

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

SAFE PILOT LADDER PROCEDURES



M.Sc. THESIS

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Department of Maritime Transportation Engineering

Maritime Transportation Engineering Programme

JANUARY 2025

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EMNİYETLİ PİLOT ÇARMIHLARI PROSEDÜRÜ

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I am surrounded by SEA...



FOREWORD

This thesis was written for my Master degree in Istanbul Technical University, with specialization in Marine Transportation Engineering. The subject of this thesis is related to increasing awareness of pilot ladder safety.

After thanking my family for their endless support, I would like to thank a few people here. I am really grateful to our Dean Prof. Dr. Ozcan Arslan, Prof. Dr. Yasin Arslanoğlu, my advisor Assoc. Prof. Dr. Tanzer Satır, Assist. Prof. Dr. Yunus Emre Senol, my greatest support Assist. Prof. Dr. Esma Uflaz and to all my professors for their guidance, endless understanding and kindness.

December 2024

Cigdem Taneli
(Captain, Marine Assurance
Superintendent)



TABLE OF CONTENTS

	<u>Page</u>
FOREWORD	ix
TABLE OF CONTENTS	xi
ABBREVIATIONS	xiii
LIST OF TABLES	xv
LIST OF FIGURES	xvii
ÖZET	xxi
1. INTRODUCTION	1
1.1 Pilot Ladders	3
1.1.1 Regulations.....	4
1.2 Literature Review	5
1.3 Hypothesis.....	9
2. MATERIALS AND METHODOLOGY	11
2.1 Fault Tree Analysis	11
3. FAULT TREE ANALYSIS: RISKS, CONTRIBUTING FACTORS OF THE FAILURE OF PILOT LADDERS	13
3.1 Non-Compliance of Pilot Ladders:	13
3.2 Intermediate Events: Equipment Related.....	14
3.2.1 Certification.....	14
3.2.2 Storage of pilot ladders	17
3.3 Intermediate Events: Human Related.....	18
3.3.1 Crew checks and inspection	18
3.3.2 Proper rigging arrangements of pilot ladder:	22
3.3.3 Failure to use personal protective equipment.....	26
3.3.4 Fatigue	26
3.4 Quantitative Analysis of Basic Events	27
4. RESULTS AND DISCUSSIONS	31
5. CONCLUSION	37
REFERENCES	39
CURRICULUM VITAE	41



ABBREVIATIONS

AMSA	: Australia Maritime Safety Agent Association)
ATSB	: Australian Transport Safety Bureau
BE	: Basic Event
CH	: Chapter
Circ	: Circular
FFPM	: Federation Française des Pilotes Maritimes (French Maritime Pilot
FFTA	: Fuzzy Fault Tree Analysis
FTA	: Fault Tree Analysis
IE	: Intermediate Event
IMO	: International Maritime Organisation
IMPA	: International Marine Pilot Association
ISO	: International Organization for Standardization
ITU	: Istanbul Technical University
MSC	: Maritime Safety Committee
P&I	: Protect and Indemnity
PMS	: Planned Maintenance System
PPE	: Personal Protective Equipment
REG	: Regulation
SMS	: Safety Management System
SOLAS	: Convention for the Safety of Life at Sea
TE	: Top Event



LIST OF TABLES

	<u>Pages</u>
Table 3.1: Linguistic expressions and corresponding fuzzy numbers.	29
Table 3.2: Expert classification parameters and scores.	29
Table 3.3: Anonymous consulted expert and their weights.	30
Table 3.4: Probability of Basic Events.....	30





LIST OF FIGURES

	<u>Page</u>
Figure 1.1 : Pilot ladder arrangements in 1600's (HMS Victory)	1
Figure 1.2 : Pilot ladder materials	3
Figure 1.3 : Pilot ladder.....	3
Figure 1.4 : Combination ladder	4
Figure 1.5 : Pilot ladder arrangement.....	5
Figure 2.1 : Fault tree analysis diagram	12
Figure 2.2 : Fault tree analysis symbols.....	12
Figure 3.1 : IMPA 2024 Safety campaign results	13
Figure 3.2 : IMPA 2024 Safety campaign summary	14
Figure 3.3 : FFMP statistics	14
Figure 3.4 : New ladder: Non-compliant	14
Figure 3.5 : After repairs	17
Figure 3.6 : Poor condition of ladder (exposed UV/sea/weather).....	18
Figure 3.7 : Parted rope	19
Figure 3.8 : Cracked step	20
Figure 3.9 : Broken spreader	20
Figure 3.10 : Not secured on deck	23
Figure 3.11 : Improperly secured	24
Figure 3.12 : Fault tree	28



SAFE PILOT LADDER PROCEDURES

SUMMARY

Pilot ladders have been in use for ages. Surprisingly, the structure of the ladders haven't changed much. It doesn't make sense, there are still casualties and fatalities occur while we are using the pilot ladder for embarking/disembarking to vessels.

It has been witnessed that companies, port state control authorities, or oil majors raising safety campaigns over and over as part of safety campaigns on pilot ladder compliance. It is very hard to understand why people are being injured or died while they use pilot ladders.

This master dissertation is divided into three parts. The first part begins with pilot ladder description. Industry regulations, and technical qualifications. Each vessel, engaged on voyages in the course of which pilots may be employed, required to be provided with pilot transfer arrangements. According to Convention for the Safety of Life at Sea (SOLAS) CH V, Regulation 23, Pilot Transfer Arrangements, the regulations are in force since 1974. There were amendments on the arrangements within 50 years, however the basic pilot ladder construction was not changed. The wooden steps, manila ropes, plastic materials remain the same.

The second part, which is the main focus of this study, lies in the fault tree analysis based on possible factors, which effects the condition of the ladders or the safety of the environment. In order to analyse the incident risk caused by pilot ladders, fault tree analysis methodology is used. Undesirable event was set as person falling from the pilot ladder. The scope of the failure divided into two categories: pilot ladder related or human error related. The equipment related intermediate events have been selected as certification and storage, on the other hand human related intermediate events selected as crew checks and inspection, proper ladder arrangement, personal protective equipment failure and fatigue was surveyed and analysed, and based on the conclusion, the most risky root cause was found among those events. Weather and manoeuvring were not added into the scope, though they will be explained as a contributing factor for the consequences.

On the third part, this master thesis will have suggestions on preventive actions to improve safety standards onboard. According to the rules and regulations, it has been observed that certification procedures are well strict, expensive and painful for the makers until the certificate is guaranteed. However once the certificate is secured for the maker, unannounced random inspections for the makers would improve the quality of the pilot ladders. By the regulations, onboard modifications on the pilot ladders should be prohibited. Crew training for how to handle and how to rig properly, is the most important action to prevent injuries or fatalities. Investments for trainings and safety improvements should be encouraged for the shipping companies. Regardless of condition of the in use pilot ladders on board, stocked pilot ladders should be supplied to vessels to prevent noncompliant pilot ladder usage.

In this thesis report, the root cause of the accidents by pilot ladders was analysed. In order to analyse the system weaknesses, the scope narrated down to human element and pilot ladder failures. The methodology of fault tree analysis is used to determine the root cause of the person falling from pilot ladders. Even though combination ladders, or trap doors are being used during the transfer of the pilots, visitors or crew; the pilot ladder compliance was the main focus of the thesis. Certification process is thoroughly explained to increase the awareness of crew and marine experts. Importance of crew checks, personal protective equipment usage, proper rigging arrangement highlighted under human factors. Once understanding the root cause of the accidents, there are suggestions recommended to eliminate the accidents.

This thesis provides a description of pilot ladders and outlines the causes of the pilot ladder accidents. Once the root cause is analysed, it would be easier to map the solutions and suggest preventive action procedures.



PİLOT ÇARMIHLARININ EMNİYETLİ KULLANIMI

ÖZET

Yüzyıllardır kullanılmakta olan pilot çarmıhları, şaşırtıcı derecede ilk yıllarında icat edildiği şekilde kullanılmaya devam edilen, oldukça basit bir düzene sahip olsa da, bunca yıldır bir ilerleme kaydedilememiş, ve halen kazalar ve ölümlere sebebiyet veren, gemilerdeki en riskli operasyonlardan birinin kaynağıdır.

Hemen hemen her denizcilik şirketinin, bayrak devletlerinin, klas kuruluşlarının ya da P&I klüplerinin ve özellikle endüstride başı çeken kimyasal/petrol şirketlerinin gemilerde emniyet seviyelerini arttırmak uğruna; özellikle pilot çarmıhları ile ilgili farkındalık kampanyaları başlattığını görmüşsünüzdür. Tüm bunca emeğe, eğitime, düzenlenip dağıtılan sirküler ya da kural düzenlemelerine rağmen kazaların olması şaşırtıcıdır. Gemilerde kullanılan çarmıhların kusurlarından öte, şirket politikalarını ve yönetmelikleri hiçe sayan gemi personeli, oluşan kazaların insan faktörü etkenini denkleme sokmaktadır. Pilot çarmıhları ile oluşan kazalar hakkında veri eksikliği olmasına rağmen, kılavuz kaptanların düzenli raporlamaları sayesinde istatistiksel veri kullanmak için bazı değerlere ulaşılabilir durumdayız. Ancak daha niteliksel verilere ulaşabilmek için hata ağacı analizi kullanarak kök nedenler bulunmuştur.

Bu tez, üç ana bölümden oluşmuştur. İlk bölümde pilot çarmıhlarının ne olduğu, nasıl bir materyalden yapıldığı, bu çarmıhlar için endüstride kabul gören yönetmelikleri anlayacağız. 1974 kabullü, Denizde Can Emniyeti Uluslararası Sözleşmesi (SOLAS) bölüm 5, madde 23'e göre pilot çarmıhları kılavuz kaptan kullanabilecek tüm gemilerin tabi olduğu bir yönetmelik yayınlamış, son 50 yıl içerisinde de bu uygulamalar elbette zaman zaman güncellenmiştir. Ancak pilot çarmıhlarının kullanıldığı malzemeler göz önünde bulundurulduğunda; sonuçta sadece tahta basamaklar, kendir halat ve kauçuk basamaklardan oluşan basit bir düzenden bahsetmekteyiz.

İkinci kısım, ve bu tezin ana kısmında hata ağacı analizi methodu kullanılarak, kazalara neden olan en riskli sebebi, diğer riskli faktörleri ve kaza sonuçlarını etkileyen etmenleri inceleyeceğiz. Hata ağacı analizi risk değerlendirme methodunu kullanırken, çok değerli kılavuz kaptanlarımız, tecrübeli zabıt ve kaptan meslektaşlarımız, ve çarmıh üreticileri ile anket yapıp, sonuçlarına göre sayısal değerler oluşturduk. Bu methoda göre, olayımız bir personelin pilot çarmıhından düşmesi olarak düzenlendi. Daha sonra bu olaya neden olabilecek sebepler pilot çarmıhı veya insan faktörü kaynaklı olarak ikiye ayrıldı. Pilot çarmıhının sertifikalı olup olmaması, gemilerde pilot çarmıhlarının saklanma koşulları kullanılan ekipmandan doğabilecek kusur olarak ve personel çarmıhları hazırlarken doğru hazırlamamak, gerekli bakım tutumlarını yapmamak, yorgunluk düzeyleri ve kişisel koruma ekipmanları kullanmamaları olarak belirlendi. Ana sebep olmasa da kazaların sonucunu etkileyecek faktörler de bu kısmın sonunda tavsiye niteliğinde bahsedildi, ki bunların en önemlileri gemilerin manevra kabiliyetleri ve hava şartları olarak değinildi. İçeriğe

gemi manevralarının veya hava şartlarının alınmamasının bir nedeni meydana gelmiş kazaların bir kısmının iyi hava koşullarında ve gemi limanda iken yaşanmış olması; bir diğerinin de gemi manevralarını etkileyen varyantların fazlalığı ve kötü hava şartları olasılığının ölçülebilir değerlere sahip olmamasıdır.

Üçüncü, ve son kısımda ise pilot çarmihini emniyetli kullanmak için yapılması gereken noktalara değinildi. Kazalara sebep veren ana sebepler bulunduğundan sonra, sorunun ortadan kaldırılması emniyet arttırmaya yönelik bir harita ve önleyici prosedürler oluşturmak elbette daha kolay olacaktır. Denizcilik şirketlerinin personel yetiştirmek için ayırdığı bütçe, ve prosedürler desteklenmeli, ve bilinçli bilimadamları yetiştirilmelidir. Gemilerde sertifikasız pilot çarmihini kullanımı önlenmeli, ve hatta yönetmeliklerce gemiadamlarının gemide pilot çarmihini üzerinde basamak veya halat gibi malzemeleri değiştirmeleri engellenmelidir. Pilot çarmihini üreticilerinin, ürettikleri ürünler için sertifika alma sürecinin oldukça pahalı ve meşakkatli olduğu gözlemlenmiştir. Ancak, sertifika alındıktan sonra, gemilere gönderdikleri ürünlerin, sertifika alınırken kullanılan malzeme ya da kalitede olup olmadığını denetleyen bir mercii bulunmamakta olup, sertifikasını almış bir üreticinin, daha sonra sattığı ürünlerin kalite standartların altında olabildiği de saptanmıştır. İşte bu olasılığın önüne geçebilmek için, pilot çarmihini üreticilerinin de habersiz, ara denetimlerden geçmeleri önerilmiştir.

Bu tez çalışmasında, öncelikle pilot çarmihlerini açıklayacağız. Ne işe yaradığı, malzemeleri, pilot çarmihleri için koyulmuş kural ve yönetmelikleri işleyeceğiz. Yüzyıllardır kullanılan ve üzerinde çokta değişiklik yapılmamış pilot çarmihlerinin halen neden bu kadar kaza ve ölüme sebebiyet verdiğini, bu sebeplerin risk değerlerini inceleyeceğiz. En riskli yani kazalara en çok sebep veren faktörü belirleyeceğiz. Hata ağacı risk değerlendirmesinde ortaya çıkan sonuçları önleyebilmek için neler yapılabilir, personelin ve pilot çarmihini kullanan kişilerin farkındalığı nasıl artırılabilir, eğitim seviyeleri nasıl geliştirilebilir diye önerilerde bulunacağız. Pilot çarmihini üreticileri dışında, pek çok kişi tarafından bilinmeyen sertifikalandırma süreci ve sertifika alımı sonrası üreticilerin tedarik ettikleri ürünlerin kalite standartları konusunda bilgilendirme yapacağız. Bu tezin amacı, pilot çarmihlerini nedeniyle meydana gelen kaza ve ölümleri engellemek, gemilerde daha emniyetli bir çalışma ortamı sağlamaktır.

Son olarak, tez konusunu belirlenmesinde rol oynayan, uzun yıllar gemilerde çalışan gemi adamlarının bile bilmediği, ancak pilot çarmihini üreticilerinin daha fazla kar elde etmek için kaliteden ödün vermeleri sonucu kusurlu, sertifika standartlarına uymayan pilot çarmihlerinin gemilere nasıl gönderildiğinden bahsederek bir farkındalık yaratacağız. Denetim sırasında ufak bir çatlak yüzünden negatif madde yiyen gemiadamları, maalesef bilmiyorlar ki gemilerine gönderilen yeni ve sertifikalı pilot çarmihleri de kusurlu olabilir. Maliyeti düşürerek daha ekonomik üretim yapmak ve daha fazla kar elde etmek amacıyla pilot çarmihini üreticileri kusurlu ürünleri de gemilere göndermekteler. Öncelikle artan maliyetler yüzünden pilot çarmihini üreticileri ucuz hammadde arayışına girdiler. Orman yangınları, ülkelere uygulanan ambargolar, plansız ağaç kesimleri yüzünden çarmih üretiminde kullanılan basamakların maliyetleri oldukça arttı. Normalde basamak üreten firmalar, pilot çarmihini üreticilerine kusursuz ürünleri belirli bir fiyata vermek üzere anlaşıyorlar. Basamaklar üretim aşamasında çatlar ya da zarar görürse; bu ürünler üreticiye geri iade ediliyor. Üreticiler bu kusurlu ürünleri piyasada 1/3 fiyatına tekrar satıyor, pilot çarmihini yapan firmalar basamaklardaki kusurları dolgu malzemesi ile kapatıp piyasaya yeni pilot

çarmıhı olarak veriyor. Dışardan bakıldığında kusuru çıplak gözle anlaşılmayan pilot çarmıhları, gemilere gönderilerek emniyetsiz bir ortam oluşturuyor.

Baktığınızda herhangi bir renk farkı ya da kusur görmediğiniz pilot çarmıhının güvenilirliğinden elbette çarmıhı kullanacak kişiler tarafından anlaşılamaz. Gemiadamlarının gemilerde çarmıhları yük testine tabi tutmaları tabiki beklenemez. Peki en başta gemiye doğru ekipmanın gönderildiğinden nasıl emin olmalı? Şirketlerdeki alım-satım departmanları da piyasada en uygun ürün veren satıcıya yönelecektir. Ancak şirket yetkilileri gerçek maliyetinin altında ürün satan firmalarla alışveriş yapmadan önce ürünlerin kalitesini sorgulamalıdır. Her zaman ucuz ürün kaliteli olmayacaktır. Sistemdeki boşluklar nedeniyle pilot çarmıhı üreticileri herhangi bir kontrol mekanizmasından geçmemektedir. Üzerinde insanların tırmandığı, kötü hava koşullarında bile tüm ağırlıklarını vererek riskli bir iş yaptıkları çarmıhlar, kusurlu oldukları taktirde insan hayatına mal olabilir. Maalesef bazı çarmıh üreticileri için maddi kazançlar insan hayatının önüne geçmiştir. Bu insanlar ya ürettikleri ürünlerin insan hayatı üzerindeki riskinin farkında değiller, ya da daha elzemi , bunu bildikleri halde riski normalleştirerek önemsizleştirmişlerdir.

Son dönemlerde duymaya başladığımız kazalardaki insan faktöründen bu tezde de bahsedeceğiz. Personel hatalarından kaynaklı kazaların nasıl önlenebileceğine ilişkin önerilerde bulunacağız. Pilot çarmıhı kullanılmadan önce yapılacak işbaşı konuşmaları, personelin yaptığı risk değerlendirmeleri, şirket prosedürlerinin uygun bir şekilde yerine getirilmesi, iletişim eksiklikleri, personelin iş yükü ve yorgunluğu, personelin bilgi donanımı gibi insan faktörüne bağlı elementleri açıklayacağız. Personelin farkındalığının artırılması için şirket yetkililerinin ya da en başta denizcilik eğitimi veren kurumların iyileştirilmeleri ya da ek eğitimlerin gemi adamlarına sağlanılabilmesi için önerilerde bulunacağız.

Geri kalmış, fakir ülkelerde liman otoritelerinin eski kullanılmayan çarmıhlarını gemilerden istedikleri, nispeten iyi durumda olan malzemeleri kullanarak yeni çarmıh üretip, boyayıp gemilere verdikleri bilinen bir gerçektir. Gemilerde kullanılmayan, çöp olarak atılmış kötü pilot çarmıhlarının sağlam kısımlarından yeni çarmıh üreterek gemilere tekrar satılır. Ancak bu tür yolsuzlukların ülkemizde de yapılıyor olması maalesef üzücü bir gerçektir. Bazı firmaların basamaklardaki çatlakları kapatmakla bile uğraşmayıp gemiye kusurlu ürün gönderdikleri tezin ilerleyen sayfalarında fotoğraflanmıştır. Gemiye gönderilmek üzere hazırlanmış bir pilot çarmıhının kondisyonunu göreceksiniz (Figure 3.4). Bu tezin amacı, okuyan her bir denizcinin pilot çarmıhına çıkmadan önce bastığı basamağın güvenilirliğini sorgulaması, ve gerekli denetimlerin düzenli olarak yapılmasına önayak olmak, ve yönetmeliklerde gemi personelinin pilot çarmıhlarında basamak değişimlerini engellemesini sağlayabilmektir.



1. INTRODUCTION

Seafarers working on a challenging environment. Emrarking on a vessel via pilot ladder, climbing up 12 meters especially on a bad weather while vessel is rolling and holding the ropes for your life is not easy. While you are climbing, the pilot ladder will move, shift, slide and you need to continue on this unstable platform to reach on top. During researches in order to see the first construction of the pilot ladders, surprisingly it was founded a structure which is simply a combination of manila rope and wooden steps. In 21st century we do use manila rope and wooden steps as well. The oldest vessels where you could see the paintings on vessels' pilot ladders, in 1600's HMS Victory's drawings clearly shows pilot ladder was rigged on her side (Figure 1.1). Tehnically, within 400 years, you would expect some technologies or changes in the equipment, however even if it was tried combination with lifters, in our centruity we are still using hand made ladders for embarkation/disembarkation to/from vessels. Considering everything is still so simple and same on construction of the pilot ladders, it is hard to understand why there are casulaties resulting from pilot ladder usages.



Figure 1.1: Pilot ladder arrangements in 1600's (HMS Victory)

In these thesis it was targetted to understand the reasons of failure of the pilot ladders. The data was quantized the human errors and equipment failures via surveying the marine experts who serve as Pilot, senior officers who use the pilot ladders on their routine tasks on board, marine safety consultants who are expert on inspection and auditing of crew and vessels condition and pilot ladder producers.

The biggest challange on the project was getting the incident/accident ratio of the failure of the pilot ladder. Unfortunately accidents, incidents and even near misses are poorly reported in the maritime indurstry. Because of that, determining the probability of the human error is quite important in the industry (Aydin, Uğurlu, & Boran, 2022). The most reliable data received through Pilot's Assossiations' database, as the Pilot's reports the non-compliant pilot ladders more accurately, comparing with seafarers and owners.

In this thesis the pilot ladder examples' photos used, which are reported to marine authorities. Capt. Arie Palmers, Oosterschelde Maritime Pilot in Netherlands, who actively takes role on International Maritime Pilots' Association provided those photos for the thesis.

In order to achieve the quantitative results for analysing the risk factors on pilot ladder safety prosedures; fault tree analysis methodology used. Marine experts' opinions were gathered to create intermediate events. The scope was restricted to human related and equipment related failures on pilot ladders. Human related failures dignosed as higher than the equipment failures itself. There are underdeveloped events such as weather or maneouver of the vessels, as their statistics on contrubution factors are hard to estimate and different variants effect the vessels' maneouvering capacities. Basic events, which are the lowest branch of the fault tree analysis, were evaluated by the marine experts, and their failure rate calculated accordingly. According to the results; the highest risk found as crew checks and maintenance are not being done as part of poor safety culture; and lowest risk was calculated as personal protective equipment not supplied to vessels suffiently. The top event's probabilty, which is person falling from pilot ladder, according to Fault Tree Analysis, was calculated as %30.33.

1.1 Pilot Ladders

Pilot ladders are in use onboard for routine jobs such as pilot embarkation, crew, surveyor, visitor boarding, draft reading, painting the ship's side and during the lifeboat drills.

In order to make a pilot ladder, you will need rubber steps, wood steps, spreader, manilla ropes, and step fixing pieces (Figure 1.2, Figure 1.3, Figure 1.4).



Figure 1.2 : Pilot ladder materials



Figure 1.3 : Pilot ladder

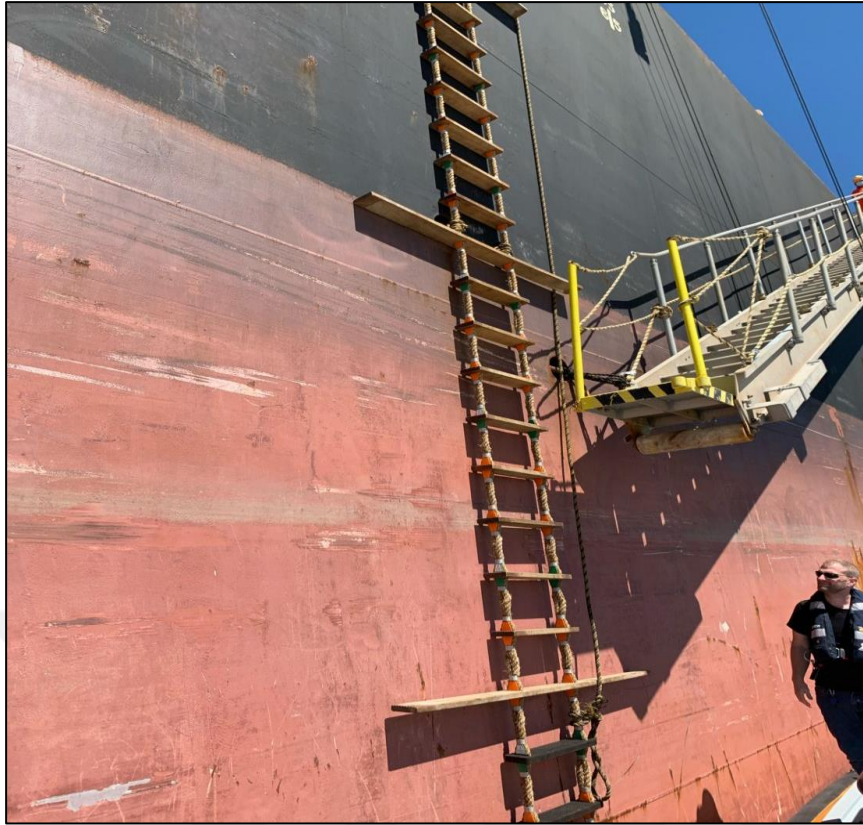


Figure 1.4: Combination ladder

1.1.1 Regulations

Regulations and guidelines regarding Pilot Ladder safety could be found:

1. SOLAS Convention Chapter V, Regulation 23: Regulations regarding Pilot Transfer Arrangements
2. IMO resolution 1045(27): Recommendation on Pilot Transfer Arrangements
3. ISO 799-1 Ships and Marine technology-Pilot Ladders-Part1: Design and Specification
4. The International Safety Management (ISM) Code

Further guidance could be useful:

Shipping Industry Guidance on PILOT TRANSFER ARRANGEMENTS Ensuring Compliance with SOLAS by International Maritime Pilots' Association, International Chamber of Shipping (2012, 2nd Edition)

Figure 1.5 shows the requirements of the proper pilot ladder arrangement.

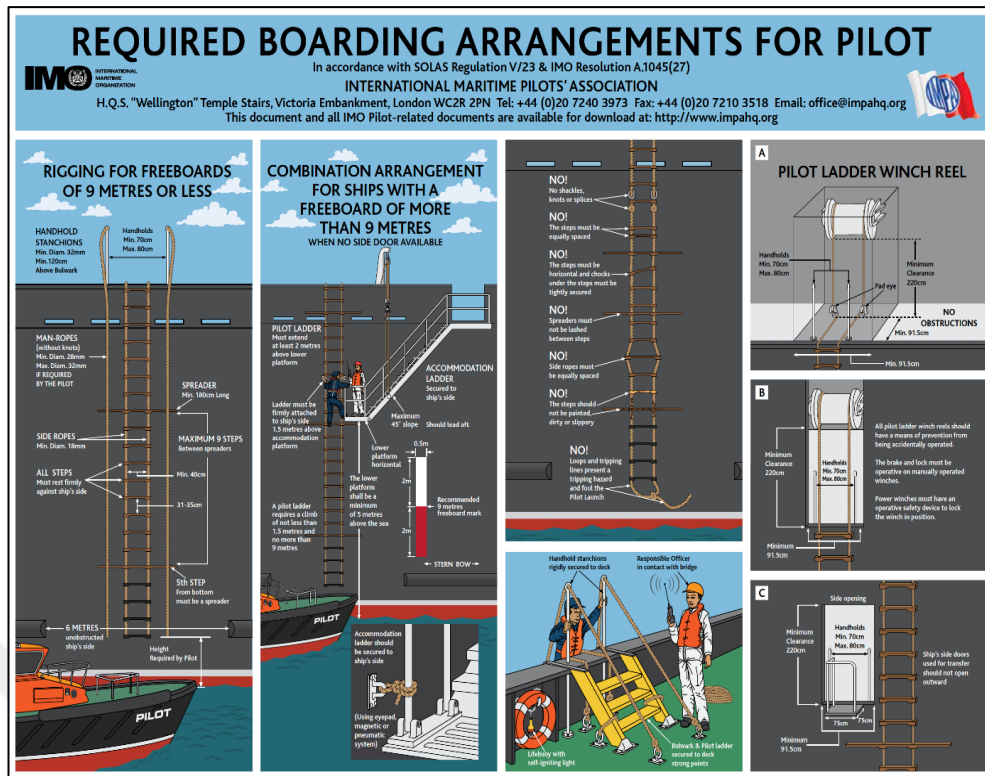


Figure 1.5 : Pilot ladder arrangement (ICS, 2022)

1.2 Literature Review

Embarkation and disembarkation arrangements haven't been changed much in the last centuries. In order to transfer to/from vessel, pilot ladders, embarkation ladders, combination of accommodation ladder and pilot ladders are in use without significant changes. Still there are so many incidents and accidents happening and causing human life. Average of 2 pilots and 21 people are being killed by pilot ladders each year (Gaillard, 2021).

However those numbers are not very trustworthy, as not all the incidents and accidents are being reported to authorities. Because of this reason, determining human error probability is vital in maritime transportation (Aydin, Ugurlu, & Boran, 2022). Apart from the human error there are uncontrollable factors, which effects the failure of a pilot ladder. Severe sea conditions being the most unpredictable one, current, wind, temperature, restricted visibility do effect the results. Nonconformities could raise because of lack of knowledge or supervision of the crew, not following the companies' planned maintenance system, insufficient purchasing, non-certified equipment being in use, insufficient personal protective equipment (PPE), fatigue as well.

Almost all of the studies related with pilotage or accidents/incident during pilot transfers, as it is hard to access ratio of the failures during vessel's routine operations. As per (Günay, 2016), occupational accidents of the maritime pilots occur significantly while the pilot is embarking or disembarking through the ladder. He observed that most the accidents end with being jammed between the vessel and pilot boat, falling into pilot boat, or falling into sea which result in serious injuries or death. His study was aimed to evaluate the physical and physiological parameters of the Maritime Pilots in respect of occupational qualification and safety.

As per (Sakar & Sokukcu, 2023) single route cause covered pilot transfer accidents, which is poor condition of pilot ladder. Splitted or cracked steps, oily or painted steps, handhold failures, poor condition of side ropes, unequally splitted steps considered poor condition. Securing failure of pilot ladder on deck, which could be caused by the sharp deck edges damaging the side ropes, securing points, shackles, bars, tongues or guardrails not in good condition.

As per another research done by (Behforouzi, 2020), the pilot ladders' safety is affected by unsafe rigging procedure or breaking of a defective pilot ladder. Similar methodology used for identifying the most common causes: surveys and interviews with marine experts, though his study aimed to highlight benefits of implementing remote pilotage in order to prevent incidents/accidents during pilot transfers. As per the interviewes there were negative incomes of remote pilotage such as communication issues between the vessel crew and VTS, and pilot's limited access to vessel's navigation equipment are being the most challanging ones.

The study of analysing the risks of the maritime pilots who encounter accidents during transfer arrangements emphasize the limited data about the topic (Tunçel & Arslan, 2022). Hence, most of the researchers have focused on pilot associations, who gather the data more systematically about the physical and physiological performances of maritime pilots. On this study potential failures identified as ineffective manoeuvres during the transfer both by vessel and pilot boat, lack of maintenance of the pilot ladder equipment, external conditions like weather and sea, insufficient illumination or the transfer area, human error, fatigue, lack of knowledge and skills of the crew. Human error leads to the improper rigging of pilot ladder, poor safety culture leads to lack of personal protective equipment usage and which bring failures.

One of the studies by (Radwanski & Rutkowski, 2022), mentions fake ladders which are being sold to vessels and classification societies certify noncompliant arrangements, which is one of the important bullet point of my thesis, and myself agree with the authors of the research paper that compliant ladders are not too hard to produce and not too expensive. The study also emphasizes that all pilot ladders to be certified, clearly identified with tags and permanent markings in order to follow up the inspection and record keeping.

Apart from the academic researches, there are articles related with pilot ladder incidents published by P&I clubs, Maritime safety agencies, and port state controls. UK P&I prepared a case study based on a falling incident from a ladder. On 3rd of July 2013, a company representative fell from a pilot ladder and landed on the pilot launch. The vessel was at anchor, engaged with loading operation. The injured person died, even he was sent to hospital. There was a lack of communication between the vessel and launch boat, as the pilot ladder was prepared too high to climb from launch and crew members were still adjusting the pilot ladders while the company representative started climbing up to the ladder.

As per (AMSA, 2021), one crewmember died while he was disembarking from the vessel, falling from a pilot ladder. The article revealed that proper risk assessment was not done before crew used the pilot ladder. (AMSA, Means of embarkation and disembarkation for ships in port [Regulation], 2023) highlights means of embarkation and disembarkation from ships in port. The section which emphasizes the prohibition of pilot ladder in port, unless the pilot ladder to be used by only pilots and other professionals such as crew or cargo masters. According to AMSA, risk assessment is vital while rigging or adjusting gangways, accommodation ladders and pilot ladders.

In May 2014, Transport Malta (TM, 2014) issued safety investigation report, based on pilot injury incident case, because of a failed pilot ladder. MV Wilson Leith disembarking the pilot, the side ropes parted soon after the pilot stepped on the ladder. According to the safety investigation report, the pilot ladder condition was in poor condition, the rope had signs of fraying and weathering, which revealed that it was not stored properly, it was not rigged properly as the ship's construction was wearing the ropes as well.

As per ATSB investigation report (UKP&I, 2022), on May 2023, a pilot boarded to vessel in Australian territorial waters, after the pilot while mooring master was climbing up the ladder, he fell from the ladder because pilot ladder ropes parted. Luckily he fell to the water, he had proper PPE which inflated automatically and he sustained minor injuries only. Later on Port state control boarded the vessel and checked the failed pilot ladder. The condition of the pilot ladder was found unsatisfactory.

In the literature, quantitative or qualitative risk assessment techniques are being used on risk-based approaches. Fault tree analysis is commonly used in maritime industries for measuring the risks quantitatively. In order to analyse risk factors in ship mooring operations (Kuzu, Akyüz, & Arslan, 2019), used fuzzy fault tree analysis method, and concluded that lack of communication, inspection of mooring ropes, and standing on the snap-back zones are the most significant risks for mooring operations. (Wang, Wang, Shi, & Zhu, 2021), benefited FTA while assessing the most significant risk factors, and effective fire fighting actions in ship fire accidents. According to the researches, the most important preventive actions on ship fires are sealing off the cabins timely, effective ventilation systems and crew proper actions on emergency response.

Fuzzy fault tree analysis (FFTA) used on another research while determining the role of human factors in maritime transportation accidents by (Zaib, Yin, & Khan, 2022), because most of the accidents have resulted from human factors. The researchers used FFTA in order to analyse the failure probability of the system. Research based on an accident of MT Key Bora, when she ran aground in China. There were total number of ten events and three intermediate events determined to create fault tree analysis. According to them, inaccurate port data was given to crew, and based on inadequate information, crew skipped the company procedures, followed the passage plan before confirming the accuracy of the data.

There is another research existing which is related with risk analysis for transfer process of maritime pilots, benefited from FTA within a fuzzy logic environment. (Tuncel, Akyuz, & Arslan, 2023). According to them most of the researches covers the physical and physiological performances of maritime pilots or difficulties related with navigational aspects; although the risks encountered by maritime pilots in the process of pilotage was limited. Hence, their studies aimed to address the risks

associated with operational process of the maritime pilots. As per the FFTA, weather conditions, unsafe rigging of the pilot ladder, non-compliant pilot ladder, mental fatigue of pilot, and lack of maintenance of pilot ladder were found the highest risks among other risks.

1.3 Hypothesis

This thesis provides a review of options for using pilot ladders in a safer way, since the accident/incident reports shows that this is a high-risk operation on board, which could cause serious injuries and fatalities. Even though same equipment has been used for centuries, proper arrangements, standardization of the ladders has yet to be achieved. In this thesis, it was aimed to highlight the safety barriers, understand the root cause of the failures, emphasize the risks and contribute reducing the number of incidents and accidents. The thesis highlights a number of key factors; failure in regulation, gaps in safety standards, training of crew, key failings which will improve the understanding of safe arrangements of pilot ladders.



2. MATERIALS AND METHODOLOGY

In this thesis fault tree analysis method used for finding the highest risks on using pilot ladders and root causes of pilot ladder procedure failures. Marine experts, Captains and Marine Pilots shared their experiences for rating the designated barriers. The problem was selected as fall from pilot ladder. After identifying the problem, intermediate events have been identified. In order to understand the root cause of the problem, marine experts' opinions were consulted to evaluate the probability of intermediate and basic events.

As per the research 160 accidents taken place between 2001 to 2021 during person transfers on board, and 120 of them belongs to pilot ladders only. Most of the pilots disagree with the number of the accidents, because not all the accidents or incidents are being reported to authorities, so actually the probability of the initiating event is higher than the reported cases. Within 18 years, 32 deaths occurred among the 8360 pilots. In that case, 1.77 pilots are being killed by pilot ladders within a year (Gaillard, 2021). This means approximately 1.8 person dies within a year, which makes the percentage as 0.0215311005 per year.

As per the fault tree analysis results, the highest risk was found crew checks and maintenance were not followed on board regularly mostly because of the crew negligence. The minimum risk calculated as personal protective equipment not being available on board while understanding the root causes of pilot ladder usage failures.

2.1 Fault Tree Analysis

Fault Tree Analysis (FTA) is a methodology, which enables us to analyze the system failures, and helps to show how system fails and how to reduce risk graphically (Figure 2.1). FTA is typically used to measure the probability of failure in any system. From top to down combination of events put in order to understand the root cause of the failure. The systematic approach works with basic events, and/or gates which connects the events to identify the cause of the the top event, which is person falling from pilot ladder in this thesis (Figure 2.2).

The main problem placed on top and branched down that represent the cause of the event. Some of the branches were further divided into branches, which reached the lowest level in the system. The gates called:

AND GATE, which means if all of the conditions came into force, the event (person falling from the ladder) would occur.

OR GATE, which means the event would occur, if one of the designated branch happens.

The purpose of the fault tree analysis are determining the potential causes in system failure, finding the probability of top events in order to evaluate the most significant risks, understanding the failure rate and probability.

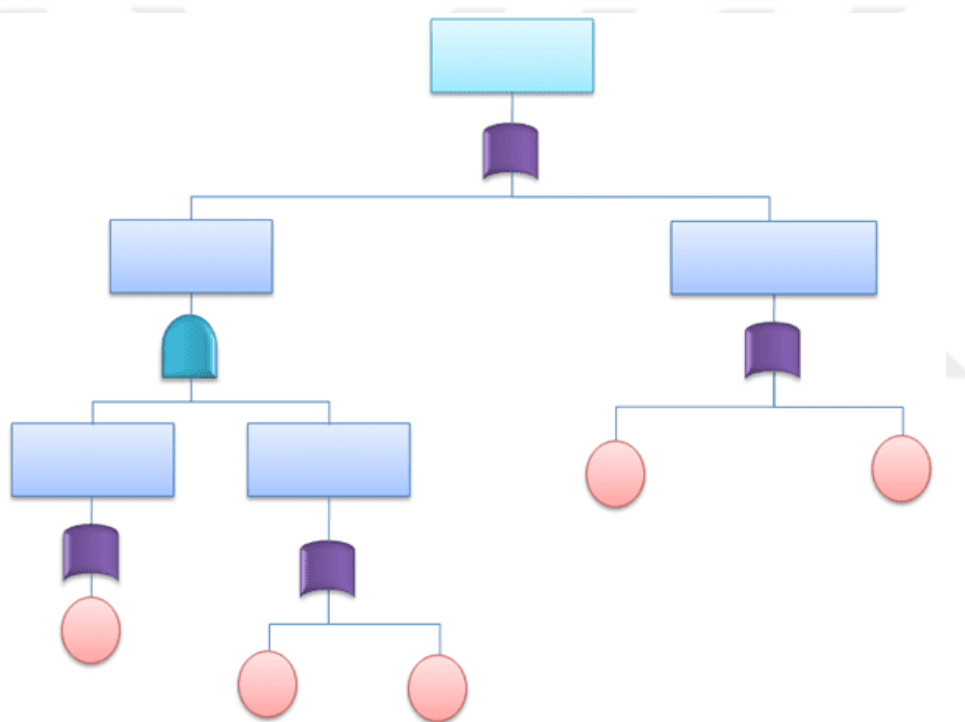


Figure 2.1 : Fault tree analysis diagram (Hessing, (n.d.))

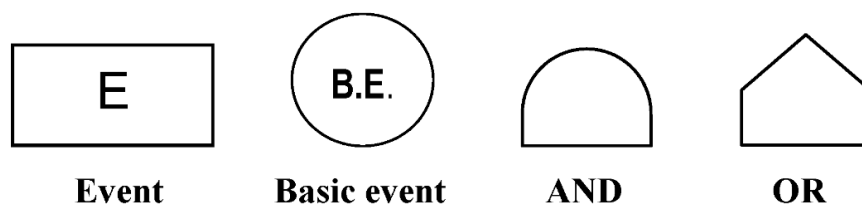


Figure 2.2 : Fault tree analysis symbols

3. FAULT TREE ANALYSIS: RISKS, CONTRIBUTING FACTORS OF THE FAILURE OF PILOT LADDERS

3.1 Non-Compliance of Pilot Ladders:

IMPA publishes each year safety campaign results since 2015 (Figure 3.1). According to surveys, IMPA publishes most common defects (Figure 3.2). IMPA safety campaign results, FFPM accidentology results (Figure 3.3) and marine experts' opinions shows the identified issues found that,

- Vessels continue to construct pilot ladders on board, not comply with basic standards
- Class societies certify non-compliant arrangements
- Dangerous boarding arrangements are rigged without officer supervision
- Fake ladders sold to vessels, not comply with the basic standards.

NON-COMPLIANCE BY TYPE OF DEFECT PILOT LADDER		
Defect	Total	% of all pilot ladder defects
Incorrectly rigged retrieval line	209	43
Steps not horizontal	56	12
Pilot ladder not against the hull throughout its entire vertical length	33	7
Pilot ladder not within the midships half length of the ship	25	5
Incorrect step fitting	21	4
Sideropes of unsuitable material	10	2
Steps slippery or contaminated	9	2
Steps not evenly spaced	8	2
Climb on pilot ladder greater than 9m	7	1
Steps painted or varnished	7	1
Steps broken	5	1
Steps made of a material other than hardwood, plastic or rubber	4	1
Other	91	19

Figure 3.1 : IMPA 2024 Safety campaign results (IMPA, 2024)

EXECUTIVE SUMMARY

Headlines from 2024

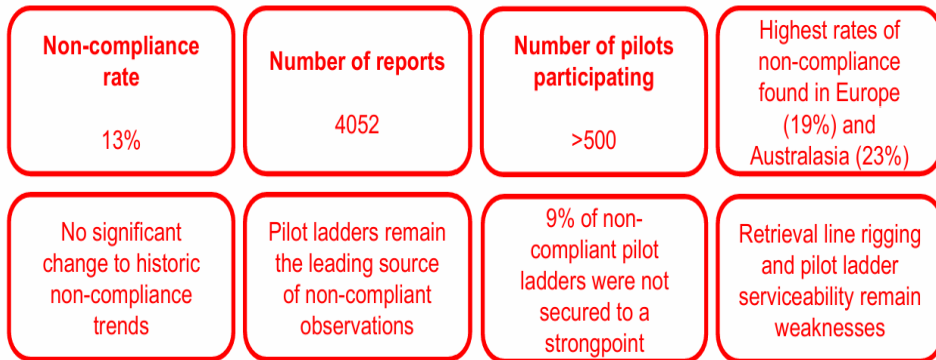


Figure 3.2 : IMPA 2024 Safety campaign summary (IMPA, 2024)

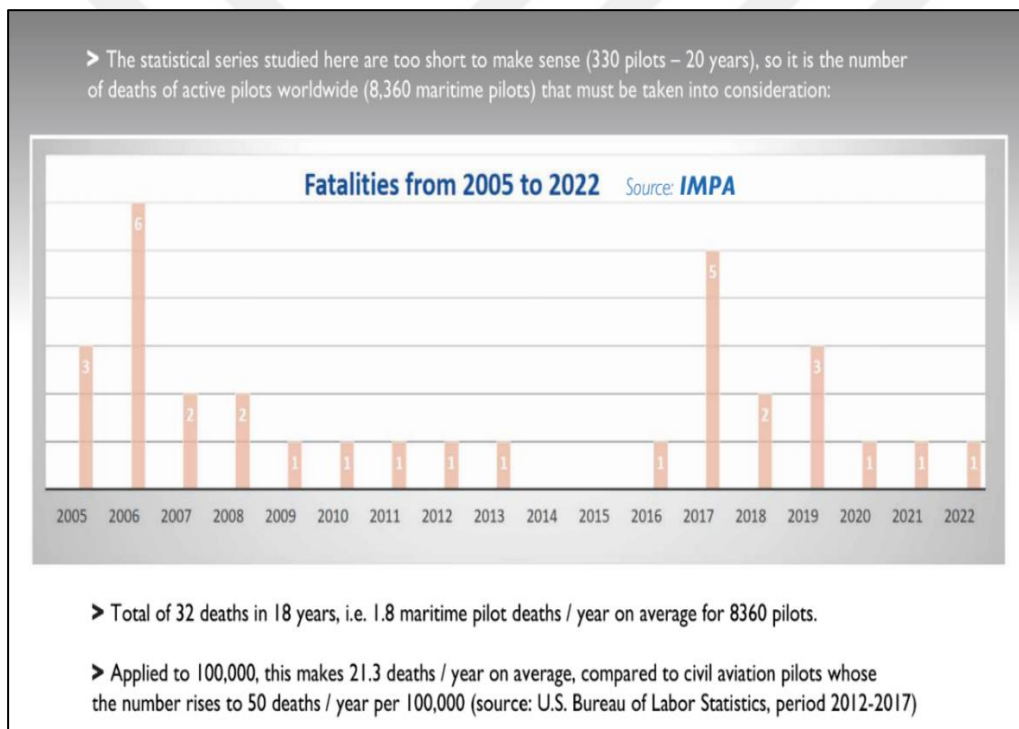


Figure 3.3 : FFMP statistics (Gaillard, 2021)

3.2 Intermediate Events: Equipment Related

3.2.1 Certification

A pilot ladder should be certified by the manufacturer as complying with the requirements of an international standard acceptable to the Organization¹. Non-compliant transfer arrangements are quite common in the marine industry. Unfortunately, makers need to get an approval only once before selling their products

in marine industry. Each year, as long as makers keep paying their fee, their products' certificates stay valid. In order to get an approval, a maker could use the best quality of steps, ropes, metal or plastic clips; however, after getting the certificate, maker could lower the standards or even worse, maker could use unacceptable, unsafe, old products for producing the pilot ladders. It is quite common practice in underdeveloped countries to receive the discarded pilot ladders from vessels. Then these people produce new ladders from old spare parts, which would be already executed their lifespan. There is no control mechanism for makers after passing the initial tests for approval of the ladders. Keeping the high-quality standard of products for a maker depends on maker's conscience. When vessel receives a new pilot ladder from chandlers, or other suppliers, a thorough check must be done for construction deficiency, and certificate check to ensure that it is fully compliant with SOLAS regulations. Estimating the quality of the pilot ladder is not an easy task, and requires experience to understand something is not right with the received pilot ladder. As per Figure 3.1 you could see a brand new pilot ladder is packed and ready to be delivered to a vessel; however the cracks on the steps could be visible. This shows that producer used defective steps while making the ladder. Producers should return their defective steps to their suppliers as per the procedure, though they could keep the defective steps with half of the price and use them randomly on their products. Since there is no control mechanism in the system, the quality of the product relies on the producers.

There is another element which affects the certification of the pilot ladder. A pilot ladder could be supplied to a vessel with a proper certificate, it could be in a good condition, a high-standard ladder, though after some time crew could make replacement on the ladder. As per the rules and regulations, if the crew repairs the existing pilot ladder, and the two steps of the repaired ladder is done different than the original construction the pilot ladder, then the ladder should be replaced and not to be used. However, if the replacement of steps done such way that looks like its original, crew could continue using the ladder. Once you remove the steps from the existing ladder, the certificate is no longer belongs to that ladder. Even though the official research show that 13.43 % of pilot ladders are non-compliant because of the crew repairs this percentage is actually around 60-85% (Rattray, 2021). Figure 3.5 shows the ladders which modified by crew. It is obvious that those ladders are not brand new, however different construction is visible, and they are still in use. People have to rely

on seamanship skills of crew while they use the pilot ladders. Unless crew was participated the practical deckhand course, integrity of the repaired pilot ladder is questionable.



Figure 3.4 : New ladder: Non-compliant



Figure 3.5 : After repairs (Palmers A., 2022)

3.2.2 Storage of pilot ladders

Keeping the pilot ladders in a good shape depends on crew. The longer pilot ladders exposed to UV, heat, cold, sea water, rain and other variants on deck, the shorter life pilot ladders will have. Proper training for crew members is vital. Once the pilot ladder used and stored in its position, ladders should be covered with tarpaulin covers to protect from the natural environment. Securing shackles could be covered with protection tapes to prevent touching directly to manilla ropes, because in a long-term metal contacts cause ropes to be rotten. To sum up crew should ensure, when not in use, pilot ladders is protected from water, paint, dampness, sunlight, and other medium likely to cause damage (Figure 3.6). As per the marine experts probability of non-compliance of this event is estimated as 10%.

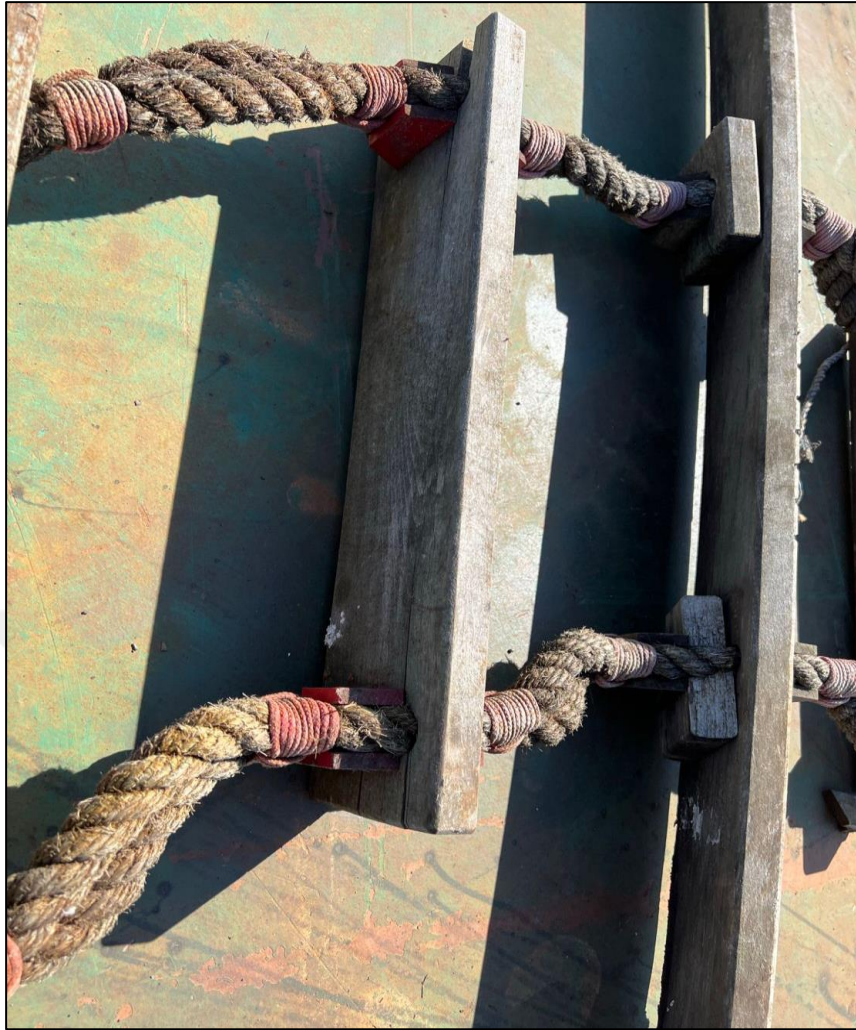


Figure 3.6 : Poor condition of ladder (exposed UV/sea/weather) (Palmers A., 2022)

3.3 Intermediate Events: Human Related

3.3.1 Crew checks and inspection

Each shipping company includes in their ISM code inspection of pilot ladders. Normally the pilot ladders and stanchions should be inspected weekly, monthly, and before each usage pilot ladders thoroughly. The inspection regime and records should be kept on board. Seafarers who are involved with the using, rigging the pilot ladders should receive the necessary training for inspection of the ladders. The Master is responsible of safe access to vessel, that means before each use, pilot ladder is free from wear or deterioration of the rope, damaged or cracked steps and spreaders, oil and grease (Figure 3.7, Figure 3.8, Figure 3.9). Furthermore, according to the companies' planned maintenance systems (PMS), every week, every month and every three months inspections should be carried out by crew. Each pilot ladder should be

clearly identified, tagged and certified accordingly to follow up the proper inspection records. It is vital that responsible officer has the proper training and knows how to inspect the pilot ladders. Laying-out the pilot ladder for close up inspection, looking for weak points, cracks and damages prevents breaking of the pilot ladder unexpectedly. Replacement of pilot ladder or steps could be found out in advance if the officer observes any crack on the steps and spreaders, or any deterioration of the ropes. For the combination, accommodation ladder condition has to be inspected as per PMS also as per MSC.1 Circ 1331 accommodation ladders must have a five yearly operational load test performance. Lubrication of moving parts, examination of wires and ropes, inspection of ant cracks and corrosion should be done by a trained person. Marine experts rated failure of this event as 40%.

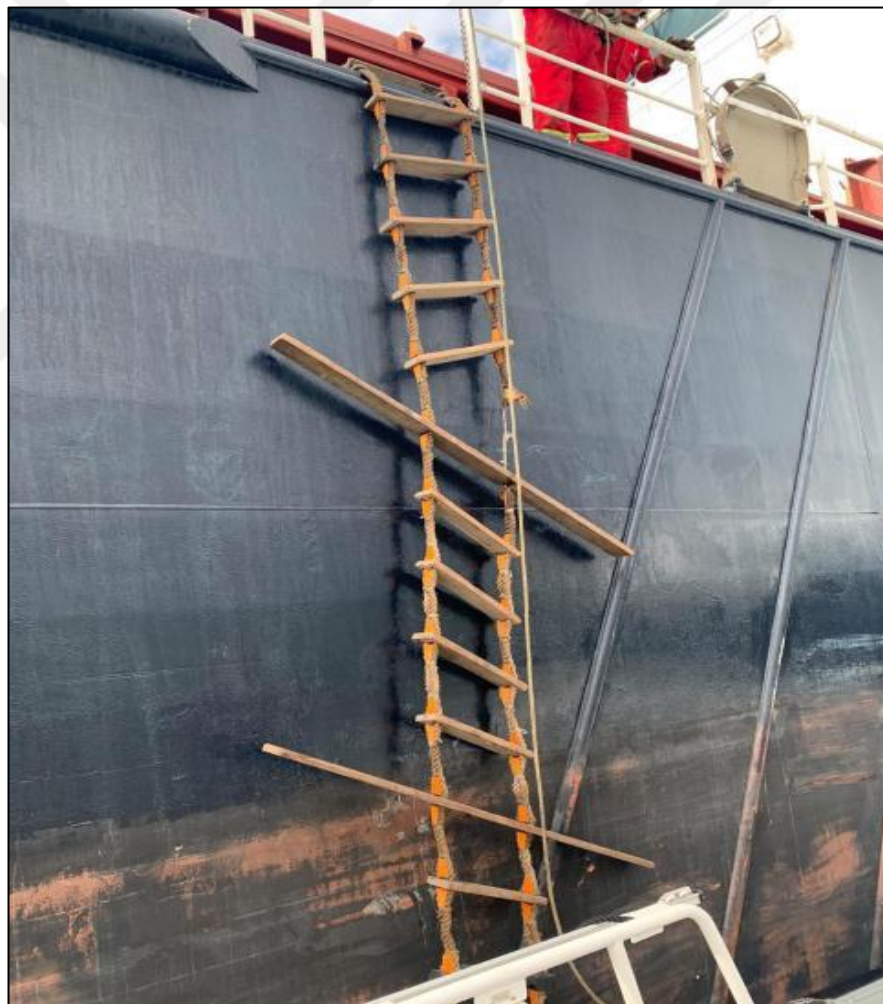


Figure 3.7 : Parted rope (Palmers A., 2022)



Figure 3.8 : Cracked step (Palmers A., 2022)



Figure 3.9 : Broken spreader (Palmers A., 2022)

As we mentioned that each shipping company includes in their ISM code inspection and maintenance schedule of pilot ladders, the failure of this intermediate event could be caused by:

- Lack of safety culture
- Lack of knowledge
- Lack of leadership or supervision
- Failure to follow rules and regulations
- Failure to follow maintenance instructions

Lack of safety culture could be caused of negligence of crew. Which means, in reality crew knows the procedures, though they do not follow them deliberately. As per fault tree analysis, the failure probability of this event was calculated as 0.06044, which is the highest factor among other events. Risk normalisation is the main reason of the lack of safety culture. Regular inspections, random checks on compliances would stress the crew to follow the requirements.

Lack of knowledge is one of the most common failure reasons on human element. There are plenty training facilities available within the industry, however there is no such practical course for seafarers on pilot ladders trainings. For seafarers most of the knowledge comes from experience, and since seafarers copy what they have seen, incorrect practices shared and followed as well. All shipping companies put into their ISM code shipboard familiarisation procedures, planned maintenance systems on equipments; however the guidance notes are usually insufficient. Moreover, even the companies comes up with perfect planned maintenance systems, crew still could fail to increase their knowledge because of negligence or language barriers. It would be advisable to prepare human friendly, easy to understand instructions on planned maintenance systems, so crew could follow the equipment inspection and maintenance procedures.

One of the other root cause for failure of crew inspection and maintenance; lack of supervision actually could eliminate the lack of knowledge. If the senior officers or company representatives could present good leadership skills, failure of the pilot ladder which is inspected and maintained by junior officers or ratings, could be

avoided. Being a role model for juniors, can actually increase the awareness of crew, and they could follow the good seamanship skills and share the knowledge with others.

As mentioned before, rules and regulations are clear to understand and each ship has a pilot boarding poster posted on the bridge (Figure 1.1). Inspections to be done onboard regularly, if there is a weak point on pilot ladders, this should be highlighted to senior officers. Replacement of the parts, or removing from service could be identified in advance to avoid any failures. Upon rigging of pilot ladders, before usage, another check should be done by a competent person, who is an officer, and condition to be reported to Master. In case of a replacement of any section of the pilot ladder, this should be done according to the regulations.

The last basic event diagnosed for failure of the crew inspection and maintenance is failure to follow maintenance instructions. Even though it represents mostly maintenance of combination ladders, pilot ladders and embarkations ladders could be maintained properly according to their manufacturer's instructions. For instance pilot ladders should be free of dirt, grease, oil, paint; so in case of a containment of those items, pilot ladder could be washed with fresh water and stored properly after drying the equipment. Moving parts of the combination ladders, wires should be maintained according to maker's instructions and company procedures in regular basis.

3.3.2 Proper rigging arrangements of pilot ladder:

As per the marine experts this safety barrier holds the highest risk among other events, which effect the half of the consequences. SOLAS 2012 regulations require a safe access at deck level. The ladder must be secured to a strong point on deck, and fixed hand hold stanchions to be provided. Securing the ladder by means of the ship side rails is not permitted.

The steps of the pilot ladders should be made by hardwood, made in one piece, free of knots. The four lowest steps may be of rubber, which also have sufficient strength and stiffness. Steps must have a non-slip surface, equally spaced that not less than 310mm or more than 350mm apart. Pilot ladders with more than five steps should have a spreader min 1.8m long, which prevents twisting of pilot ladder. Side ropes should be made of manila or other equivalent strength and characteristics. As long as the freeboard of the vessel is less than 9 meters, compliance is radically easy. However once combination ladder arrangement is required; securing access becomes

problematic, because regulations do not prescribe how the ladder is to be secured at deck level. According to defective ladder reports shows securing arrangements which are not in line with good seamanship (Figure 3.10). For a proper combination ladder, accommodation ladder shall be sited leading aft, the lower platform shall be secured to ship's side to ensure accommodation ladder held firmly against ship's side within the parallel body length of the ship. Also the lower platform should be minimum of 5m above sea level. If it is secured with magnets; two magnets required instead of one. Stanchions at the lower step / platform of the pilot ladder should be properly secured. In case of an existing trap door, person has to lean back to access to the trap door and the transition through trap doors must be provided with adequate handholds. Accommodation ladder angle (depending on the design) should not be more than 45°. Manropes required to be 28-32mm diameter. When the ladder is in use, the ropes cannot come in contact with the ship's hull. Metals used for clamping and fastening shall be corrosion resistant.

The use of mechanical pilot hoists is prohibited by SOLAS.

Most of the accidents and incidents could be prevented if crew members have enough training and understanding of handling the pilot ladders. Half of the time pilot ladders are not being properly rigged. This barrier was estimated as 49% (0,49) failure.



Figure 3.10 : Not secured on deck (Palmers A., 2022)

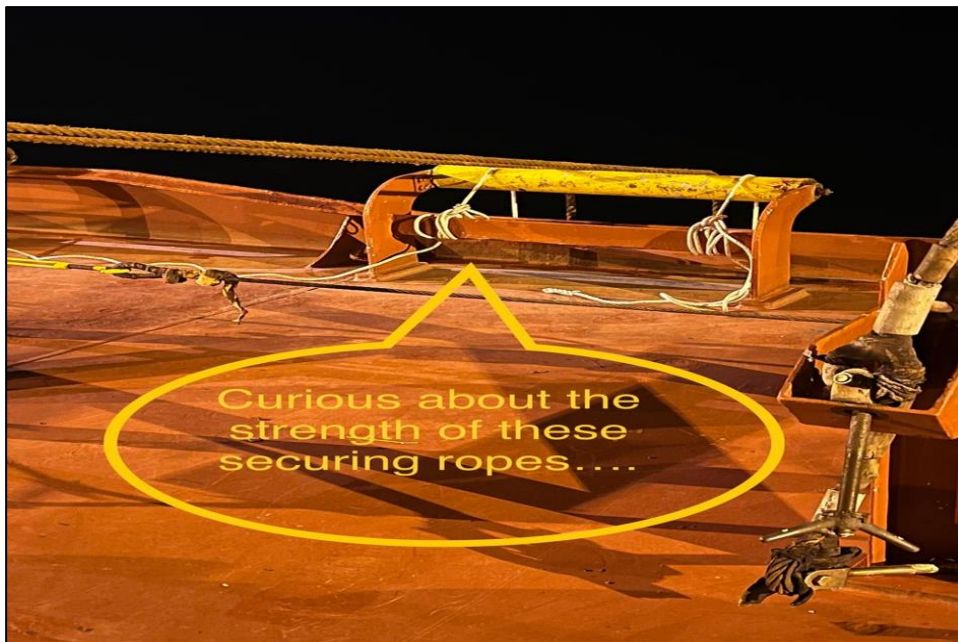


Figure 3.11 : Improperly secured (Palmers A., 2022)

There are five basic events diagnosed for proper rigging arrangements:

- Lack of safety culture (negligence)
- Lack of knowledge
- Lack of leadership/supervision
- Failure to follow rules and regulations
- Lack of communication

As per Figure 3.11, the pilot ladder was not secured on a strong point on deck, and the ropes which are used for securing the equipment is too thin to carry the weight of a person. There should be question mark on crew member who actually prepare the ladder, who inspected and reported to bridge that pilot ladder is rigged. This example shows not only a crew member failed to prepare the pilot ladder properly, but also other crew members who saw and did not see anything wrong with the arrangement. The risk of person falling from pilot ladder is normalised and neglected by crew members. Trainings to be provided for crew members how to prepare the pilot ladders. During monthly safety meetings, this should be highlighted to increase the awareness. Unsafe act/condition reports to be prepared and circulated among the fleet to avoid reoccurrence. Company representatives should focus on safety culture onboard during their attendances. Master and safety officer to ensure compliance during their safety rounds to keep up with the requirements.

Lack of knowledge is easy to solve, if proper trainings are carried out on board on regular basis. Upon boarding a vessel, shipboard familiarisation to be completed for each crew member. Their scope of job, expected duties are already mapped for them, however the work performance to be checked some time to time by seniors to ensure compliance. For example 3rd Officer or 2nd Officer might be on duty while vessel is approaching to pilot boarding ground. In case of those officers are performing those duties the first time, they might not be fully familiar with the requirements. In that case, any mistakes done by ratings might not be picked up by officers. At the same time, while combination ladders are being arranged, crew might forget to put the magnets, or they might not secure the ropes on sturdy ground on deck. Risk assessment, completion of company checklists, tool box meetings to be carried out in advance to understand the gaps on crew knowledge.

Lack of leadership/supervision is vital for proper arrangements on pilot ladders. There are many ratings serving onboard, who had not gone proper seamanship trainings to do the job. Officers need to be alerted, and guide the crew accordingly if any failure or weak signals sighted among them. Refreshment trainings could be provided for crew, who has difficulties for understanding the requirements. Such training records to be well maintained, and lessons learnt to be discussed among crew during safety meetings. Compliance could be checked during internal audits, drills, vessel visits by company representatives.

Failure to follow rules and regulations is one of the factors which leads to improperly rigged pilot ladders. Company checklists, critical operation checklists, safety assessments are the designated barriers created by companies to eliminate the problems of improper arrangements of pilot ladders. In case crew has the tick box culture, all checklists could be filled perfectly, without actually going through each item and ensuring the safe pilot ladder rigging procedures. These gaps could be identified during internal audits. The more assessments done for crew, the safer arrangements could be assured. Further trainings could be given to crew. There are online courses, training programmes available for crew. Companies to ensure there is enough budget for training purposes. Some of the training companies such as VIDEOTEL, KARCO, OCEAN TECHNOLOGIES, or class training facilities are very helpful to understand the requirement, and crew could benefit from the videos

created by them. Circular letters, safety bulletins could be prepared and shared within the fleet to ensure crew members comply with rules and regulations.

Lack of communication is the last basic event diagnosed for improper pilot ladder arrangement. It is a requirement to officer's supervision on top of the pilot ladder with communication equipment to contact with bridge. Furthermore, it is very common to have misunderstandings between pilot and vessels. For instance, pilot might ask certain distance from water level, though this could be misunderstood by bridge team, or among vessel personnel while relaying the message to crew.

3.3.3 Failure to use personal protective equipment

Using proper personal protective equipment (PPE) will not eliminate the fall from pilot ladder, though it could reduce the severity of consequences. Wearing a lifejacket with a luminous device and AIS beacon with automatic triggering, working gloves with grip, pants and long-sleeved jacket, helmet, shoes with good tread and slip resistant soles, and portable lamp will reduce the severity of injuries. Fall preventing devices also quite useful equipment, which will prevent falls.

There might be two reasons of PPE failure; one is being lack of purchasing and PPE not available onboard, and the other reason is crew neglecting to use PPE. With a proper planning, crew could assure there is always sufficient PPE available onboard. Enough stocks can be ordered in advance during convenient port calls. On the other hand, it is hard to achieve full compliance when there is a crew member who chooses not to wear lifejacket while climbing down from a pilot ladder. Not only climbing up or down from the pilot ladder, but also while arranging combination ladder; crew needs to use full PPE to prevent themselves falling down and in case of an accident to avoid serious consequences. Stop the job authority, raising hazardous occurrences, harsh punishments, such as not to be re-employed by company, could prevent crew negligence on usage of PPE.

3.3.4 Fatigue

It has been known that pressure on crew members constantly increasing nowadays. Charterers or owners request to keep the vessel running constantly, effects the crew members in negative ways. At the same time, frequent vessel turnaround requirements in ports, and not having enough pilots to engage with the pilotage leads to fatigue on

pilots. Even though it is known that Master has the authority to stop the vessel's operation if he/she sees fit to give enough rest for crew, in practical all Masters avoid to use that call. Crew members always having questions about job security, being blamed by company, not to be reemployed by the company if they raise their voices about being tired. Larger corporate companies might have flexible understandings and have ways to deal with charterers to protect their crew; however small companies are afraid to lose the client, and they tend to provide all requests in tight vessel schedule. It should be well known that if it is required, all operations could be stopped in order to give compensatory rest for crew. It is Master's responsibility to ensure his/her crew is well rested. If a person is too tired to focus, it is possible to make mistakes, lose balance, and have an accident. Fatigue should be always evaluated, while preparing risk assessment before using the pilot ladder. Also pilot should have right to reject the scheduled vessels, if they see themselves not fit for duty, which could prevent undesired accidents.

3.4 Quantitative Analysis of Basic Events

According to U.S. Bureau of Labour Statistics, 21.3 deaths year on average occurs because of fall from pilot ladders (Gaillard, 2021). As an initiating event fell from pilot ladder calculated as 0.2115% (0.0215311005) based on 1.8 pilot deaths among 8360 pilots, according to 2005-2021 accidentology results.

Fault tree analysis methodology used to visualise the system weakness, failures and to calculate the probability of each basic events (Figure 3.12). The experts' linguistic expressions taken into consideration while evaluating the fuzzy sets (Table 3.1). Each experts' opinion weighted according to their professional experience (Table 3.2, Table 3.3).

In order to evaluate the logic gates, below formulas have been applied (Table 3.4) :

AND Gate

$$P_{AND} = P(A) \times P(B) \times \dots \times P(N) \quad (3.1)$$

where $P(A), P(B), \dots, P(N)$ are the probabilities of the input events.

OR Gate

$$POR=1-(1-P(A))\times(1-P(B))\times\cdots\times(1-P(N)) \quad (3.1)$$

where $P(A), P(B), \dots, P(N)$ are the probabilities of the input events.

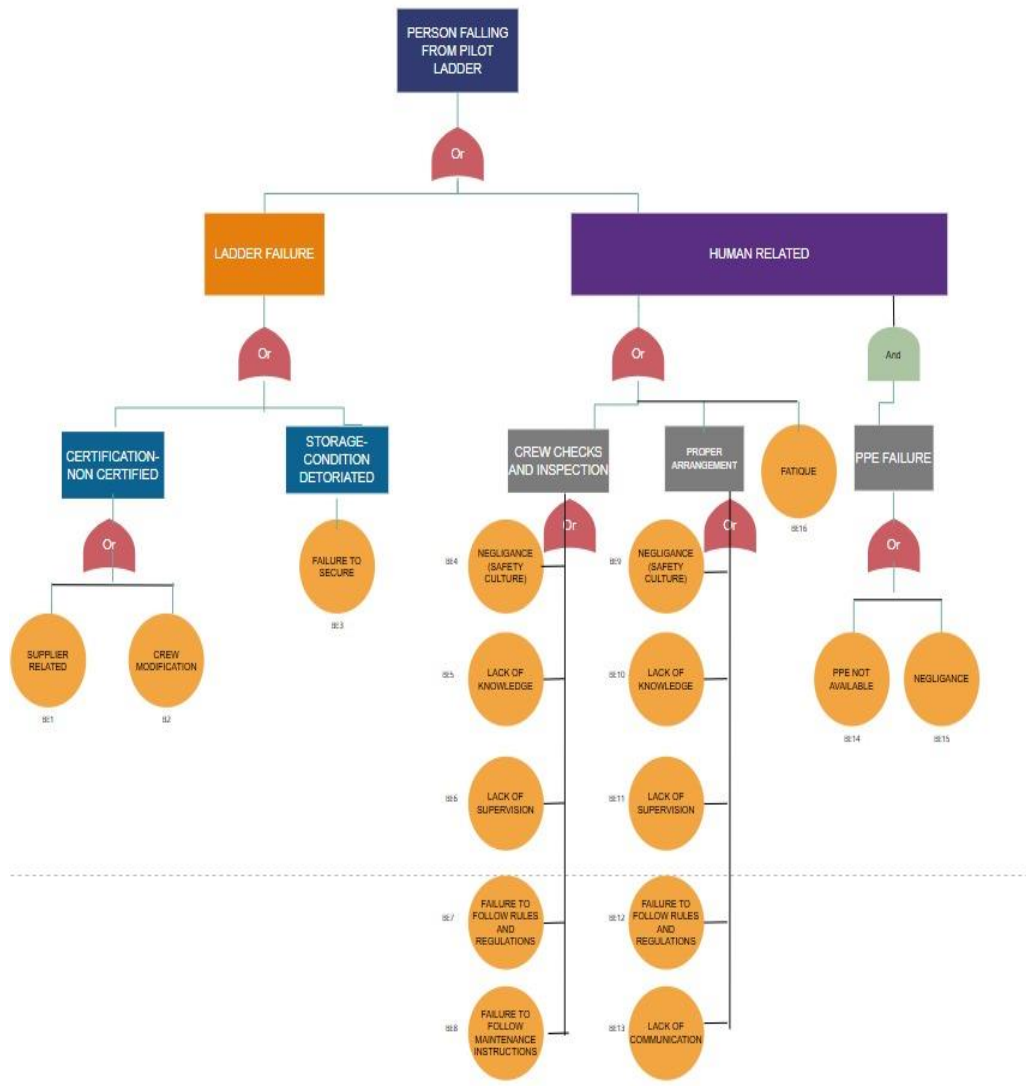


Figure 3.12 : Fault tree

Table 3.1: Linguistic expressions and corresponding fuzzy numbers.

Linguistic expression	Fuzzy sets
Very Low (VL)	(0,0,0.1,0.2)
Low (L)	(0.1,0.2,0.2,0.3)
Mildly Low (ML)	(0.2,0.3,0.4,0.5)
Medium (M)	(0.4,0.5,0.5,0.6)
Mildly High (MH)	(0.5,0.6,0.7,0.8)
High (H)	(0.7,0.8,0.8,0.9)
Very High (HV)	(0.8,0.9,1,1)

Table 3.2: Expert classification parameters and scores.

Parameters	Classification	Score
Professional Position	Academician	5
	Company operations manager	4
	Company deck inspector	3
	Master	2
	Chief officer	1
Sea service time (year)	≥ 16	5
	11 - 15	4
	6 - 10	3
	3 - 5	2
	≤ 2	1
Shore service time (year)	≥ 26	5
	16 - 25	4
	11 - 15	3
	6 - 10	2
	≤ 5	1
Educational level	PhD	5
	Master	4
	Bachelor	3
	HND	2
	School Level	1

Table 3.3: Anonymous consulted expert and their weights.

No of experts	Professional position	Sea service time (year)	Shore service time (year)	Education level	Weighting factor	w
1	Academician	3-5	11-15	PhD	14	0.11
2	Master	3-5	≤ 5	MSc	13	0.10
3	Academician	≤ 2	≤ 5	bachelor	15	0.12
4	Academician	≤ 2	≤ 5	bachelor	13	0.10
5	Operations manager	11-15	11-15	MSc	15	0.12
6	Operations manager	≥ 16	16-25	PhD	16	0.13
7	Master	6-10	≤ 5	MSc	9	0.07
8	Academician	6-10	≤ 5	bachelor	13	0.10
9	Deck inspector	3-5	6-10	PhD	12	0.09
10	Chief officer	3-5	≤ 5	bachelor	7	0.06

Table 3.4: Probability of Basic Events

BEs	FP of BEs	BEs	FP of BEs
BE1	0.00153	BE09	0.04179
BE2	0.00595	BE10	0.03668
BE3	0.00218	BE11	0.03323
BE4	0.06044	BE12	0.01000
BE5	0.04156	BE13	0.00142
BE6	0.02058	BE14	0.00136
BE7	0.03373	BE15	0.03663
BE8	0.05102	BE16	0.01260

4. RESULTS AND DISCUSSIONS

Fault Tree Analysis (FTA) is a methodology, which enables us to analyze the system failures, and helps to show how system fails and how to reduce risk graphically. Usage of the pilot ladder is a critical operation on board. When the pilot ladder is in use, embarking and disembarking safely, must be the high priority. The appliances shall be kept clean, properly maintained, and stowed, to be inspected regularly to make sure they are safe to use. Regulations and recommendations should be considered for a fully compliant pilot ladder. Embarkation point should be well lit, no fendering or permanent structure around the pilot ladder, no overboard discharge near the pilot ladder should be kept in mind during person transfer via pilot ladder. At least an officer and one more crew member should be present with a radio at the gangway area, in case of an emergency to be able to contact with the bridge and act promptly. The lifebuoy with self-igniting light is mandatory near the pilot ladder area as per the SOLAS.

Below are the results from fault tree analysis, while diagnosing the top event:

BE1- Supplier provided non-certified pilot ladder:

$$P(BE1)=0.00152999620272502$$

BE2- Crew modified the pilot ladder:

$$P(BE2)=0.00595123467879078$$

$$P(BE1 \text{ OR } BE2)=P(BE1)+P(BE2)-P(BE1) \times P(BE2)$$

$$P(BE1) \times P(BE2)=0.00152999620272502 \times 0.00595123467879078 \approx 0.0000091$$

$$P(BE1 \text{ OR } BE2)=0.00152999620272502+0.00595123467879078-0.0000091$$

$$P(BE1 \text{ OR } BE2) \approx 0.0074721 \quad (4.1)$$

The intermediate event of a pilot ladder, which is non-certified calculated as $0.0074721 = \%0.747$

In this case, intermediate event of equipment related failure could be calculated as:

$$P((BE1 \text{ OR } BE2) \text{ OR } BE3)=0.00747+0.00218497716945308-(0.00747 \times 0.00218497716945308)$$

$$P(BE1 \text{ OR } BE2) \times P(BE3)=0.00747 \times 0.00218497716945308 \approx 0.0000163$$

$$P((BE1 \text{ OR } BE2) \text{ OR } BE3)=0.00747+0.00218497716945308-0.0000163 \approx 0.0096387$$

$$P((BE1 \text{ OR } BE2) \text{ OR } BE3) \approx 0.0096387 \quad (4.2)$$

Pilot ladder failures, which are resulted because of equipment related failures founded that %0.964.

The first human related failure, crew checks and maintenance probability (BE3,..., BE8) calculated as:

$$P(BE4 \text{ OR } BE5 \text{ OR } BE6 \text{ OR } BE7 \text{ OR } BE8)=1-((1-P(BE4)) \times (1-P(BE5)) \times (1-P(BE6)) \times (1-P(BE7)) \times (1-P(BE8)))$$

$$P(BE4 \text{ OR } BE5 \text{ OR } BE6 \text{ OR } BE7 \text{ OR } BE8)=1-((1-0.06043644126169854) \times (1-0.04156117497520598) \times (1-0.020576972805433195) \times (1-0.033732124988504954) \times (1-0.05102302218641715))$$

$$1-P(BE4)=1-0.06043644126169854=0.9395635587383015$$

$$1-P(BE5)=1-0.04156117497520598=0.958438825024794$$

$$1-P(BE6)=1-0.020576972805433195=0.9794230271945668$$

$$1-P(BE7)=1-0.033732124988504954=0.966267875011495$$

$$1-P(BE8)=1-0.05102302218641715=0.9489769778135829$$

Multiplying these findings:

$$0.9978150228305469 \times 0.9395635587383015 \times 0.958438825024794 \times 0.9794230271945668 \times 0.966267875011495 \times 0.9489769778135829 = 0.8069$$

Finally subtracting from 1:

$$P(\text{Crew Checks and Maintenance})_{OR}=1-0.8069=0.1931 \quad (4.3)$$

Crew checks and maintenance failure probability calculated as %19.31 accordingly.

The second human related failure, proper rigging arrangement calculated as:

$$P(\text{Proper Arrangements})_{OR}=$$

$$1-(1-P(BE9)) \times (1-P(BE10)) \times (1-P(BE11)) \times (1-P(BE12)) \times (1-P(BE13))$$

POR

$$=1-(1-0.04179102838863597) \times (1-0.036677328829012555) \times (1-0.03322637667441679) \times (1-0.010004236546143378) \times (1-0.001422737794273658)$$

$$1-P(BE9)=1-0.04179102838863597=0.958208971611364$$

$$1-P(BE10)=1-0.036677328829012555=0.9633226711709874$$

$$1-P(BE11)=1-0.03322637667441679=0.9667736233255832$$

$$1-P(BE12)=1-0.010004236546143378=0.9899957634538566$$

$$1-P(BE13)=1-0.001422737794273658=0.9985772622057263$$

Multiplying these findings:

$$0.958208971611364 \times 0.9633226711709874 \times 0.9667736233255832 \times 0.9899957634538566 \times 0.9985772622057263 = 0.8818$$

Finally subtracting from 1:

$$P(\text{Proper Arrangement})_{OR}=1-0.8818=0.1182 \quad (4.4)$$

Intermediate event of proper pilot ladder rigging arrangements calculated as %11.82 accordingly.

The third human related intermediate event, personal protective equipment failure calculated as:

$$P(\text{PPE Failure})_{OR}=1-(1-P(BE14)) \times (1-P(BE15))$$

$$POR=1-(1-0.0013641552942552084) \times (1-0.036633156748575126)$$

$$1-P(BE14)=1-0.0013641552942552084=0.9986358447057448$$

$$1-P(BE15)=1-0.036633156748575126=0.9633668432514249$$

Multiplying these findings:

$$0.9986358447057448 \times 0.9633668432514249=0.9621$$

Subtracting from 1:

$$POR=1-0.9621=0.0379 \quad (4.5)$$

Failure of the PPE usage calculated as %3.79.

All human related failure probabilities calculated together as:

$$P(\text{Human Related})_{\text{OR}} = 1 - (1 - P_1) \times (1 - P_2) \times (1 - P_4) \times (1 - P_{\text{AND}})$$

$$P(\text{Human Related})_{\text{OR}} =$$

$$1 - (1 - 0.1931) \times (1 - 0.1182) \times (1 - 0.0125956196910476) \times (1 - 0.0379)$$

$$1 - 0.1931 = 0.8069$$

$$1 - 0.1182 = 0.8818$$

$$1 - 0.0125956196910476 = 0.9874043803089524$$

$$1 - 0.0379 = 0.9621$$

Multiplying these values:

$$0.8069 \times 0.8818 \times 0.9874043803089524 \times 0.9621 = 0.7047$$

Subtracting from 1:

$$P(\text{Human Related}) = 1 - 0.7047 = 0.2953 \quad (4.6)$$

The human-related failure probability (with the combination of OR and AND gates) is approximately 0.2953, or 29.53%.

In order to calculate our top event, person falling from pilot ladder, calculated as below:

Equipment related failure: P1

Human related failure: P2

Probability of Top Event with OR gate:

$$P(\text{Fall}) = 1 - (1 - P_1) \times (1 - P_2)$$

$$P_{\text{fall}} = 1 - (1 - 0.0096387) \times (1 - 0.2953)$$

$$1 - 0.0096387 = 0.9903613$$

$$1 - 0.2953 = 0.7047$$

Multiplying these values:

$$0.9903613 \times 0.7047 = 0.696703265491$$

Subtracting from 1:

$$P(\text{Fall}) = 1 - 0.696703265491 = 0.303296734509 \quad (4.7)$$

The probability of a person falling from the pilot ladder (based on the OR gate logic between equipment failure and human-related failure) is approximately 0.3033, or 30.33%.

As per the FTA created for this thesis, the highest risk was found crew checks and maintenance were not followed on board regularly mostly because of the crew negligence. The minimum risk calculated as personal protective equipment not being available on board while understanding the root causes of pilot ladder usage failures. Total failure probability of person falling from pilot ladder was calculated as %30.31 according to fault tree analysis.

Half of the incidents and accidents could be prevented if crew is well trained and knows how to inspect and maintain the pilot ladders. If responsible officer carries out his/her duties as per company procedures, rules, and regulations; any deficiency could be found in advance and be rectified before any person steps on the pilot ladder.



5. CONCLUSION

After 800 years of using the similar equipment for person transfer on board, it is surprising that people still die or injured. Using pilot ladder is a high-risk operation, proper risk assessment must be in place before using the pilot ladder. Apart from the mentioned barriers, there are uncontrollable events like weather and sea condition, visibility, temperature, humidity should be taken into consideration while assessing the risk. It is to be noted that each usage of the equipment has unique scenario. The risks while crew checking the drafts in port contains falling from height into hard surface/jetty, though the risk while pilot is boarding to vessel and falling into sea, vessel's manoeuvring capacity, draft restriction involves other elements to be analysed. Regardless of a task before each usage of the pilot ladders, tool box meeting to be carried out and all risks to be analysed.

Shipping companies need to make sure that they supply to the vessel trustworthy, certificated products, and they should have a system for training their crew for proper handling, storage and securing of pilot ladders. From the vessel's side Master has to ensure that condition of the pilot ladders are in good shape, without any crack, damage, oil or grease, securing arrangements are met with the regulations. All ladders onboard should be clearly identified with tags, certified and inspection records should be well maintained. During person transfer, an experienced officer and at least one more crew member stay stand-by with a radio in case of an emergency. Communication with bridge should be established before a person steps on the ladder. For a safe access well-lit deck, no obstruction on the pilot ladder area must be provided. From the person, who has to use the pilot ladder, he/she has to use proper personal protective equipment for safe operation. The people who design the ships don't have to sail on them, as a seaman we are the ones who should encourage the good seamanship and follow the rules and regulations.

The gap in inspection of suppliers to be filled. Random checks, annual audits or inspections for the suppliers who actually makes the product, could be arranged by authorities. Even though the certification process is quite tough when makers apply to

obtain it, there is no guarantee that makers would continue producing the high quality of pilot ladders within the industry.

Once the pilot ladder is onboard, proper checks to be done to ensure the ladders are not defective. Clear instructions to be written in company Safety Management Systems (SMS) with regards to lifespan of pilot ladders. Instead of replacing the steps, keeping spare non-used pilot ladders should be put into regulations. Considering the price of the pilot ladder, this enforcement could not harm the owners drastically. Until this rule becomes practice, proper deckhand courses to be provided for crew in order to increase knowledge about the pilot ladders.

Crew inspection and maintenance schedule should be thoroughly followed, since this human related factor was diagnosed as the highest, %19.31, failure of pilot ladder. Senior officers must ensure the compliance. Planned maintenance schedules required to be regularly checked by senior management team to confirm all inspections done according to plan. During inspections, audits, and vessel visits, planned maintenance records to be verified. Random checks of comparison of actual conditions of pilot ladders and maintenance records to be carried out. In that case it could be easily identified if crew is following rules and regulations or not.

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