for shipowners seeking charter agreements with major industry players such as BP, Repsol, and Shell, who offer premium freight rates for compliance (Taflı, 2006). The program serves as a resource for vessel operators to evaluate, measure, and enhance their management systems. Targeting all tank vessel operators—including coastal tankers and barges—TMSA provides guidelines for best practices and encourages continuous improvement in safety management (OCIMF, 2008).

The Oil Companies International Marine Forum’s (OCIMF) Ship Inspection Report Programme (SIRE) along with the Tanker Management and Self-Assessment (TMSA)

program have played a crucial role in enhancing maritime safety, having conducted over 180,000 inspections to date (Orhan and Çelik, 2023). To ensure consistency across inspections, participants strive to establish optimal scheduling procedures. Various methodologies to achieve this goal have been explored by researchers such as Cebi et al. (2009) and Raman and Shankaranarayanan (2018).

Conversely, Grbic et al. (2018) highlight an issue of overlapping inspection items within different inspection frameworks applied to oil tankers over short intervals. This redundancy not only adversely affects vessel safety but also unnecessarily strains onboard human resources and generates negative economic impacts. Supporting this perspective, Bijwaard and Knapp (2009) analyzed data from 50,000 ships spanning 1978 to 2007 and concluded that while inspections generally contribute to maritime safety, excessive inspections may fail to deliver expected economic and operational efficiencies, underscoring the need for optimization.

Heij et al. (2011) further emphasize that inspection regimes incorporating clear, easy-to-follow rules could lead to substantial safety improvements, balancing thoroughness with practicality.

In response to evolving industry needs, OCIMF is developing a risk-based vessel inspection system intended to replace the existing SIRE program. Known as SIRE 2.0, this new system consolidates all of OCIMF's inspection initiatives into a unified framework. Adopting a risk-based methodology, SIRE 2.0 provides a more thorough inspection process, featuring enhanced tools, improved governance mechanisms, and more detailed reporting capabilities (Arslan et al., 2016). The overarching aim of SIRE 2.0 is to “future-proof the tanker inspection process” (OCIMF, 2023).

The COVID-19 pandemic has underscored the critical importance of digital transformation, prompting the maritime industry to embrace change and transition into the era of smart shipping, overcoming the operational disruptions experienced during the health crisis (Kartsimadakis, 2023). During this period, many shipping companies adopted remote audit programs, laying the groundwork for digital auditing supported by technological advancements. With the introduction of SIRE 2.0, pre-inspection planning, inspection procedures, and result compilation will be fully digitized, enabling companies to monitor vessel status in real time. However, the inspection

process itself will evolve, requiring more extensive crew preparation and new vetting routines for inspectors evaluating vessels (OCIMF, 2022).

While Montenegro and Nylund (2023) acknowledge that these changes initially increase the crew's workload, they argue that effective leadership will eventually alleviate this burden. Importantly, SIRE 2.0 introduces a novel aspect by incorporating the human factor into the inspection framework. A new tool, called the Human Response Tool, has been developed to assist in assessing human performance during vetting inspections, marking a significant innovation in the evaluation process (Montenegro and Nylund, 2023).

## **2.2 Human Factor**

The concept of the "human factor" has been acknowledged in professional and academic fields since the 1990s and continues to gain prominence in maritime safety discussions today. The International Maritime Organization (IMO), which plays a central role in shaping maritime regulations, defines the human element as "a complex, multi-dimensional issue that affects maritime safety, security, and marine environmental protection" (IMO, 2024). Meanwhile, the Oil Companies International Marine Forum (OCIMF) describes human factors as "the physical, psychological, and social characteristics influencing human interaction with equipment, systems, processes, other individuals, and work teams" (OCIMF, 2024). Within maritime literature, terms such as "human error," "human factor," "human action," and "human element" are frequently used interchangeably (Wróbel, 2021).

The maritime sector has witnessed a significant cultural shift toward automation, particularly in navigation systems (Hetherington et al., 2006). The primary goals of this automation are to enhance safety and improve operational efficiency (Harris, 2016). However, increased automation has also transformed the seafarer's role onboard (Grech and Horberry, 2002). According to Cicek et al. (2019), technological advancements are expected to fundamentally reshape employment patterns in the maritime industry while simultaneously increasing the demand for highly skilled and qualified personnel. Notably, operators tend to exhibit decreased vigilance once automated systems are in place, with attentiveness waning further if the systems perform reliably over extended periods (Lützhöft and Dekker, 2002).

Although modern vessels are equipped with advanced technologies such as sophisticated navigation systems, onboard data analytics tools, and bridge resource management systems, human factors continue to be a predominant cause of maritime accidents (Fan et al., 2020). Even in cases where accidents were initiated by automation failures, human error was found to be responsible for approximately 60% of such incidents (Pazouki et al., 2018). There is no evidence suggesting that reducing crew sizes on the bridge lowers the rate of individual errors. On the contrary, Aguiar et al. (2015) argue that increased mental workload onboard can negatively affect situational awareness.

Research indicates that the leading causes of ship collisions are predominantly linked to human factors. Safety investigation analyses covering the period from 2014 to 2022 revealed that 59.1% of accident events involved direct human actions, while 50.1% of contributing factors were associated with human behavior. When these elements are combined, human factors were implicated in 80.7% of the maritime casualties and incidents reviewed (EMSA, 2023). Although Wróbel (2021) contends that the widely cited estimate attributing 80% of maritime incidents to human factors remains unproven, data from studies by Ung (2018), Graziano et al. (2016), and Quin and Scott (1982) confirm that over 75% of accidents occurring between 1982 and 2016 were indeed related to human error.

Since its emergence in the 1990s, the concept of the “human factor” has been explored from multiple perspectives. Hollnagel (1998) posits that human errors cannot be directly observed but must be inferred indirectly by analyzing human behaviors, which are then evaluated against standardized criteria. Conversely, Baker and McCafferty (2005) offer a structured classification by dividing human behavior and error into four categories: skill-based, decision-based, perceptual, and violations, thereby providing a comprehensive framework for understanding their complexities.

While accident databases provide some basic information, detailed maritime accident investigation reports offer a far richer source of data. These reports delve into the navigational context, outline the chain of failures, consider environmental influences, identify both direct and indirect causes, and describe the actions taken during the incidents (Fan et al., 2018). Research and statistics consistently highlight that human errors—such as poor decision-making, ineffective resource management, failure to comply with regulations, skill-related mistakes, and communication lapses—are the

leading factors behind most maritime accidents (Çelik and Cebi, 2009; Fan et al., 2018; Yıldırım et al., 2019).

According to Hanzu-Pazara et al. (2008), key human factors leading to maritime incidents include crew fatigue, poor communication and coordination on the navigation bridge, and insufficient technical expertise. They also point out that lack of familiarity with the ship's systems, flawed automation design, and decisions made based on inadequate or incomplete information represent additional challenges requiring improvement. Hetherington et al. (2006) echo these concerns but group them into three intertwined categories: issues related to design, individual factors, and organizational or management shortcomings. Although "human factors" are often defined separately, it is frequently the case that a combination of several factors simultaneously contributes to accident occurrence (Corovic and Djurovic, 2013).

Hanzu-Pazara et al. (2008) states that fatigue, inadequate communication and coordination on navigational bridge, and inadequate technical knowledge are the main human factors. Also, inadequate knowledge of own ship system, poor design of automation and decisions based on inadequate information are other issues that should be enhanced. Hetherington et al. (2006) also emphasize the same factors but they defines these factors as three interwoven stages as- desing issues , personal issues and organizational and management issues. Although "human factors" are defined separately, it is often observed that multiple factors contribute to the causes of accidents Corovic and Djurovic (2013).

Various methods have been utilized by researchers to investigate and define the impact of "human factors" within the maritime industry. Comprehensive and detailed reviews on the application of human factor techniques in maritime transportation and the shipping sector have been provided by Shi et al. (2021) and Wu et al. (2022). Techniques such as HFACS (Human Factor Analysis and Classification System), THERP (Technique for Human Error Rate Prediction), SLIM (Success Likelihood Index Method), HEART (Human Error Assessment and Reduction Technique), CREAM (Cognitive Reliability and Error Analysis Method), SOHRA (Shipboard Operation Human Reliability Analysis), and SHERPA (Systematic Human Error Reduction and Prediction Approach) have been employed in numerous studies, including those by Celik and Cebi (2009), Martins and Matruna (2010), Chauvin et al. (2013), Abbasi et al. (2015), Akyuz and Celik (2015), Islam et al. (2016), Akyuz et al.

(2018), Ernstsen and Nazir (2018), Galieriková (2019), Ahn and Kurt (2020), Erdem and Akyuz (2021), Wróbel et al. (2021), and Maternová and Materna (2023).

The OCIMF has recognized the importance of "human factors" and, as mentioned earlier, integrated the assessment of bridge crew members' non-technical skills into the "Navigational Assessment and Audit" process within SIRE 2.0. The primary objective of this navigational assessment and audit is to detect substandard practices, improve navigational standards to ensure safe and efficient voyages, and provide assurance to companies that navigation and watchkeeping meet high-quality standards. With the introduction of SIRE 2.0, these evaluations now encompass an appraisal of personnel's non-technical skills as well (OCIMF, 2018). Beyond the expected training level and equipment, ship personnel are also required to demonstrate specific non-technical skills. According to the OCIMF (2018) guidelines—which are also referenced in our study—companies are advised to evaluate their staff's competencies in non-technical skills across at least seven key categories.

### **2.3 Navigational Assessment and Audit**

The term "audit" gained significant attention in the literature after the 1980s, coinciding with shifts in societal structures. As Power (2000) highlighted, this period marked the rise of a new social awareness emphasizing transparency, quality assurance, and accountability, which in turn fueled the widespread adoption of the "audit" concept.

With the increase in maritime transport volumes, regulatory frameworks in maritime trade have become increasingly vital. The growing magnitude of cargo and trade activities necessitates stricter inspection procedures to guarantee safety, protect the environment, and comply with international standards. These regulations are essential not only for securing trade operations but also for preserving marine ecosystems. In the realm of maritime transportation, the International Maritime Organization (IMO) serves as the key regulatory body fostering a culture of safety at sea. As a specialized agency of the United Nations, the IMO is responsible for improving the safety and security of global shipping while addressing vessel-related pollution issues. Furthermore, the IMO deals with legal matters such as liability, compensation, and the facilitation of international maritime traffic (IMO, 2024b).

IMO conventions must be transposed into national law to be applicable to ships flying a country's flag. This allows nations to effectively enforce port State control and meet their other responsibilities under the applicable IMO frameworks (IMO, 2024b).

An examination of research on maritime transportation safety regimes shows that Knapp and Franses (2010) conducted a descriptive analysis of safety regimes within the maritime sector and provided suggestions for their enhancement. Their study identified the key stakeholders involved in the safety regime established by three major organizations: the United Nations (UN), the International Maritime Organization (IMO), and the International Labour Organization (ILO).

Following the incorporation of the International Safety Management (ISM) Code into SOLAS, all stakeholders assumed responsibility for ensuring vessels implement a Safety Management System (SMS). Part A of the ISM Code specifies the requirements for developing Safety Management Systems, while Part B addresses certification and verification procedures.

By expanding regulatory responsibilities to include shore-based management, the ISM Code moved beyond the traditional emphasis on shipboard compliance. This evolution positioned the ISM Code as a comprehensive and effective framework for enforcing international maritime regulations (Demirci and Cicek, 2023).

In addition to the ISM Code, the International Maritime Organization (IMO) has put forward several key technical conventions that require vessels to be inspected when they arrive at foreign ports to confirm compliance with IMO regulations (Kamal and Altunışık, 2024). According to Article 94 of the United Nations Convention on the Law of the Sea (1982), flag States bear the responsibility to maintain effective oversight over their ships and operations, ensuring adherence to both national and international labor laws. However, competitive pressures between flag States and the delegation of regulatory duties to Recognized Organizations have weakened the enforcement capabilities of many flag registries.

To overcome these enforcement gaps, port State control (PSC) has emerged as the foremost system to monitor compliance with international standards and to protect coastal zones from the risks associated with substandard vessels (Bhatia et al., 2024). The way this inspection regime is applied can differ significantly depending on the enforcing authority. To harmonize inspection procedures and encourage regional

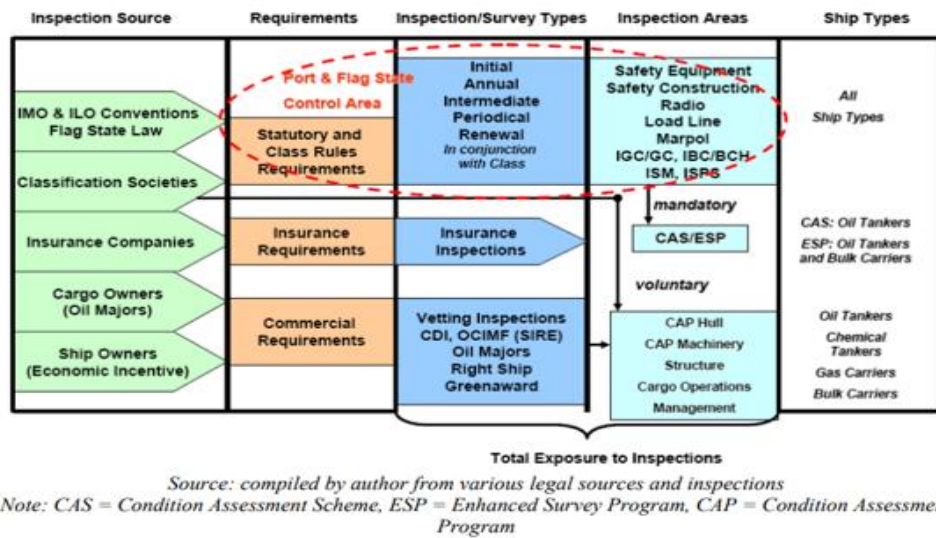
collaboration, several Memorandums of Understanding (MoUs) have been created since the establishment of the Paris MoU in 1982 (Hare, 1996; Graziano et al., 2018). The PSC framework has sparked considerable academic inquiry aimed at evaluating its effectiveness. A number of studies have investigated how well PSC functions and its conformity with the ISM Code (Bell, 1993; Plaza, 1994; Anderson, 2002; Meija, 2005). For example, Cariou et al. (2008) assessed the outcomes of 4,080 inspections conducted from 1996 to 2001, while Knapp and Franses (2007) examined a much larger sample of 183,819 inspections performed between 1994 and 2001 across different PSC regimes to determine regional variations. Moreover, Heij et al. (2011) utilized an extensive dataset of 400,000 inspection records to analyze the regime's effectiveness and identify areas for improvement.

It is evident that inspection practices in the maritime industry extend beyond port State control (PSC) alone. Inspection obligations can arise from multiple sources, including flag State inspections, audits under the International Safety Management (ISM) and International Ship and Port Facility Security (ISPS) Codes, as well as classification society surveys conducted either on behalf of flag States—acting through Recognized Organizations—or for the purpose of maintaining a vessel's classification status. Moreover, private entities such as Protection and Indemnity (P&I) clubs also carry out inspections to assess risks for insurance coverage.

In their research, Knapp and Franses (2010) provide a comprehensive overview of the various inspection types operating within the IMO framework. They also explore the hierarchy among these mechanisms and how they interrelate, as illustrated in Figure 2.1.

While Figure 2.1 provides a comprehensive overview of the components within the inspection regime, it is important to note that the majority of inspections are concentrated in the chemical and oil transport sectors, given the elevated risk profile of these operations. Vetting inspections mandated by industry organizations such as OCIMF and INTERTANKO play a dominant role, particularly for oil tankers, chemical tankers, gas carriers, and offshore vessels (Knapp and Franses, 2010). Grbic et al. (2018) examine the complex inspection landscape surrounding oil tankers, which are subject to a wide array of both mandatory and voluntary inspections, audits, and surveys initiated by multiple stakeholders—including port and flag States, Recognized Organizations, insurance providers, cargo owners, and the shipowners themselves.

Based on their analysis, oil tankers are typically exposed to 13 major inspections, as summarized in Table 2.1.



**Figure 2.1 :** Summary of inspection and audit components (Knapp and Franses 2010).

While numerous studies have explored the effectiveness of the 13 principal inspection types and proposed strategies for their enhancement (Hänninen and Kujala, 2014; Fan et al., 2014; Aydın et al., 2022), others have focused on leveraging inspection data to make predictive assessments regarding vessel performance and safety outcomes (Demirci and Cicek, 2022).

Beyond the aforementioned inspections, tankers, chemical carriers, and offshore vessels are also subject to Navigational Assessments and Audits—an oversight mechanism managed by OCIMF to ensure navigational safety. These audits, which form the core focus of this thesis, are designed to evaluate the competence of the vessel’s bridge team and examine their responses to a variety of operational scenarios, with the ultimate goal of preventing incidents or maritime casualties (Marine Safety Consultant, 2024).

The Nautical Institute (2019) describes a navigational assessment as a tool that will almost inevitably reveal deficiencies that must be addressed to safeguard not only the individual conducting navigation but also the entire crew. Serving as a vital supplement to the navigation-related components of the SIRE program, navigational assessments help verify bridge team performance and adherence to best practices.

OCIMF’s (2018) guidance document outlines the framework in detail, including the purpose of navigational assessments, the qualifications and expectations of the evaluator, implementation procedures, and the operational standards to be applied.

**Table 2.1 : Important inspections of tankers.**

Number	Inspection
1	PSC Inspection
2	Flag State Inspection
3	Annual Class Survey
4	ISM Code Audit
5	ISPS Code Audit
6	Insurance Survey
7	Vetting Inspections
8	Internal Audit
9	Green Award Inspection
10	MLC Audit
11	Internal MLC Audit
12	Internal ISM Code Audit
13	Internal ISPS Code Audit

**2.4 Overview on Literature Review**

This literature review undertook a thorough and critical examination of scholarly works addressing the historical development of maritime safety, as well as the investigation of maritime accidents and incidents, with a particular focus on identifying their underlying causes. The reviewed studies offer substantial insights into the systemic factors contributing to maritime accidents, propose various frameworks for improving safety, and emphasize the indispensable role of human factors in maintaining operational safety at sea.

Despite the breadth and depth of existing research on maritime safety, a clear gap emerges when attention is directed toward the specific area of *Navigational Assessment and Audit*, particularly in the context of tanker vessel operations. Apart from the operational guidelines issued by OCIMF, the academic literature is remarkably silent on evaluating the effectiveness, implementation practices, or impact of this safety mechanism. No empirical or analytical studies were identified that systematically assess its contribution to navigational safety.

This critical absence in the literature highlights a pressing research need and serves as the foundation upon which this thesis is constructed. By addressing this unexplored dimension, the present study aims to contribute original insight into the application

and operational relevance of navigational assessments, thereby enriching the discourse on maritime safety and supporting evidence-based improvements in navigational oversight.





### **3. METHODOLOGY**

The methodological framework of this study has been shaped by the foundational principles outlined in the OCIMF guideline, which served as the primary reference for conceptualizing the audit process. Drawing on the structure and key components presented in the guideline, a tailored model was developed to align with the specific objectives and scope of this research. This section begins with a concise overview of the OCIMF guideline, followed by a detailed exposition of the proposed model constructed for the purposes of this study.

#### **3.1 Navigational Assessment and Audit Guide**

##### **3.1.1 Introduction, scope and purpose**

A wide range of stakeholders in maritime transportation—including shipowners, cargo operators, port authorities, shipping agencies, maritime companies, insurance providers, and vessel crews—actively engage in implementing preventive strategies aimed at reducing the likelihood of accidents and operational disruptions. To ensure consistency and enforceability of these safety practices, international organizations such as the International Maritime Organization (IMO), International Labour Organization (ILO), European Union (EU), INTERTANKO, and OCIMF play a pivotal role in developing standardized frameworks and monitoring their application through regulatory oversight mechanisms.

Given the inherently high-risk nature of tanker transportation, the establishment, implementation, and continuous monitoring of rigorous safety and security standards pose significant challenges and financial burdens for industry stakeholders. In response to these complexities, the Oil Companies International Marine Forum (OCIMF) has assumed a leading role in defining safety protocols and promoting best practices for the effective management of tanker operations. To this end, OCIMF has introduced a range of programs designed to enhance safety and operational performance across the sector.

One such initiative is the Tanker Management and Self-Assessment (TMSA) program, which offers a structured framework for stakeholders to evaluate and improve their safety management systems. With the release of its third edition, *TMSA 3*, in April 2017, the program expanded its structure from 12 to 13 elements by incorporating a new focus area: *Maritime Security*. Among these 13 core elements, detailed in Table 3.1, *Navigational Safety* is listed as the fifth element and serves as the conceptual foundation for the *Navigational Assessment and Audit* mechanism. This mechanism, which is central to the present thesis, outlines stakeholder responsibilities and performance expectations related to navigational safety.

**Table 3.1 : Key elements.**

Nu.	Key Elements
1	Leadership and the safety management system
2	Recruitment and management of shore-based personnel
3	Recruitment, management, and wellbeing of vessel personnel
4	Vessel reliability and maintenance including critical equipment
5	Navigational safety
6	Cargo, ballast, tank cleaning, bunkering, mooring and anchoring operations
7	Management of change
8	Incident reporting, investigation, and analysis
9	Safety management
10	Environmental and energy management
11	Emergency preparedness and contingency planning
12	Measurement, analysis, and improvement
13	Maritime security

While the Captain bears ultimate responsibility for navigational safety aboard the vessel, the International Safety Management (ISM) Code mandates that companies establish and maintain robust safety standards. In this framework, the *Navigational Assessment and Audit* process serves as a critical instrument enabling shipowners, operators, and masters to systematically identify areas requiring improvement and thereby enhance navigational safety (OCIMF, 2018).

Prior to the promulgation of a standardized implementation guide, practices related to navigational assessments exhibited significant variability across organizations. To rectify this disparity, OCIMF issued the *Navigational Assessment and Audit Guide* in 2018, concomitant with the publication of TMSA 3. The guide specifically targets companies, relevant personnel, and masters, aiming to rigorously evaluate the proficiency of bridge team members during navigation, standby, and pilotage operations.

In pursuit of the three primary objectives outlined above, the assessment framework is fundamentally structured around two core domains: technical skills and non-technical skills. Within the technical skills evaluation, assessors systematically appraise the bridge team members' proficiency in regulatory compliance, adherence to company procedures, and mastery of navigational regulations. Conversely, the non-technical skills assessment focuses on evaluating the capabilities of all team members in areas such as effective teamwork, stress management, and response to emergency situations. Throughout this process, assessors place particular emphasis on a range of critical non-technical competencies, including but not limited to the following:

- Situational awareness
- Decision-making
- Communication
- Teamwork
- Leadership
- Coping with stress
- Coping with fatigue.

### **3.1.2 Structure**

Navigational safety is frequently conceptualized narrowly as the secure execution of maritime operations during a vessel's passage at sea. However, this guide broadens that perspective by emphasizing that navigational safety must be ensured from the very outset of a vessel's journey, beginning in port. To provide a comprehensive and rigorous evaluation of navigational performance, the guide prescribes a bifurcated assessment approach, encompassing both Static and Dynamic components, thereby facilitating a thorough and integrated framework for navigational assurance.

**Static Assessment:** This phase, predominantly conducted while the vessel remains berthed, encompasses the critical preparatory activities essential for safe navigation. It involves a meticulous evaluation of the voyage plan's accuracy, the adequacy and currency of navigational charts, the operational status of bridge equipment, as well as the thoroughness of relevant documentation and record-keeping. Moreover, this assessment rigorously examines compliance with the company's prescribed policies

and procedures. The Static Assessment is systematically divided into four principal components: Company Policy, Passage Planning, Bridge Equipment, and Forms and Checklists, each integral to ensuring a robust foundation for navigational safety.

Dynamic Assessment: This phase primarily concentrates on assessing the bridge team's operational competencies during active navigation, with particular emphasis on their coordination, stress resilience, and the effective execution of pilotage maneuvers. The evaluation framework is further delineated into seven distinct components: Company Policy, Bridge Team Organization, Duties, General Navigation, Passage Planning, Utilization and Comprehension of Bridge Equipment, and Pilotage. Each sub-component plays a crucial role in providing a comprehensive appraisal of the team's performance under dynamic conditions.

Each item within these sections consists of binary "Yes/No" questions, often accompanied by auditor comments designed to provide constructive feedback to the company and support the continuous improvement of subsequent inspections.

### **3.1.3 Template**

Within the auditing of an institution, organization, or operational system, it is paramount to precisely articulate the audit's objectives, scope, and methodologies. However, the cornerstone of a rigorous audit process fundamentally lies in the meticulous development of checklists, which serve as essential instruments to guide and standardize the evaluation. In this context, the OCIMF guideline furnishes a comprehensive and methodically structured template, facilitating organizations in designing and executing their audit procedures with enhanced consistency and effectiveness. This template is systematically divided into three core sections, as shown in Figure 3.1, encompassing:

- Navigational Assessment Report: Includes assessment data and summary
- Part A: Static Assessment Template
- Part B: Dynamic Assessment Template.

This guide serves as a fundamental reference for conducting the *Navigational Assessment and Audit*, a vital framework aimed at enhancing navigational safety. It offers a standardized yet adaptable structure that maritime stakeholders—including companies—can employ to establish and refine their navigational oversight practices.

Navigational assessment report					
Vessel		Voyage number			
Dates of assessment					
From		To			
Trading pattern					
From		To			
Staff on board during assessment					
Rank	Name	Nationality	Time in Rank	Time with Company	Time on Board
Master					
Chief Officer					
2nd Officer					
3rd Officer					
Extra					
Chief Engineer					
2nd Engineer					
Operations assessed (if tick all boxes that apply)					
Channel/straits	Pilotage	Coastal	Deep sea		
Berthing	Unberthing	Anchoring	STS operations		
In port	Restricted visibility				
Assessment conducted by					
Company Superintendent					
Date of assessment review in office					
Date of action items agreed					
Date of assessment closure					
Assessment summary					

Part A: Static assessment template				
Section 1 - Company Policy				
ID	Question	Y	N	Assessor's Comments
1.01	Does the company have robust and detailed navigational policies and procedures? <i>The company should have a set of detailed navigational policies and procedures. The procedures should include references to appropriate industry standards, including the ICS Bridge Procedures Guide. If the navigational policies and procedures are provided in electronic format only, then a back-up, independent power supply to the computer is to be provided. An up-to-date copy of the company's navigation policy and procedures should be available on the bridge and the bridge team should be familiar with the contents.</i>			
1.02	Have all non-conformances from previous assessments been closed out effectively? <i>Previous assessments should be reviewed and any outstanding non-conformances should be checked during the assessment. Any items from previous assessments that require reevaluation should be checked. Previous assessments may include company assessments, the Master's assessment and third-party inspections such as SIRE.</i>			

Part B: Dynamic assessment template				
Section 1 - Company Policy				
ID	Question	Y	N	Assessor's Comments
1.01	The Master applies overriding authority and responsibility effectively. <i>The Master has overriding authority and responsibility to make decisions about safety, security and pollution prevention. The Master should not be constrained in any way or by any party from taking any decision which, in their professional judgement, is necessary for safe navigation. The decision-making process should be based on human factors, including:</i> <ul style="list-style-type: none"> <li>• Communications with the bridge team. The Master should ensure that all communications are clearly understood and should be open to dialogue and challenge.</li> <li>• Situational awareness. The Master should have complete awareness of all bridge team activities and be able to distinguish the finer points from the overall picture. Input from all should be welcomed.</li> <li>• Ensuring that the team is neither over-pressured, nor complacent – both lead to mistakes. In addition, the team should not be fatigued or distracted.</li> <li>• Ensuring that best practice is followed at all times. The Master should lead by example. This includes understanding the team's various experience levels and training, coaching and mentoring members as applicable. Cutting corners is strongly discouraged.</li> <li>• Promoting teamwork and a strong safety culture.</li> </ul>			

**Figure 3.1** : Template of best practice guide (OCIMF, 2018).

Although the guide predominantly relies on binary Yes/No questions to evaluate the effectiveness of the vessel's navigational management system, it is essential to complement this qualitative approach with a robust quantitative evaluation. Objective measurement is critical to accurately determine the extent to which specific standards are satisfied during an audit.

Recognizing this gap, we developed a tailored model inspired by the OCIMF framework that systematically assigns quantitative values to each audit criterion. This novel quantified audit model is intended to provide a more precise, transparent, and actionable assessment of navigational performance.

## 3.2 Our Quantified Audit Model

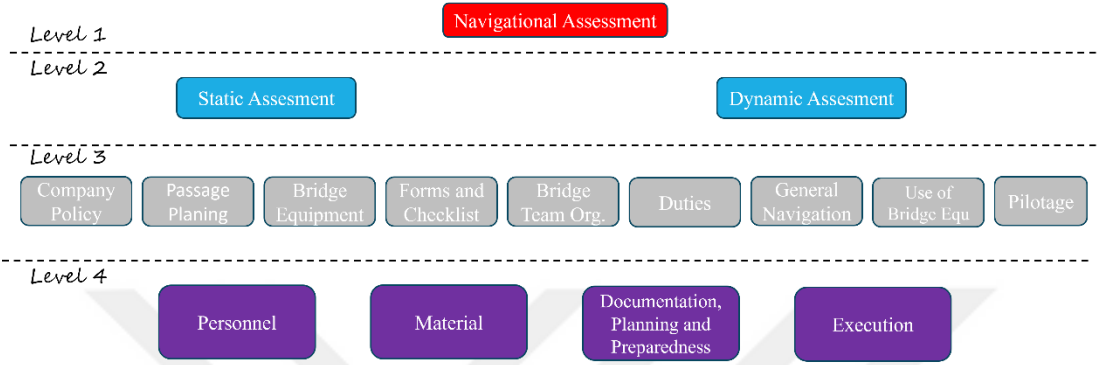
### 3.2.1 Taxonomy

Auditing a unit against established international standards serves to measure the degree of conformity with those benchmarks. Nevertheless, the selection of specific standards critically determines the relevance and applicability of the audit outcomes to the operational realities of the sector being evaluated.

In order to produce navigational assessment and audit reports that are comprehensive, precise, objective, and clearly interpretable for end users, we propose a novel quantified navigational assessment and audit model. While our model draws conceptual inspiration from the existing *Guide to Best Practice for Navigational*

*Assessments and Audits*, it distinguishes itself through the introduction of a distinct analytical framework.

Our approach is anchored in the guide’s original bipartite structure; however, we have extended this framework by incorporating an additional hierarchical level, resulting in a four-tier taxonomy as illustrated in Figure 3.2.



**Figure 3.2 :** Taxonomy of proposed model.

The initial three levels of our proposed model correspond closely with the structural framework presented in the guide. However, a distinctive feature of our approach is the introduction of a fourth hierarchical dimension. While acknowledging that ship inspections traditionally rely on discrete checklist items, we posited that these items may be grouped under broader thematic categories that encapsulate their fundamental purpose. Upon detailed analysis of the inspection questions outlined in the guide, it became apparent that the accompanying remarks often fall short of accurately pinpointing the critical areas of concern on board. For instance, within the same subsection of "Company Policy," the two questions illustrated in Table 3.2 clearly embody divergent implications for both the audit process and the organizational dynamics of the bridge team.

**Table 3.2 :** Two different questions in “Company Policy” subpart.

Q.Nu.	Question
A.1.07	Are essential/critical systems tests being carried out as per company requirements?
A.1.12	Are bridge manning levels being maintained as per company requirements?

It is clearly evident that while the first question pertains to material preparation, the other addresses personnel-related matters. In this case, to derive more meaningful results from the inspection, these items should not be evaluated together under the

same category. To address this, we proposed associating each question with one of the main categories: "Personnel," "Material", "Documentation, Planing and Preparedness" and "Execution". In many NATO member states, particularly within the Turkish Navy, the combat readiness of warships is assessed through a structured inspection program. These inspections evaluate ships under three core areas: personnel, training, and material readiness. Based on the findings, deficiencies are identified and areas for improvement are determined. This study proposes that the same auditing framework used for naval vessels can be applied to tanker ships. Therefore, Level 4 of the taxonomy has been defined to include these assessment categories.

### 3.2.2 Checklists

In designing the checklists that form the foundation of the inspection process, we adhered to the core question structure outlined in the guide to maintain alignment with industry standards. As illustrated in the Table 3.3, the checklist comprises two main parts and a total of 11 sub-parts.

**Table 3.3** : Checklist scheme of proposed model.

Part	Sub_Part	Total Questions
Static Assessment	Company Policy	15
	Passage Planning	10
	Bridge Equipment	29
	Forms and Checklist	7
Dynamic Assesment	Company Policy	16
	Bridge Team Organization	11
	Duties	14*
	General Navigation	33*
	Passage Planing	6
	Use and Understanding of Bridge Equipment	10
	Pilotage	8

\* *More than best practice guide.*

The OCIMF guide was instrumental in shaping the foundational structure of our assessment questions; however, we adopted a distinctly outcome-driven approach in their detailed formulation. Given that navigational inspections inherently involve the entire bridge team as the focal point, it was essential to ensure that each query could be evaluated across all watch rotations. Since maritime operations typically follow a three-watch system, certain questions necessitate independent responses for each

watch segment. To accommodate this operational reality, we refined the questions by integrating specific sub-questions, each introduced by the phrase “When the ... Officer is the Officer on Watch (OOW).” For example, the initial item within the Dynamic Assessment’s Passage Planning section—“The passage plan is effectively monitored and executed”—pertains universally to all watchkeeping personnel. Consequently, this general query was expanded into tailored sub-questions addressing the distinct responsibilities of each watch officer, ensuring comprehensive and contextualized assessment.

Following the establishment of these detailed questions, the subsequent imperative was to systematically classify them within overarching thematic categories. While individual checklist items possess discrete relevance, their aggregation within shared categories often uncovers varied underlying issues. As previously noted, questions relating to the operability of equipment versus crew familiarity with those systems—although grouped under the same category—represent inherently different operational dimensions. To capture this complexity, we organized the evaluated activities of the crew into four principal categories defined by their domain of influence: “Personnel,” “Material,” “Documentation, Planning, and Preparedness,” and “Execution.” This taxonomy facilitates a granular diagnosis of operational shortcomings; for instance, should weaknesses be identified in passage planning, the model allows differentiation between knowledge gaps among personnel, deficiencies in procedural documentation, or lapses in the practical execution of tasks.

It is also important to highlight that certain operational topics intrinsically do not align with every category. For instance, the subject of “Forms and Checklists” is exclusively procedural and thus excludes personnel-related inquiries, resulting in an absence of questions under the “Personnel” category within this domain.

### **3.2.3 Weight determination**

The audit process can be executed using the question framework we have developed; however, this methodology inherently presumes that all checklist items carry equal weight. Although this assumption is not fundamentally erroneous, it fails to accurately represent practical realities within maritime operations. For example, the absence of a critical document does not equate in severity to an inadequate bridge manning level. Likewise, the navigational risk posed by a faulty radar system far exceeds that of

missing binoculars. Consequently, it becomes imperative to assign relative importance to each audit criterion, while maintaining coherence and rationality in the evaluative process. To address this, we employ a weighting system as outlined in Table 3.4, enabling a more nuanced and realistic appraisal of navigational safety factors.

**Table 3.4 : Weight definition.**

Weight	Definition
5	Critically Important
4	Important
3	Moderate
2	Low
1	Very Low

Establishing the relative significance of individual questions enhances the practical relevance of the audit. Nonetheless, presuming that each inspection category holds equal importance, similar to the assumption made for individual questions, would misrepresent operational realities. For instance, the absence of required forms does not exert the same influence on safety as deficiencies in core navigational practices. Therefore, it is essential to extend the weighting methodology to the broader inspection categories as well. These category-level weightings have been systematically determined through consultations with subject matter experts to ensure their validity and applicability.

### **3.2.4 Non-technical skills (Human factor)**

The evaluation of the human factor, recognized as a predominant contributor to maritime incidents, has gained enhanced prominence with the implementation of SIRE 2.0 inspections. Moreover, assessing this human element constitutes a fundamental objective within the framework of the Navigational Assessment and Audit. To address this imperative, we have devised an innovative approach that extends beyond the scope of the existing OCIMF guide.

As previously noted, navigation is inherently a dynamic activity involving distinct roles for each crew member, which necessitates that many assessment questions be applied across all watch shifts. Consequently, we have elected to analyze the responses to inspection questions as an indicator of individual and collective competence among personnel.

In this study, we systematically review each of the 160 checklist items, isolating those questions pertinent to the seven non-technical skills identified by the guide. The subset of questions relevant for the quantification of non-technical skills is detailed and categorized in Table 3.5.

**Table 3.5 :** Total questions of non-technical skills.

Non-Technical Skills	Total Questions
Situational Awareness	14
Decision-making	3
Communication	4
Teamwork	11
Leadership	11
Coping with Stress	1
Coping with Fatigue	3

The competencies of watch officers in key non-technical skill areas are assessed based on their answers to specific inquiry items. This assessment provides insight into each officer’s individual capabilities and enables meaningful comparisons across different personnel.

**3.2.5 Evaluation**

This section outlines the methodology by which auditors will evaluate each item and the nature of data generated from this process. A particular emphasis is placed on the numerical scoring system, which constitutes a key advancement of our proposed model in comparison to the existing guideline. Auditors will commence their assessment by systematically addressing each question in the checklist, applying the quantitative rating scale detailed in Table 3.6.

**Table 3.6 :** Score definitions.

Score	Evaluation
0-30	Very Poor
30-50	Poor
50-70	Weak
70-80	Standard
80-90	Good
90-95	Very Good
95-100	Excellent

In this section, we explain in detail how our weighted calculation model has been constructed and how the resulting score has been determined based on this model.

Sets, indices and parameters as;

$i \in I$	: Set of parts	( <i>Static Assessment, Dynamic Assessment</i> )
$j \in J$	: Set of sub-parts	( <i>11 sub-parts, 4 Static-7 Dynamic</i> )
$J_i \subset J$	: Set of sub-parts $i, i \in I$	( <i>Sub-parts of each part i</i> )
$k \in K$	: Set of sections	( <i>Personnel, Material, Documentation, Execution</i> )
$w_{ijk}$	: Weights of section $k$ of sub-part $j$ of part $i$	
$s_{ijk}$	: Score of section $k$ of sub-part $j$ of part $i$	
$d_i$	: Numerical evaluation of part $i$	
$p_i$	: Final weights of part $i$	
$E$	: Final Evaluation	

So, score of part  $i$  as stated in equation (3.1);

$$d_i = \sum_j \sum_k \frac{s_{ijk} * w_{ijk}}{\sum w_{ijk}} \quad (3.1)$$

Final evaluation as in equation (3.2);

$$E = \sum_i \frac{d_i * p_i}{\sum p_i} \quad (3.2)$$

In addition to obtaining numerical results, we aimed to assign each vessel a letter grade, shown in Table 3.7, following the audit and maintain this information in the records. This approach seeks to provide the auditing company with a standardized assessment of its fleet's condition while also encouraging personnel to strive for achieving the highest letter certification. For example, a vessel that receives a score of 77 in the audit will be assigned a "C" certification based on the audit results.

**Table 3.7 : Grades.**

Score	Grade
0-30	F
30-50	E
50-70	D
70-80	C
80-90	B
90-95	A
95-100	A+



## **4. CASE STUDY**

This study theoretically proposes a novel at-sea assessment methodology specifically designed for tanker vessels, aimed at enhancing navigational safety in maritime transport. To evaluate the practical relevance and effectiveness of this framework in real-world conditions, the model is applied to a tanker that has recently undergone an inspection.

The names of the company and the vessel that supported the fieldwork of this thesis have been anonymized in accordance with the company's confidentiality policies.

Supporting this applied research, the company assists in determining the weighting factors for each item on the inspection checklist, facilitating the application of the model through certified inspectors, and providing comprehensive feedback on the results.

The model's deployment is structured into three primary stages. Initially, coordination meetings with company officials are conducted to introduce the assessment framework and establish consensus on its implementation procedures. Subsequently, authorized inspectors conduct a thorough review of the checklist items, assigning appropriate weightings to each. In the final application phase, the refined model is utilized on the vessel by two certified inspectors.

The process concludes with an evaluative meeting involving company representatives to analyze and interpret the data obtained during the application. The following sections offer a detailed explanation of each stage within this implementation process.

### **4.1 Development of Checklists and Model Implementation**

Meetings aimed at defining the applicable assessment model and integrating inspectors' field experience resulted in the identification of the checklists incorporated within the framework. The development of these checklists primarily relied on company manuals, which are aligned with current maritime regulations, as well as the operational dynamics of maritime navigation and the practical expertise of personnel.

The quantity and categorization of the checklist items included in the finalized model are presented in Table 4.1.

**Table 4.1 : Questions.**

Part	Sub_Part	Main Questions	Total Questions
Static Assessment	Company Policy	15	141
	Passage Planning	10	24
	Bridge Equipment	29	97
	Forms and Checklist	7	22
Dynamic Assessment	Company Policy	16	64
	Bridge Team Organization	11	64
	Duties	14	52
	General Navigation	33	191
	Passage Planing	6	15
	Use and Understanding of Bridge Equipment	10	41
	Pilotage	8	12

In addition to the identification of a total of 723 questions, 7 critical control items that aim to reveal the non-technical skills of ship personnel are also determined. The distribution of these critical items is presented in the Table 4.2.

**Table 4.2 : Distribution of non-technical skills checklist**

Non-Technical Skills	Main Questions	Total Questions
Situational Awareness	14	34
Decision-making	3	10
Communication	4	4
Teamwork	11	12
Leadership	11	11
Coping with Stress	1	1
Coping with Fatigue	3	8

Although we used checklists consisting of the number of questions presented in Table 4.1 and Table 4.2, companies or stakeholders that adopt this model approach may create their own checklists with a different number of questions based on their own policies.

Following the identification of the key inspection areas and their corresponding checklists, the weighting of each checklist item was established through a survey conducted with a panel of 12 participants, all of whom are captains and inspectors employed by the company.

Furthermore, based on the insights gathered and the content of the checklists, it was recognized that the static and dynamic inspection phases should not be equally weighted. Therefore, alongside the individual checklist items, the weights assigned to the static and dynamic phases, including their respective subcategories, were also determined. These weightings are detailed in Table 4.3.

**Table 4.3 : Parts and sub\_parts weights.**

Part	Part Weight	Sub_Part	Sub_Part Weight
Static Assessment	40	Company Policy	20
		Passage Planning	30
		Bridge Equipment	40
		Forms and Checklist	10
Dynamic Assessment	60	Company Policy	10
		Bridge Team Organization	20
		Duties	15
		General Navigation	25
		Passage Planning	10
		Use and Understanding of Bridge Equipment	15
		Pilotage	5

The developed weighted assessment model was applied onboard the vessel during both berthing and sea passage phases over a three-day period by two authorized inspectors from the Company. Throughout the implementation, the ship’s command and bridge team—including the master and three watchkeeping officers—as well as the deck crew, were evaluated using the model.

This assessment was carried out under actual operational conditions to verify the model’s practical applicability and its alignment with routine navigational and safety operations. The participation of both senior and junior deck personnel allowed for a thorough evaluation of onboard safety protocols, bridge resource management, and adherence to international maritime safety regulations.

## 4.2 Results

Before analyzing the collected data, a comprehensive evaluation of the model’s applicability was conducted. During a debriefing session with the inspectors following the field application, it was reported that the model proved to be practical and feasible for use in operational environments.

The inspectors highlighted that the model incorporated essential factors influencing navigational safety, aligning with the guidelines set forth by the International Maritime Organization (IMO) framework and the International Safety Management (ISM) Code. They further noted that, beyond serving as a compliance and monitoring instrument, the model facilitated just-in-time training and raised awareness among the ship’s crew, particularly concerning safe navigation practices and operational risk management.

Moreover, the inspectors suggested that the model’s effectiveness could be enhanced by integrating a user-friendly digital interface. Utilizing tablet devices to perform the checklist-based evaluations was seen as a promising approach to improve both the efficiency and accuracy of the assessment process, minimizing time requirements while enabling real-time data capture and analysis.

**4.2.1 Technical skills**

The analysis of the implementation outcomes yielded an overall evaluation score of 86.019 for the vessel, which corresponds to a Grade B (GOOD) according to the rating criteria specified in Table 4.4. This score denotes a satisfactory degree of compliance with the prescribed safety and operational performance standards.

**Table 4.4 : Score definition.**

Score	Grade
0-30	F
30-50	E
50-70	D
70-80	C
80-90	B
90-95	A
95-100	A+

Although the score reflects a robust adherence to established navigational protocols and procedural requirements, it concurrently underscores the existence of domains with scope for further enhancement. The grading was calculated through a weighted scoring methodology that systematically incorporated both critical safety indicators and recognized best practices, thereby aligning with internationally endorsed maritime safety frameworks.

Following the determination of the final score, a more granular analysis was conducted based on the taxonomy delineated in Section 3.2.1 and visually represented in Figure

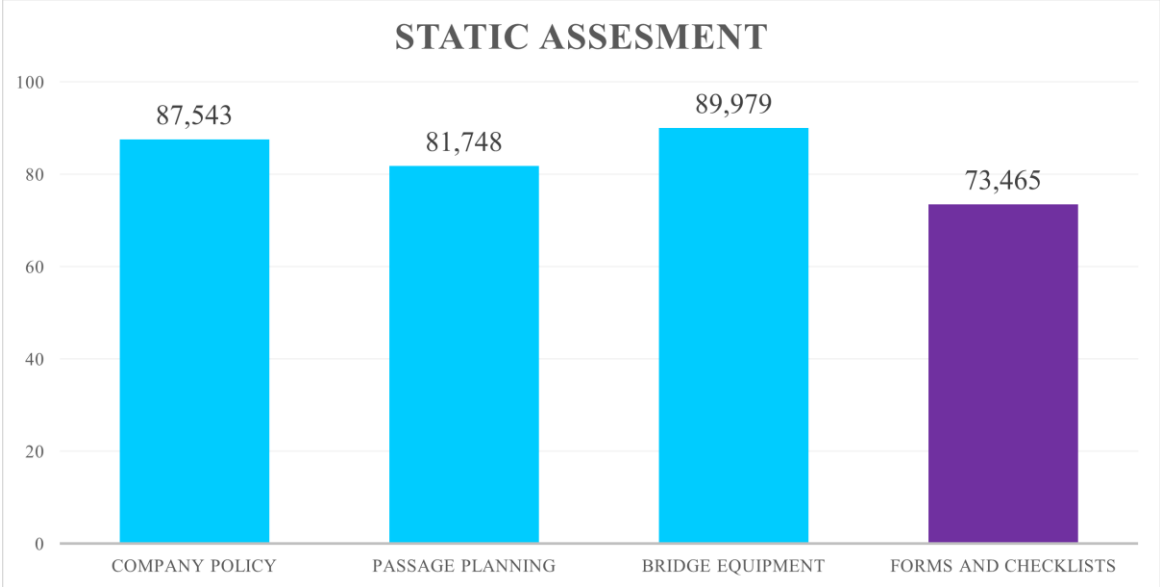
3.2. Within this analytical structure, the detailed assessment outcomes pertaining to Levels 2 and 3 of the evaluation hierarchy are comprehensively presented in Table 4.5. The results demonstrated that the vessel’s static assessment score (85.371) and dynamic assessment score (86.451) exhibited no statistically significant difference. This minimal variance indicates a consistent performance level across both static parameters—encompassing procedural compliance, documentation accuracy, and structural preparedness—and dynamic factors, such as operational conduct, crew responsiveness, and real-time situational management. The close correspondence between these scores reflects a balanced and cohesive application of safety and operational standards during both routine preparedness and active navigational operations.

**Table 4.5 : Parts and sub\_parts results.**

Part	Part Scores	Part Weight	Sub_Part	Sub_Part Scores	Sub_Part Weight
Static Assessment	85,371	40	Company Policy	87,543	20
			Passage Planning	81,748	30
			Bridge Equipment	89,979	40
			Forms and Checklist	73,465	10
			Company Policy	83,065	10
Dynamic Assesment	86,451	60	Bridge Team Organization	84,410	20
			Duties	86,563	15
			General Navigation	84,180	25
			Passage Planing	93,511	10
			Use and Understanding of Bridge Equipment	89,721	15
			Pilotage	88,471	5

A comprehensive review of the static assessment identified “Bridge Equipment” as the strongest element within bridge organization, while “Forms and Checklists” emerged as the weakest area necessitating targeted attention and improvement, as depicted in Figure 4.1.

This finding underscores a notable deficiency among shipboard personnel in the preparation and upkeep of essential documentation, in line with established maritime regulatory requirements. Such shortcomings point to lapses in procedural adherence and record-keeping practices, which may adversely impact the vessel’s overall safety management system. Therefore, fostering enhanced awareness and competency regarding regulatory documentation protocols is crucial to reinforce the administrative foundations that support onboard safety.

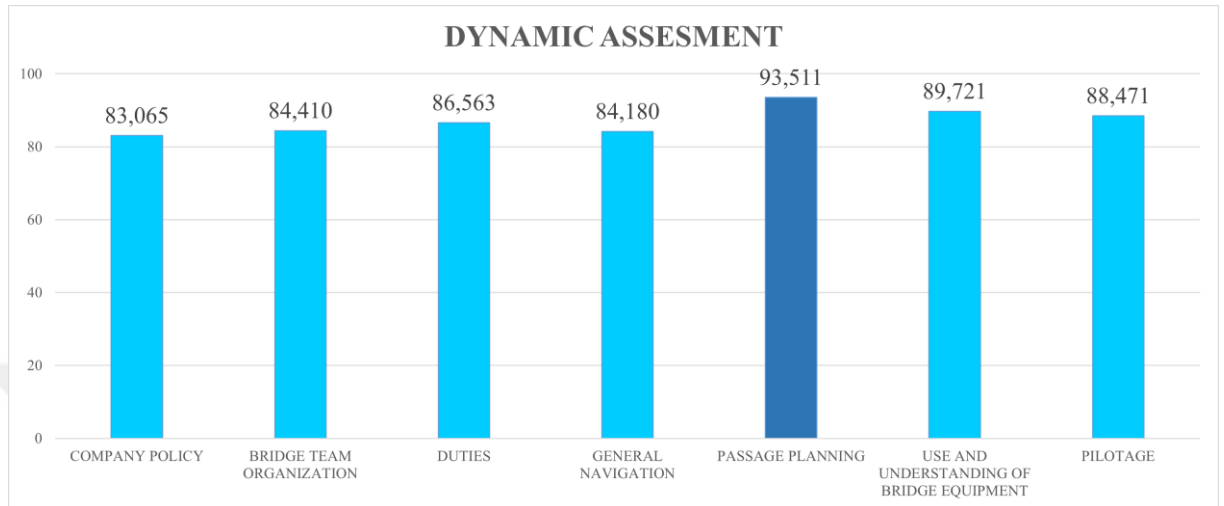


**Figure 4.1 :** Static assesment results.

An in-depth evaluation of the dynamic assessment identified “Passage Planning” as the most proficient area within the bridge team’s performance. Although other dynamic components exhibited relatively uniform competency levels, adherence to “Company Policy” was comparatively weaker, as demonstrated in Figure 4.2.

This disparity suggests that, while the crew effectively conducted passage planning in alignment with established navigational standards and best practices, there was a noticeable shortfall in their understanding and implementation of the company’s specific policies during navigation. This reveals a critical gap in embedding corporate operational guidelines into the bridge’s real-time decision-making processes. Addressing this gap through targeted training and reinforcement of internal policy awareness is essential to enhance compliance and cultivate a stronger safety culture onboard.

Building upon the analyses conducted at Levels 2 and 3 of the model taxonomy, attention was directed toward Level 4, which systematically examines the dimensions of Personnel, Material, Documentation–Planning–Preparedness, and Execution within both static and dynamic assessment frameworks.

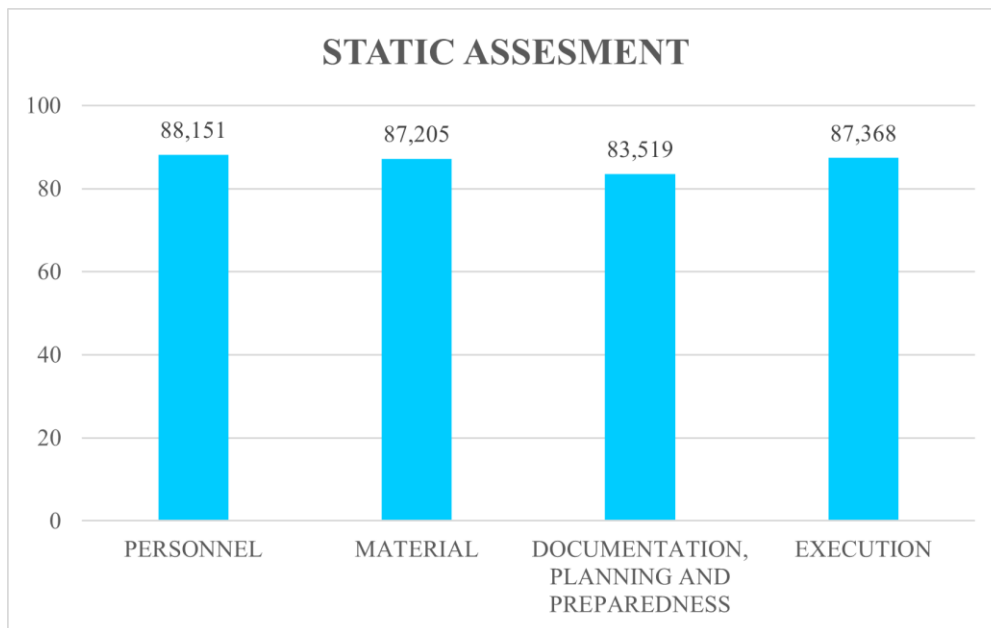


**Figure 4.2 :** Dynamic assesment results.

The static evaluation at this level corroborated earlier observations from Level 3, revealing a coherent pattern wherein the four core components demonstrated closely aligned scores. Notably, “Documentation” was identified as the most deficient domain, echoing the previously detected weakness in “Forms and Checklists,” as depicted in Figure 4.3.

This convergence of findings accentuates a pronounced need for comprehensive remedial interventions targeting the documented inadequacies, particularly in areas relating to documentation fidelity, voyage planning rigor, and navigational preparedness. Such deficiencies suggest systemic lapses in adherence to procedural protocols and highlight vulnerabilities in the administrative infrastructure supporting safe navigation.

Consequently, these results underscore the imperative to fortify compliance mechanisms, elevate the precision and accessibility of operational records, and rigorously align navigational planning processes with both the stringent mandates of international maritime legislation and bespoke company standards. Advancing these dimensions is essential not only for safeguarding navigational integrity but also for optimizing the vessel’s overall operational resilience and safety culture.



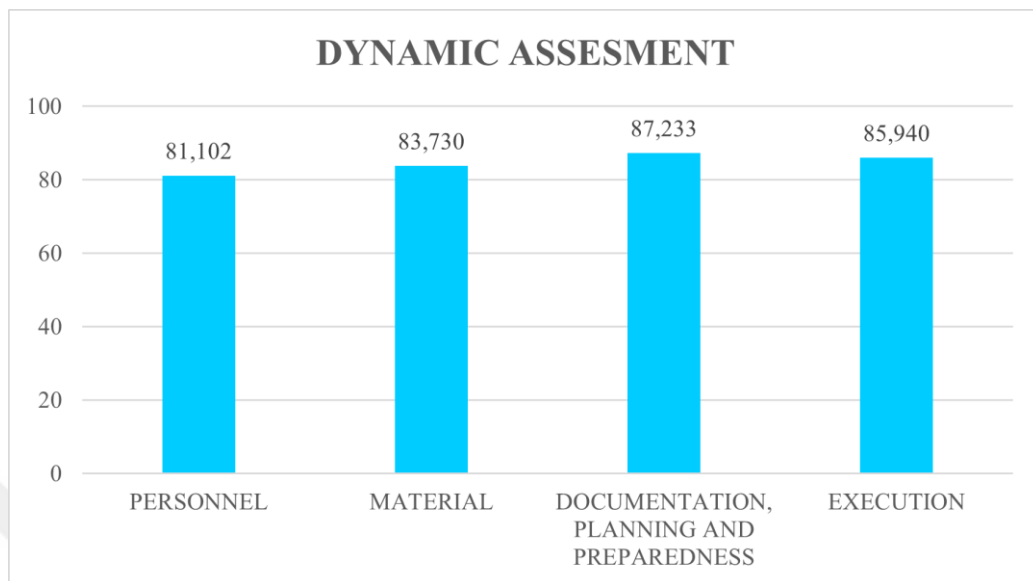
**Figure 4.3 :** Static assesment level 4 results.

A comprehensive examination of the Level 4 outcomes derived from the dynamic assessment, as depicted in Figure 4.4, reveals a notable shift in the highest-performing domain compared to the static assessment. Specifically, "Documentation, Planning, and Preparedness" emerges as the most proficiently managed area in the dynamic context. While this discrepancy may initially seem considerable, it is consistent with the findings from the Level 3 assessment, which indicated a heightened awareness and adherence to procedural and regulatory standards, particularly in relation to documentation practices and record-keeping procedures within the bridge team.

Nevertheless, the dynamic assessment also emphasizes the critical need for targeted interventions to enhance the operational proficiency of personnel engaged in navigational duties. This is crucial for ensuring the sustained effectiveness and safety of bridge operations, especially in real-time navigation scenarios where the ability to respond promptly and effectively is paramount.

In summary, the findings pertaining to non-technical skills highlight distinct discrepancies between the static and dynamic assessment outcomes. The static assessment, which primarily focuses on port operations and pre-voyage preparations, identifies gaps in the bridge team's performance in areas such as the implementation of forms, checklists, and documentation procedures. On the other hand, the dynamic assessment, conducted during active navigation, points to the necessity of a more thorough evaluation of crew competencies. This approach would facilitate the

identification of specific performance gaps and guide the development of corrective measures aimed at ensuring both the safety and efficiency of navigational operations.



**Figure 4.4 :** Dynamic assesment level 4 results.

#### **4.2.2 Non-technical skills**

Within the context of the applied model, the evaluation of non-technical skills was conducted by systematically assessing the competence of the bridge team's organizational structure, in accordance with the standards delineated in the STCW Code (Section A-VIII/2) and established Bridge Resource Management (BRM) principles. Concurrently, the methodology facilitated a targeted analysis of human factors, utilizing carefully selected items extracted from standardized checklists specifically tailored to reflect the operational context of the vessel.

This evaluation encompassed a thorough assessment of human factor competencies in critical areas such as situational awareness, decision-making, communication, teamwork, leadership, stress management, and fatigue management. The analysis involved the ship's master and three watchkeeping officers, ensuring a holistic representation of the bridge team's operational effectiveness.

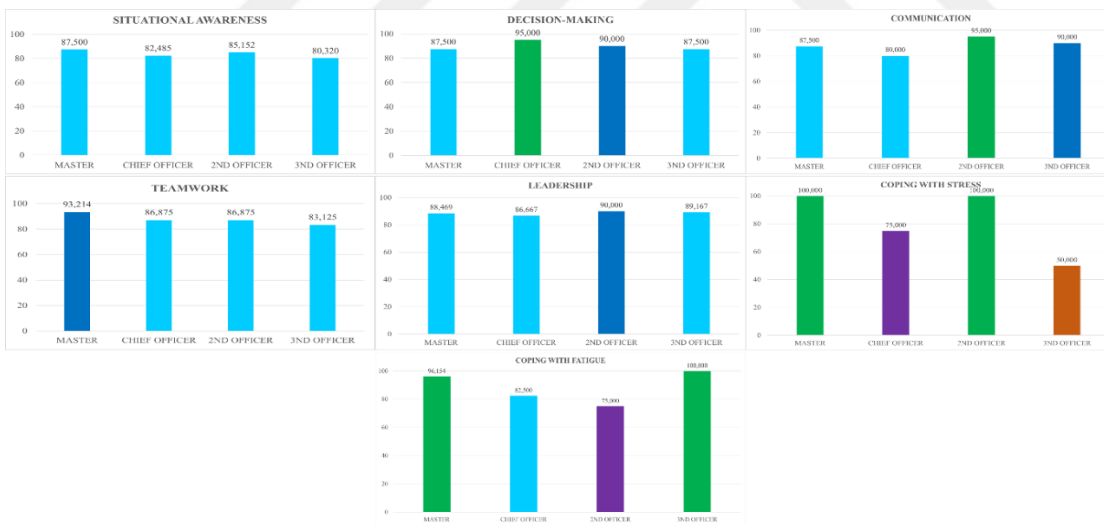
The results presented in Table 4.6 provide a detailed, individual assessment of each officer's human factor competencies. These findings not only underscore the relative strengths and weaknesses demonstrated by each officer across the various domains of non-technical skills, but also offer a nuanced understanding of how individual performance influences the collective dynamics of bridge operations.

**Table 4.6 : Non-technical results.**

Officer	Situational Awareness	Decision Making	Comm.	Teamwork	Leadership	Stress	Fatigue
Master	87,500	87,500	87,500	93,214	88,469	100,000	96,154
Chief Officer	82,485	95,000	80,000	86,875	86,667	75,000	82,500
2nd Officer	85,152	90,000	95,000	86,875	90,000	100,000	75,000
3th Officer	80,320	87,500	90,000	83,125	89,167	50,000	100,000

A detailed analysis of the results indicates that, in five out of the seven assessed domains, no significant differences were observed among the officers. However, in the domains of "Coping with Stress" and "Coping with Fatigue" substantial disparities in performance were evident, as presented in Figure 4.5.

Specifically, the 3rd Officer exhibited noticeable challenges in managing stress, while their ability to cope with fatigue appeared to be within acceptable limits. Furthermore, the results showed that the 2nd Officer consistently outperformed the Chief Officer across all assessed domains, with the exception of fatigue management.



**Figure 4.5 : Individual results of non-technical skills.**

These discrepancies suggest the presence of potential operational risks, particularly in high-pressure situations where stress resilience is critical for maintaining situational awareness and making sound decisions. The observed deficiencies in stress management may compromise the officers’ capacity to respond effectively in critical scenarios, highlighting the need for targeted training interventions aimed at enhancing stress coping mechanisms.

## **5. CONCLUSIONS AND RECOMMENDATIONS**

### **5.1 Summary**

Chapter 1 introduces the general issues and objectives of the research. The primary aim of this thesis is to develop a comprehensive navigational assessment model for tanker vessels, drawing upon the principles outlined in *A Guide to Best Practice for Navigational Assessment and Audit*.

Chapter 2 provides an extensive literature review on key topics, including the SIRE program, navigational assessment and audit procedures, and the influence of human factors on navigational safety and performance.

Chapter 3 begins with a conceptual overview of navigational assessment, elaborating on its scope and relevance within the broader context of maritime safety and operational performance. This is followed by a detailed presentation of the assessment model developed specifically for this research, including its structural components, methodological framework, and intended application.

Chapter 4 focuses on assessing the practical implications and actual contributions of the developed model to the field of maritime safety. The model is applied to a vessel that has recently undergone an assessment or inspection, and the results of the implementation are presented and discussed in detail.

Chapter 5 concludes the thesis by summarizing the key findings, offering an analysis of the main conclusions, and providing recommendations for future research and development in the area of navigational safety.

### **5.2 Contribution and Main Findings**

The study presents a novel numerical approach to the at-sea inspection process of tanker vessels, with the expectation that the proposed model, when incorporated into operational evaluations, will yield significant advantages for maritime stakeholders. One of the primary benefits of this model is its ability to provide stakeholders with

comparative data regarding operational strengths and weaknesses, thereby facilitating a systematic documentation of findings. This feature not only enables the tracking of improvements or regressions over time but also supports benchmarking against prior assessments, creating a more transparent and consistent framework for performance evaluation.

In addition, the model offers valuable insights into the competencies of deck officers onboard, effectively enabling a comparative analysis of individual performance within the broader workforce of the company. This aspect of the model is poised to enhance human resources management by promoting evidence-based decision-making. Through a detailed evaluation of personnel competencies, the model supports the identification of gaps in training and proficiency, thereby fostering more targeted professional development programs. Such targeted interventions are anticipated to optimize crew management strategies, ensuring that training and performance enhancement efforts are aligned with the specific needs of the crew and the operational demands of the vessel.

Overall, the findings underscore the potential of the proposed model to not only advance the effectiveness of navigational assessments but also to contribute to more informed and strategic personnel management practices within the maritime industry. By integrating the model into routine operational protocols, maritime organizations can enhance both the safety and efficiency of their fleet operations, while simultaneously fostering a culture of continuous improvement and professional growth among their crews.

### **5.3 Future Work**

This thesis introduces an innovative approach to the navigational assessment mechanism, which is a critical practice within the maritime industry for ensuring the safe navigation of tanker vessels. Given the evolving nature of maritime operations and the increasing complexity of modern vessels, there is significant potential for the further development and refinement of the proposed model.

Future studies could enhance the model through the integration of advanced technologies such as fuzzy logic and artificial intelligence (AI) techniques. By incorporating fuzzy logic, the model could account for the inherent uncertainties and

ambiguities present in real-world maritime operations, thus improving the model's adaptability and decision-making capabilities in dynamic, real-time conditions. Additionally, the integration of AI techniques, such as machine learning, could enable the model to continuously learn from data collected during inspections, thereby evolving to reflect emerging trends and operational challenges.

Beyond tanker operations, the model has significant potential for adaptation and application across other segments of the maritime sector, such as cargo ships, passenger vessels, and offshore platforms. By customizing the model to address the specific needs and operational realities of these different vessel types, it could serve as a versatile tool for improving navigational safety and operational efficiency across the entire maritime industry.

In conclusion, the potential for future enhancements to the model through the integration of cutting-edge technologies, as well as its broader application across various maritime sectors, presents an exciting opportunity for advancing the field of maritime safety and operational performance.



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