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MASTER’S DISSERTATION

STRATEGIE OF IMPLEMENTATION OF RISK MANAGEMENT FRAMEWORK IN PORT TERMINAL - CASE STUDY - THE PORT OF MATOLA

BY

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Maputo

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STRATEGIE OF IMPLEMENTATION OF RISK MANAGEMENT FRAMEWORK IN PORT TERMINAL - CASE STUDY - THE PORT OF MATOLA

Dissertation presented to the Faculty of Engineering in Partial Fulfillment of the Requirements for obtaining the academic title of Master in Health, Safety and Environment, by UEM.

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Recommendation of the board of examiners

The undersigned certify that they have read and recommend to the Faculty of Engineering a thesis entitled "**Strategie of implementation of risk management framework in port terminal - case study - the port of Matola"** submitted by **Júlio Douglas Mandlaze**, in partial fulfillment of the requirements for the degree of Master Program in **Health, Safety and Environment Engineering.**

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Declaration

I, **Júlio Douglas Mandlaze**, declare that this end-of-course work was exclusively carried out by me. The same is now submitted in accordance with all the requirements for obtaining a Master's degree in Health, Safety and Environment at Eduardo Mondlane University.

………………………………………………………….

(Júlio Douglas Mandlaze)

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Abstract

The Ports present a key element of the involved shipping networks to support the connectivity of the globally markets. Therefore, it is crucial to carry an effective safety assessment of the ports to ensure the robustness and sustainability. This thesis proposes a risk management framework (RMF) to address issues encountered during the risk analysis process in the Port of Matola. The RMF starts with Hazard identification (HAZID), that was conducted through an appropriate literature review, observations, and conversation with Port specialist at Port of Matola during the internship. The several hazards identified were organized in correspondent risk criteria, and seven risk criteria were idenfied namely: Environmental, Port Security, Human Related Error, Technical, Safety Management, Business and Natural Disaster Risk Criteria. In each risk criteria there are several hazards related. However, the order in which design decisions or tactics are incorporated within a company has a significant impact on how well the available bugged is addressed in the architecture solution for risks. As a result, in the second phase of the proposed RMF of this research a risk assessment was conducted. The principle of the risk assessment is to organize the risk criteria in a sequence of priority. The Analytical Hierarchal Process (AHP) method was used for determining the relative weights of the risk criteria identified and prioritize. The five high weight risk criteria were selected to proceed in the next steps of the RMF. The hazards from each risk criteria were treated also in the AHP environment, the objective was to find the high weight hazards related to each top five risk criteria. The priority hazards from each risk criteria were treated has the top event to be used to conduct the FTA in subsequent step from the RMF. Nevertheless, because Port security is one of the major concerns for Port authority, its crucial to address the level of security of the port of Matola and this were incorporated in the RMF. The level of security of Ports are based on ISPS code assumption, and to access this level, the Security Risk Factor Table (SRFT) and Trapezoidal Fuzzy Number (TFN) were the support tools, and once applied the level of security for port of Matola were found to be moderate as per ISPS code. In the RMF, the mitigation alternatives are the addressed as the last step. For mitigation alternatives the international standards, ISO and international security codes applied in Port terminals were the focus for mitigation alternatives of the risk criteria.

Keywords: Risk Management Framework, HAZID, AHP, FTA, Port Security.

Resumo

Os Portos representam um elemento chave das redes de navegação envolvidas para apoiar a conectividade dos mercados globais. Portanto, é crucial realizar uma avaliação de segurança efectiva dos portos para garantir a robustez e sustentabilidade. Esta tese propõe um Quadro de Gestão de Risco (QGR) para abordar questões encontradas durante o processo de análise de risco no Porto da Matola. O QGR começa com a identificação de perigos (HAZID), que foi realizada através de uma revisão de bibliográfica apropriada, observações e conversas com especialistas portuários no Porto da Matola durante o estágio. Os vários perigos identificados foram organizados em critérios de risco correspondentes. Foram identificados sete critérios de risco, nomeadamente: Critérios de Risco Ambiental, Segurança Portuária, Erro Humano, Técnico, Gestão de Segurança, Empresarial e de Desastres Naturais. Em cada critério de risco existem vários perigos relacionados. No entanto, a ordem na qual as decisões ou tácticas de design são incorporadas em uma empresa tem um impacto significativo sobre o quão bem o dinheiro disponível é tratado na solução de arquitetura para riscos. Como resultado, na segunda fase do QGR proposto para esta pesquisa foi realizada uma avaliação de risco. O princípio da avaliação de risco é organizar os critérios de risco em uma sequência de prioridade. O método Analytical Hierarchal Process (AHP) foi utilizado para determinar os pesos relativos dos critérios de risco identificados e priorizados. Os cinco critérios de alto risco de peso foram selecionados para seguir nas próximas etapas do QGR. Os perigos de cada critério de risco também foram tratados no ambiente AHP, o objectivo era encontrar os perigos de alto peso relacionados a cada um dos cinco principais critérios de risco. Os perigos prioritários de cada critério de risco foram tratados como o evento de topo a ser usado para conduzir o FTA na etapa subsequente do QGR. No entanto, porque a segurança portuária é uma das principais preocupações da autoridade portuária, é crucial abordar o nível de segurança do porto da Matola e isso foi incorporado no QGR. O nível de segurança dos Portos baseia-se no quadro do código ISPS, e para aceder a este nível, a Tabela de Fatores de Risco de Segurança (SRFT) e o Trapezoidal Fuzzy Number (TFN) foram as ferramentas de apoio, e uma vez aplicado o nível de segurança para o porto da Matola foram considerados moderados de acordo com o código ISPS. No QGR, as alternativas de mitigação são abordadas como último passo. Para alternativas de mitigação as normas internacionais, ISO e códigos internacionais de segurança aplicados em terminais portuários foram o foco para alternativas de mitigação dos critérios de risco.

Palavras-chave: Quadro de Gestão de Risco, HAZID, AHP, FTA, Segurança Portuária.

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1. Introduction

1.1. Generality

The size and complexity of the activities of Port Terminal and the nature of the products handled make the analysis of hazards and their control in structured framework a priority procedure for the sustainable management of these infrastructure.

The mobilization of products in Ports requires the mobility of land and marine transport, which converge to the unloading and loading process.

The impacts that can arise from hazards generated by the operations of Port Terminals can be local, regional, and socio-economic in scope that is reflected at national and international levels.

This thesis focuses on the assessment of hazards and management on basis of risk management framework to be applied for Port of Matola in Mozambique. The Port of Matola handles cargoes of minerals (coal and magnetite), cereals, aluminum and alumina and fuels. The logistics and operations for handling each type of cargo are carried out at the respective docks, some under concession and some carried out by the Port authority. The present thesis will focus on the risk assessment of the operationalization of the fuel terminal under the concession of Port authority – Ports and Railways from Mozambique (CFM) – Direction of Matola Port (DPM), where the author is in an internship.
After recognizing the hazards, internal or external hazards, that comes from Port operationalization, a systematic approach for prioritization of this hazards will be conducted and then, organize in scale of the most relevant to the less to give consistence for Port professionals judgments decision, for prevent the risk related to each hazard. For hazard prioritization will be using a method of mathematical thinking called Analytical Hierarchical Process (AHP), developed in past 65 year by Thomas Saaty. The tool become a great for decision making using the prioritization assumption (Saaty, 1990)**.**

The terminals of Port of Matola are marine terminal, and they comprise of grain terminal, mineral (coal and chromite) terminal, aluminum terminal and fuel terminal. The last terminal is the only non-concession terminal in Matola Port, it is operated and managed by the public company CFM through the direction of DPM. Beside fuel terminal, the DPM is responsible for safety, hygiene, protection, traffic controls of the Port areas not under concession.

To achieve the objectives that will be proposed, some health, safety and environment (HSE) analysis tools will be used to identify, quantify, and qualify the hazards for Port of Matola. The tools will be integrated in a risk management framework proposed to be applied in Port of Matola.

1.2. Problem statement

The complexity and need to supply national and international markets are centered on the logistical and operational capacity of marine terminals. The structural organization of the continents allows certain countries to be located on the coast and others within the continents, however, because the world is a global network and with an industry and individual needs fed by this global network of exchanges, offshore countries constitute the entry and exit door for various products used to supply the needs locally and upstream of the ports.

The Ports of different countries are continuously in competition to achieve more and more gain through more and more demand, which leads to each one of them looking to improve their capacity. These improvements in terms of capacity and the provision of services also lead to an increase in the Port's operational capacity. However, the operationalization of Ports also contributes to the increase in negative experiences.

The activities in Port of Matola are high-risk activity due to the types of products handled such as, fuels that are toxic, volatile and at top of the chain of explosive substances, handling of coal/chromite ores that are reduced to fine particles that are easily suspended in the atmosphere in fine dusty particles. The dusty is susceptible to inhalation, adsorption on the skin, in addition to generating dust curtains that obstruct visibility and this dust is also deposited on all infrastructures in the port and surrounding areas that include the sea and possible residencies and communities close to Port of Matola. The movement of this products is made by means of transport (fuel ships, trucks, trains) and, the mechanisms used for loading and unloading fuels. All of this means are susceptible to failure, to clash in case of traffic in sea or land in the Port jurisdiction. Therefore, the risks related to Port activity must be integrated into a risk management system to evaluate the relevant risks to take prevention action and develop a conscious methodology for mitigation.

To define the circumstances of the thesis project and support the objectives of the work the following five questions are asked – ‘What? What? What? What? How’ ('W.W.W.W.H.') (Table.1)?

Table 1- Project circumstances questions.

Order of Questions	Questions Designations	Application
What	What are the reasons to access risk related to Port Terminals?	Sustainable Management.
What	What are the risks associated with Port Terminals?	Anything that can cause harm to people, property, products, environment, and reputation.
What	What are the tools that can be used to evaluate the risks?	To find the best tools for quantitative and qualitative analysis.
What	What are the quality, safety and security management standards (QSSMS) that can be integrated in Port Terminals?	Review and propose QSSMS that can be used in Port.
How	How can the identified risk be mitigated?	Select Strategies to control hazards/risks.

1.3. Justification

In Mozambique, there is a little literature on risk management in national ports, which somehow makes the present thesis a contribution to the knowledge of risks associated with Port activity, whose use may be extremely relevant for the managers of Port of Matola as well as for other Ports that share the same business at national level so that they have access to knowledge of the hazards, internal and external, that may impact port activity and bringing negative impact on the environment, work, infrastructures, the society in which it is inserted, relations between regions in the event of non-operation of the port due to accidents that can be mitigated when there is prior knowledge of these, and also contribute to an awakening of interest by the academic community in bringing more studies related to port activity in Mozambique.

1.4. Objectives

1.4.1. General objective:

- To propose a risk management framework for Port of Matola in Mozambique.

1.4.2. Specific Objectives:

- To propose a novel/model for risk prioritization.
- To prioritize the risk.
- To conduct Failure Tree Analysis (FTA) of the high-level risks.
- To propose mitigation alternatives for the identified risks.

2. Literature Review

Supply chain management is responsible for the movement of materials all the way from initial suppliers through to final customers. Customers of the logistic supply chain are interested that then delivery of goods takes place safely and within the time provided. It is therefore necessary to study the reliability of logistics chains to better express their operating capacity, operating during a given period, in specified exploitation conditions. If some elements of the logistic supply chain become inoperable, it can remain functional even though with low operating performance, in this sense one of the most frustrating problems when dealing with reliability, it's before, dealing with risks knowing that they come in so many different forms delay (Rosca, Rosca, & Rusca, 2014).

According to (Fuentes Bargues, Gonzales Cruz, Gonzales Gaya, & Baixauli Perez, 2017)**,** risk is understood as the possibility that someone or something is adversely affected by a hazard, otherwise can be defined as a measure of the severity of a hazard or the measure of the probability and severity of adverse effects. They can appear at any point in a Port logistic system, they can interrupt the supply of raw materials or products, they can cause demand fluctuations (peak or collapse), inventory problems (lack or crowding) and dispatch delay.

For (Rosca, Rosca, & Rusca, 2014), to support decision-making on design and operation, the risks must be analyzed, and the analyses include identification of hazards and threats, cause analyses, consequence analyses and risk description.

(Aven & Vinnem, 2007)**,** stated that, the totality of the analyses and the evaluations of hazard and risk are referred to as risk assessments. Risk assessment is followed by risk treatment, which is a process involving the development and implementation of measures to modify risk, including measures designed to avoid, reduce, transfer, or retain risk. Risk transfer means sharing with another party the benefit or loss associated with a risk. It is typically affected through insurance.

(Tixier, Dussere, Salvi, & Gaston , 2002)**,** also supports the necessity of previous risk assessment study in industrial plants by saying that, to face up to major accidents, a previous analysis should be done. The forward-looking risk analysis allows to do an exhaustive identification of potential hazardous sources to prevent accident scenarios and to assess potential impact on human, environmental and equipment targets to propose prevention or protection

Risks can range on a scale from small delay to a natural disaster, from short term to a permanent damage, with effects localized on a part of a supply chain or affecting the whole chain activity (Rosca, Rosca, & Rusca, 2014),

Many decisions are based on individual conscious in many companies, mostly from top management, nevertheless this decision can be accompanied by inconsistencies that may affect the manager's defense in the event of a negative event. (Akaman, 2016), on is work stated that, pure quantitative methodology may fail in safety precautions subject due to involving intangible factors such as emotional behavior, motivation, discipline, social interactions etc. Therefore, it's important to address qualitative based approach and transform it a quantitative data to support decision making using mathematical models in risk assessment.

For (Rosca, Rosca, & Rusca, 2014), because accidents in Ports are of extreme complexity and severe, it requires the implementation of risk management system together with mathematical models to criticize emotional thinking and reduce inconsistencies for management decision.

2.1. Risk Management

Risk management is an integral aspect of a goal-oriented regime. It is acknowledged that risk cannot be eliminated but must be managed. Is the proper framework for obtaining high levels of performance. The Risk management covers all coordinated activities designed to direct and control an organization about risk, whereas the risk management process is the systematic application of management policies, procedures, and practices to the tasks of establishing the context, assessing, treating, monitoring, reviewing, and communicating risks (Aven & Vinnem, 2007)**.**

The risk management allows Port administration to take appropriate measures to reduce the consequences of a risk, to provide a good reliability of the logistic system or to design a resilient one (Rosca, Rosca, & Rusca, 2014)**.**

Some organizations are very interested in the question of port security. The International organizations such as IMO and ILO interest in current research to develop mandatory regulation and advisory duties for the departure country, the ship, the host country, the entire operationalization of port logistic. These regulations and advisory duties have benefits in security and environment for the operations, port security, the ship, infrastructure, the environment, the, people directly involved and not directly involved, communities, country, etc. Thus, it's important to look at these advisory duties and mandatory regulation to introduce in the risk management framework from the company.

2.2. Model to Apply in Risk Management Framework

Several models can be applied in the risk management framework, and they are the traditional risk assessment approaches such as Event Tree Analysis (ETA), Fault Tree Analysis (FTA), Failure Mode and Effects Analysis (FMEA), risk assessment matrix, etc.

These models have been criticized with two major deficiencies by (Yang et al. 2009; Cao and Lam 2019)**,** by saying that, they are relying too much on failure data and hence exposing the inability to process data with a high level of uncertainty; and the insufficient ability to synthesis different types of data, qualitative and quantitative. According to the same authors, as a result, new uncertainty methods have been proposed to address the above deficiencies, such as fuzzy set theory (FST), Bayesian Network (BN), evidential reasoning (ER), and Markov models.

Beside the above models Analytical Hierarchical Process (AHP) created by Thomas Saaty during the sixties has been recently large applied on different business, including the Port logistic sector. In the present work will be applying the AHP model for our risk management framework for Port of Matola.

AHP is a choice help model. This choice help model will portray complex multifaceted or multi-standards issue into an order, progressive system is characterized as a portrayal of an unpredictable issue in a staggered structure where the main level is the objective, trailed by the degree of elements, rules, sub-measures, down to the last degree of choices (Ishak & Wanli, 2020)**.**

According to (Saaty, 1990) the most creative task in deciding is to choose the factors that are important for decision. In the AHP these factors are arranged, once selected, in a hierarchical structure descending from an overall goal to criteria, sub criteria and alternatives in successive levels.

With hierarchy, a complex problem can be broken down into groups which are then arranged into a hierarchical form so that the problem will appear more structured and systematic (Ishak & Wanli, 2020)**.**

2.2.1. Procedures for AHP

The procedures for AHP that will be presented is from (Saaty, 1990) and it will be used for this project. The AHP procedures follow this step:

1- **Pair Comparison Matrix**

For pair comparisons matrix it used the risk criteria defined in the HAZID to construct the pairwise comparison matrix *"n * n"* (Table 2*)*, that illustrates the relative contribution or influence of each element to each of the objectives or criteria level above it.

Table 2 - Matrix for risk criteria pair-wise comparison (adapted fro Saaty, 1990).

Risk Criteria	R1	R2	….	Rn
R1	R_{11}	R_{12}	….	R_{1n}
R2	R_{21}	R_{22}	…	R_{2n}
…	…	…	….	….
Rn	R_{n1}	R_{n2}	….	R_{nn}

The factors {R_i} and {R_j} can be interpreted as the degree of preference of ith criteria over jth criteria. The comparisons are based on the choice or judgment of the decision maker by assessing the level of importance of an element compared to other elements. The judgements will be carried out in the form of the pre-defined linguistics variables (Table 3). The linguistic variables then will be transformed into the intensity number and will be made ready for the pair-wise comparisons. The standard preference scale used for AHP linguistic variables is 1 to 9 scale which lies between "equal importance" and "extreme importance.

Table 3: Linguistic variables Intensity for Comparative Scale of Criteria (Source: Saaty, 1990).

Intensity Number	**Interpretation**
1	Requirement X and Y are of equal value
3	Requirement X has a slightly higher value than Y
5	Requirement I have a strongly higher value than Y
7	Requirement X has a very strongly higher value than Y
9	Requirement X has an absolute higher value than Y
2,4,6,8	These are intermediate scales between two adjacent judgements

Reciprocals	If Requirement X has a lower Value than Y

2- Sum the values in each column

Sum the values in each column of the pair-wise comparison matrix and find the total value.

3- Normalization Matrix

Normalize data is by dividing the value of each element in the paired matrix with the total value of each column. The result will be the normalized pair-wise matrix.

4- Compute the Average of each Row

Compute the average of the elements in each row of the normalized pair-wise comparison matrix; This average will be the risk score and from there, priorities for the risk criteria can be ranked, accordingly equation (1):

$$Risk\ Criteria\ Score\ (Risk\ Score) = \frac{\sum Risk\ Criteria\ (line)}{n} \quad (1)$$

Equation 1: Risk Criteria Score (Risk Score) (adapted from Saaaty, 1990).

Where:

n = Total Number of Risk Criteria Alternative.

5- Compute Eigen Value

The eigenvalue is the weight of each element and is given by the following equation (2):

$$\lambda 1 = \frac{Risk\ Criteria\ Score}{Value\ of\ risk\ score\ in\ the\ first\ cell\ of\ normalized\ matrix} \quad (2)$$

Equation 2: Eigen Value (adapated from Saaty, 1990)

Where:

$\lambda 1$ = is the eigen value of the first risk criteria in the normalized matrix, the first cell in normalized matrix.

The eigenvalue for the next risk criteria in the normalized matrix is given with the same formula but the cell value will be from the second column second line, for the third risk criteria the value will be from the third column and third line and so on.

After finding the eigenvalue for each criteria alternative in the normalized matrix then we find the maximum eigenvalue (ʎmax) as the result of summation of all criteria alternatives eigenvalue (Ishak & Wanli, 2020).

6- Test the consistency of the hierarchy.

Based on Saaty (1990) an important consideration in this process is to evaluate consistency of the pair-wise judgements provided by the decision maker and this is done with the following conditions:

1 – Calculate the Consistence Index (CI)

$$CI = \frac{ʎmax - n}{n - 1} \quad (3)$$

Equation 3: Consistence Index (Source: Saaty, 1990).

2- Find the Random Index (RI) – Is the random index for the matrix size "*n*" and depends on the number of items being compared and is shown in the table below (Table 4).

Table 4 - Random index for matrix *"n"*.

Number of Criteria (N)	Random Consistency Index (RI)
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32

8	1.41
9	1.45
10	1.49
11	1.51
12	1.54
13	1.56
14	1.57
15	1.59

3 – Calculate the Consistency Ratio (CR)

The degree of consistency is satisfactory if: CI / RI <0.10. If it the consistency does not meet with CR <0, 10 then the assessment must be repeated (Sailfullah, 2019; MokthariK, 2011).

The math behind the AHP procedures presented above will be developed under excel file.

3. Methodology and Data Analysis

The methodology will be conducted in a way to design a risk management framework to be applied in Port of Matola according to the following steps:

3.1. Step 1: Literature Review

It will focus on:

- Consultation of scientific articles specialized in studies of Port operations where case studies of other Ports with the same operational objectives as the Port of Matola will be analyzed.
- Concepts related to the framework such as risk management, risk assessment will be focus.
- A models used in risk management will be presented and the model to used will be selected.
- The procedures for the model selected will be presented.
- Lessons learned from accidents at some international petrochemical ports.

3.2. Step 2: Description of Port of Matola Industrial Process

- Demonstrate the operating mode of Port of Matola.

3.2. Step 3: Data Collection: Hazard Identification (HAZID)

The HAZID is employed to reach the origins of risks, failures, and losses. The HAZID is a general term used to describe an exercise whose goal is to identify hazards and the associated events that have the potential to result in a significant consequence (PQRI, 2015).

For the present thesis the HAZID was proceed on face-to-face contact with people in the research setting, together with verbal data and observations at Port of Matola. The data was collected through experts from Department of Security, Safety and Environment (DSSE), Maintenance Department (MD) and Operation Department (OD). A literature reviews was also a source of data HAZID from other Ports with the same objectives has Port of Matola.

After identified the hazards, we will organize in groups of risk criteria. Each hazard will be grouped in its risk criteria group.

3.3. Step 4: Data Analysis: Risk Assessment

The collected data must be further analyzed prior to be used in other stages of the research. In a continuous way to follow a risk management framework the data will be analyzed under the concepts of risk assessment.

Risk assessment is a key part of risk management, defines risk as a measure of human injury, environmental damage, or economic loss in terms of both the incident chance and the magnitude of the injury, damage, or loss (Mokhtan, Ren, & Roberts, 2011)**.**

Risk assessment will be conducted to increase visibility of risks that may impact the Port of Matola and, this would be helpfully to identify the most relevant risks to be preventing and/or design strategies of mitigation in case of occurrence.

In risk assessment we will:

- Use a mathematical tool called Analytical Hierarchical Process (AHP) to rank the risk criteria groups in terms of priority.
- High level risk criteria will be prioritized.
- Proceed with AHP for rank the risks related to the priority risk criteria.
- High level risk from priority risk criteria will be used as top event for Failure Tree Analysis (FTA).
- Perform FTA of the top event.
- Perform a Security Risk Management (SRM) study for Port of Matola to meet the security level of Port of Matola using Security Risk Factor Table (SRFT) and Fuzzy Set Theory.

3.4. Step 5: Risk Mitigation Alternatives

In this step some mitigation measures will be proposed and inspecting their priority for Port of Matola.

3.5. Risk Management Framework

The methodology presented above can be summarized in a single flowchart that corresponds to the Risk Management Framework (RMF) (Figure.1), proposed to be used in Port of Matola. In the next chapter will be dedicated to text the RMF.

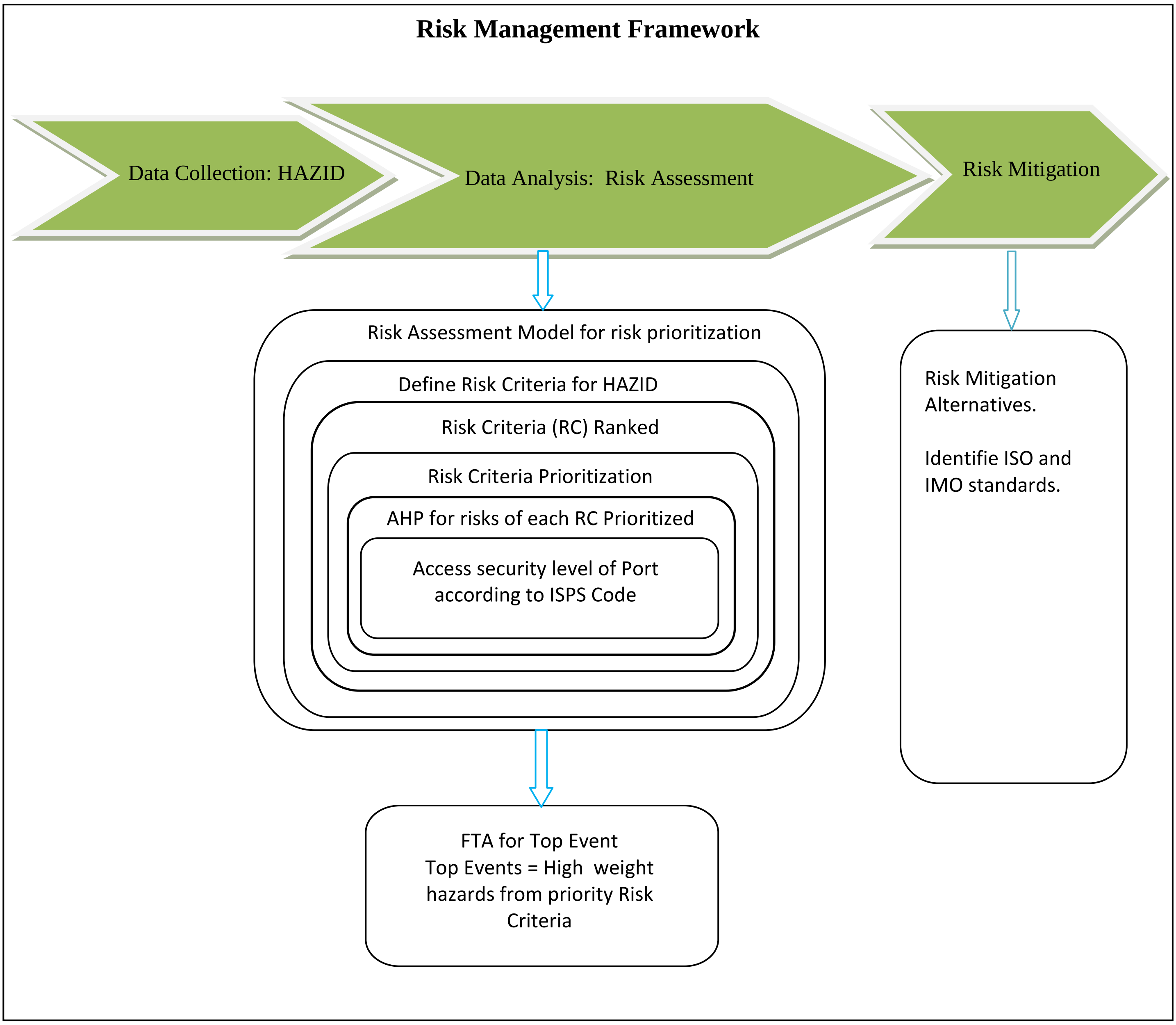


Figure 1: Risk Management Framework for Port of Matola

4. Analysis and Discussion

4.1. Case Study – The Port of Matola

Port of Matola is in the southern region of Mozambique in the Matola industrial complex. It has maritime access through the extension of the Maputo channel in the Espirito Santo.

The Port of Matola is made up of four (4) quays adapted for handling, liquid, and solid prodcuts (Figure 2). This quay will be considered has Port of Matola Systems, and each one with they function operations.

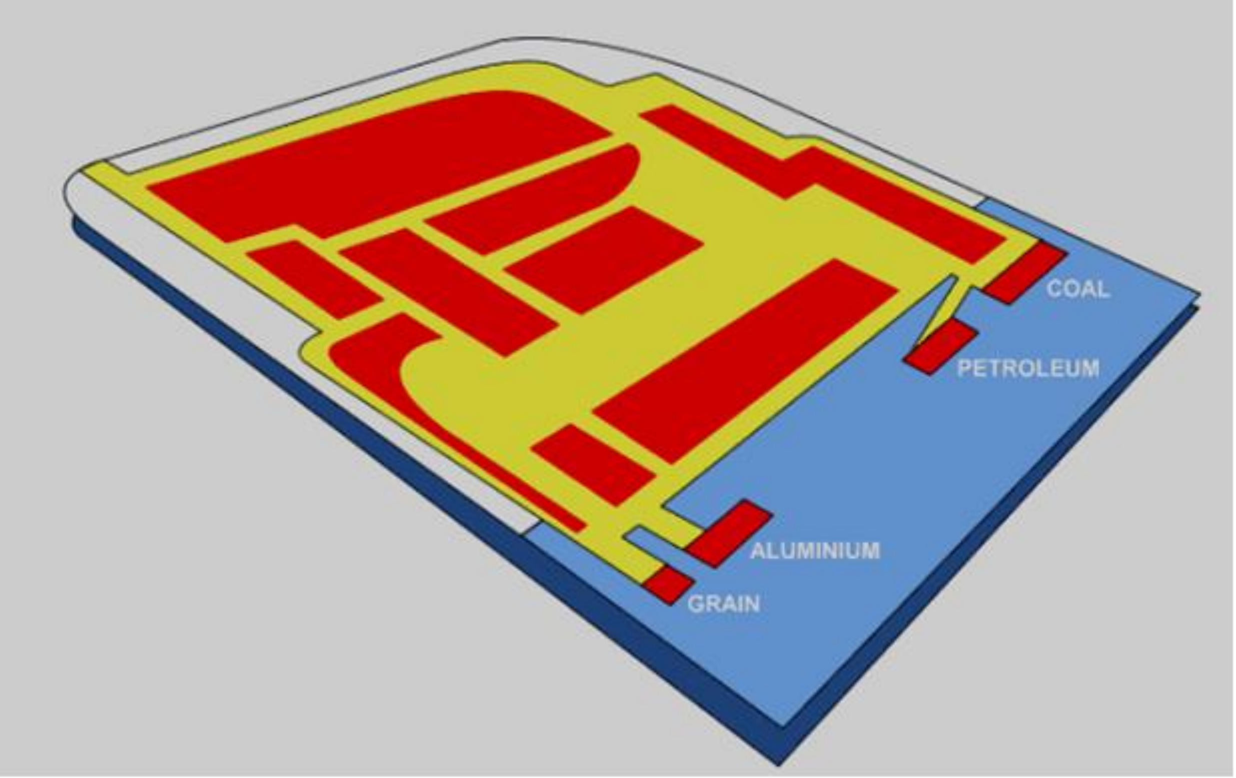


Figure 2: Berths of Port of Matola.

The main operation that acts under the Port of Matola in the four terminal is dived in three main system, and they are:

- System 1: System unloading;
- System 2: System storage;
- System 3: System loading.

4.1.1. The Petroleum Terminal

The petroleum terminal is where did the internship toke place and is operated and managed by Ports and Railways of Mozambique (CFM). The direction of Port of Matola is the Port authority. The fuel terminal has a docking platform with an area of 150m2 and duques d'alba positioned to allow the docking of ships with 240 meters of LOA, with a minimum depth of 12 meters and a length of about 75 meters, being able to accommodate ships from 2,500 DWT to 50,000 DWT, with an installed capacity of 5,000,000 Tons per year (CFM collaborator)**.** The dock of petroleum terminal is equipped with four articulated unloading arms and a conduit system that directs the products to the storage deposits of companies located inside the Port of Matola.

At the dock the system starts from unloading the fuels from ships to pipelines, comprising the system 1, from the pipeline the fuel is redistributed to the tanks to be stored at the fuel terminals facilities inside the Port of Maputo, comprising the system 2. From the storage tanks the fuel is loaded into the tank trucks, tanks from trains, comprising a system 3 from where is delivered. The figures below (Figure 3) illustrate the three main systems for the petroleum terminal.

In addition to being responsible for the petroleum terminal, the management of the Port of Matola is responsible for guaranteeing the safety, health, and environment of the entire area of the port not under concession.

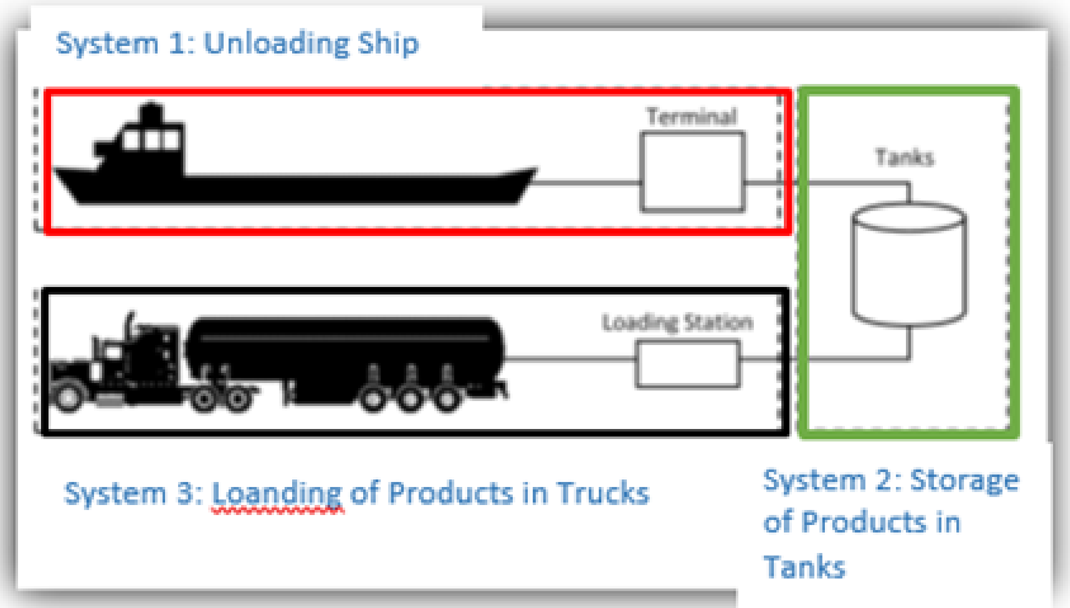


Figure 3: Petroleum terminal main system

4.1.2. The Grain Terminal

The Port of Matola has also a grain cereals terminal that in addition to handling cereals, this terminal is prepared to handle vegetable oil. This Terminal is equipped with silos with the capacity to store 80,000 tons of cereals per year and a handling capacity of 400,000 tons per year. The three main process systems are illustrated in figure below (Figure 4), starting from unloading grains from ship (system 1), storage the grain in silos (system 2) after this the processes follows the system 3 that is of loading the grains to trucks that will supply the market.

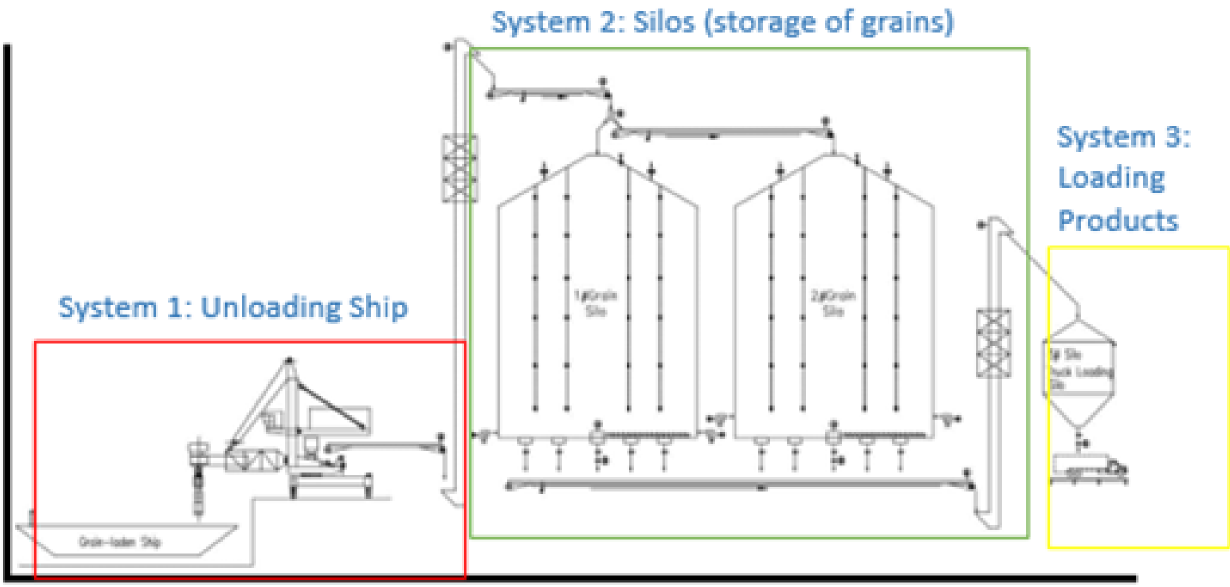


Figure 4: Grain terminal main systems.

4.1.3. The Aluminum Terminal

The aluminum terminal pier measures 210 meters long, 25 meters wide and an average. The three main systems for operacionalization occur in as follows: The system 1 is the unloading process of the raw material for aluminum production from the ships in the quays through suction and transferred to the Silos by means of a conveyor belt to be stored at the system 2, after it follows the system 3 of loading into truck to the next destination. The reverse process happens. Aluminum ingots are brought by trucks (system 1) and stored in the yard (system 2) and later loaded onto ships to the next destination (system 3). The systems are represented in the figure below (Figure 5). This terminal has the capacity to handle 600,000 tonnes of raw material annually for aluminum production, essentially alumina and petroleum coke, and 250,000 tonnes of finished metal for export.

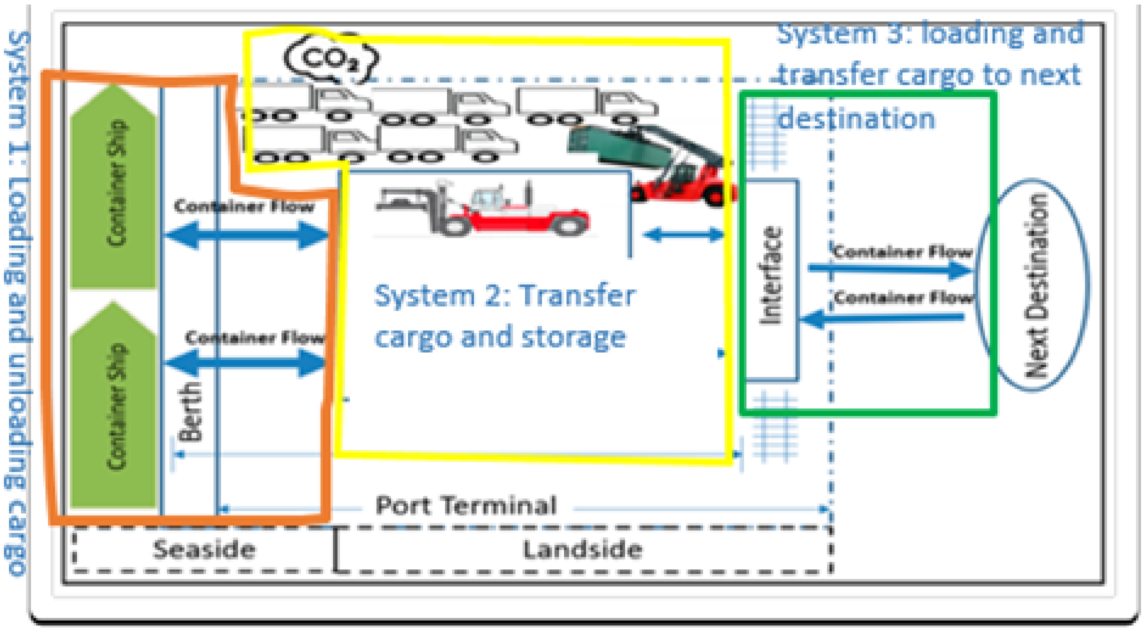


Figure 5: Aluminum terminal main systems.

4.1.3. The Chromium and Coal Terminal

The chromium and coal terminal also is divided into 3 main systems (Figure 6). The input mineral via trains, trucks to the port at the coal terminal, this entry process corresponds to system 1, than the mineral is stored at open storage space as stockpiles in system 2 and later this is loaded onto the ships on the pier in system 3 from where is taken to the next destination. The Matola coal terminal has an open-air storage area of 170,000 square meters.

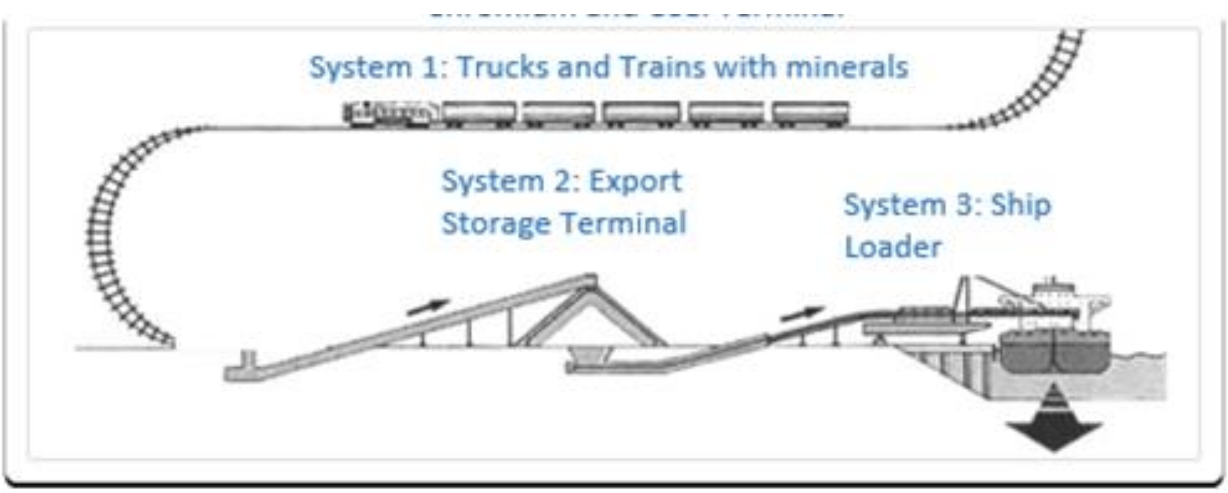


Figure 6: Chromium and Coal main systems terminal

4.2. Functional Analysis of Fuel Terminal System Product

Functional Analysis is an approach whose goal is to express the need in terms of service functions expected. Its aim is to reach a product which to satisfy the user's requirements (Ilie, Daniel, Anghel, & Ilie, 2011).

The service functions are the functions expected from the product and it is divided into principal functions (SF), which represent the purpose of the products action, and constraints functions (CF) which represent the actions and/or re-actions of the products towards different environmental elements, due to its presence in the system and in the environment.

This diagram (Figure 7) shows the relationship between the fuel terminal and the external environment in an octopus diagram.

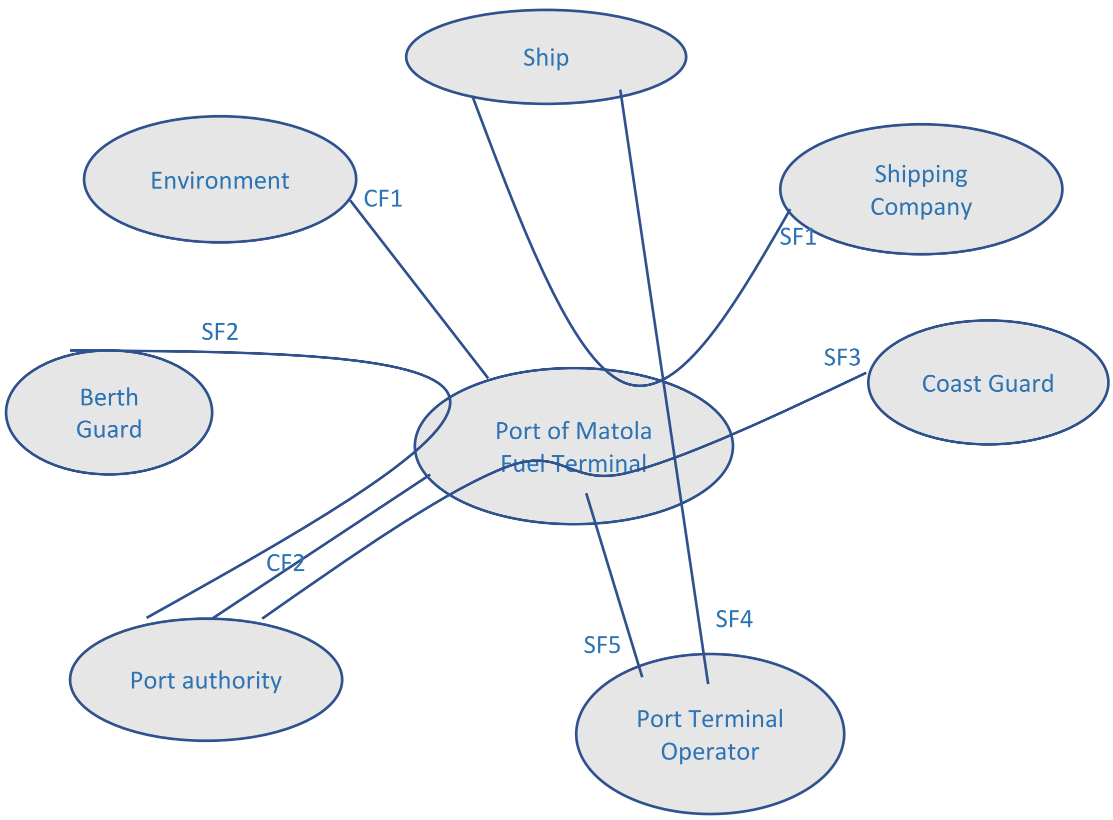


Figure 7: The environment and service functions of petroleum terminal at Port of Matola

The service functions of the product Port fuel terminal are presented in the table 5.

Table 5 - Functions of the product "Fuel Port Terminal of Port of Matola".

Nº	**Service Function (SF)**	Nº	**Constrain Function (CF)**
SF1	To allow to shipping company the possibility to go to the ship	CF1	To resist to the environment's actions
SF2	To allow the berth guard the possibility to guarantee safe patrol	CF2	The fuel terminal must be adapted for an intervention always when port authority finds necessary.
SF3	To allow the coast guard to get into the quay to contact Port authority in the case of any emergency		
SF4	To allow the Port terminal Operator to orient the ship to docking and contact with the ship during unloading operation		
SF5	To guarantee to the operators work in a safe condition.		

4.3. Hazard Identification (HAZID)

The table below (Table 6) shows the result of hazard identification according to the assumption presented in chapter methodology step 3.

Table 6 - Hazard identification for Port of Matola and related risk criteria.

Code / Identified Hazard	Causes	Consequence	Type of Risk Criteria
A1. Gas Emissions	Mostly from ship and tanker operation in Ports Terminals.	Gas emissions in ports have been linked to bronchitis symptoms, respiratory issues, and premature births.	Environmental
A2. Dust Emissions	Handling of coal and chromium minerals	Lung diseases	Environmental
A3. Muskelethal Disorder (MSD)	Cozy conditions for pier workers during the night period, poor handling techniques or tasks involving repetitive movements and/or excessive force.	Back pain and muscle injuries.	Human made error
A4. Inexistence of safety database	Lack of knowledge of the importance of registering safety lessons learned database by managers	It eliminates the opportunity to research, identify and react appropriately and if it happens again the consequences can be much more difficult to manage.	Technical
A5. Terrorism	Economy destabilization; Transport of weapons; Criminal uses for drug and contraband goods smuggling, support terrorist group network, suicide operations.	Disruption of national and regional oil and gas supply; Infrastructure and ships destruction; Theft on moored ships.	Por Security

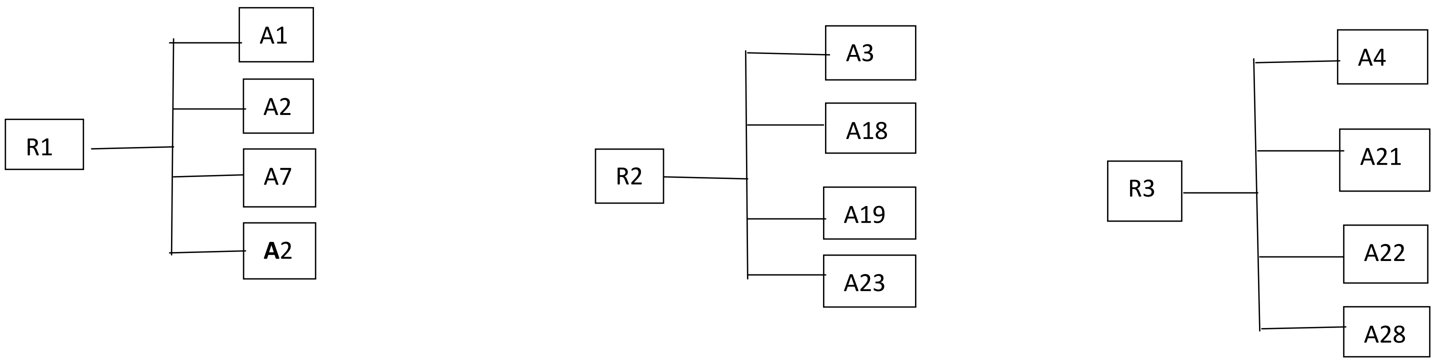
A6. Tsunami	A large displacement of the ocean wave, usually the result of an earthquake below the oceans or as result of large mass movement of air under the oceans.	Port infrastructure destruction; Disruption of regional oil and gas supply.	Natural Disaster
A7. Oil Spill	Operational accidents during loading, unloading, ships accidents during maneuver.	Sea pollution, sea habitat destruction; Discredited port.	Environmental
A8. Lack of Fire Drills	No schedule for firefighting exercises	Lack of opportunity to demonstrate fire-fighting capability under simulated fire conditions; Lack of knowledge of the ability to safely evacuate; No guarantees that you are aware enough of these responsibilities.	Safety Management
A9. Inexistence of checklists for different works	Lack of guidance and initiative for creating checklists due to lack of knowledge of their importance.	Lack of standardization of security knowledge; Reduction of the ability to predict the performance of a team, of a component, through standardized checklists.	Safety Management
A10. Heat detector in relevant facilities		Safety management	Safety management
A11.No fixed gas detectors and combustible detectors in areas prompt for spill or gas release.	Lack of resilient initiative; lack of budget	Quick disposal of spillage or gas leak; reduction of containment and combat capacity.	Safety management
A12.No protective firefighting clothes at	Lack of resilient initiative in the application of occupational safety concepts	Reduction in the ability to fight an imminent fire in high-risk installations, the case of the Pier.	Safety management

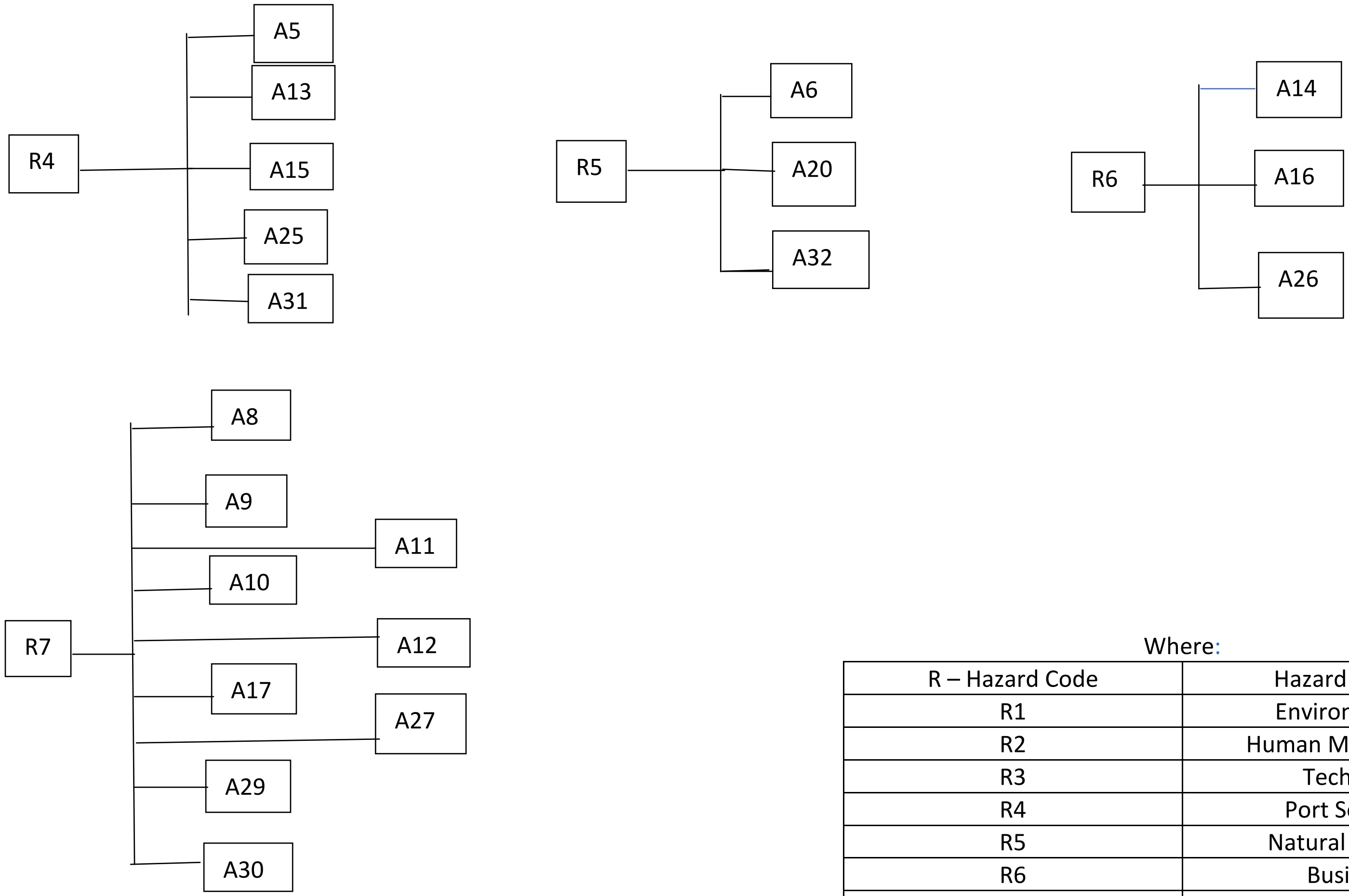
least 2 at berth for firefighting proximity.			
A13.Visibility	Lack of strategic investment in creating lighting conditions in Porto	Reduction of the ability to visualize any infraction or attempt of any action in Porto; Increased probability of accidents due to lack of visibility; reduction of combat capability or mitigation of any occurrence. Increase in the rate of infractions by delinquents. Inappropriate behavior of staff stationed in the waiting lot.	Port Security
A14.Poor communication between Port Stakeholders	Lack of communicative sharing between Porto stakeholders.	Reduction of control, prevention, and mitigation initiatives in a joint venture system.	Business
A15.collision with the pier	Human error; premeditated actions	Damage to infrastructure; reduction of the operational capacity or the termination of the terminal; wounds; Loss of lives.	Port Security
A16.Lack of Port Strategic Alliance	Inexistence of on-site training agenda, in international ports to collect good practices and technology and make the transfer.	Lack of dissemination of knowledge; Reduced technical and operational advances; reduced competitive ability.	Business
A17.Luck of update contingency Plans and Drills	Lack of initiative to create prevention and mitigation actions.; Failure to frame activities according to national laws and international standards.	Lack of occurrence mitigation capacity; Lack of staff training due to lack of plans. Impacts of catastrophic occurrences due to lack of knowledge of intervention procedures.	Safety Management
A18.Lack of judgment for potential risk	Lack of training and knowledge of standards to anticipate the identification of a potential hazard.	Preventive action not triggered and subsequent record of occurrence.	Human Made Errors

A19.Skills based error	Lack of training	Breaking of the productive chain; wounds; Loss of life.	Human Made Errors
A20.Storm	Natural Disaster	From the lowest to catastrophic	Natural Disaster
A21.Lack of Maintenance Equipment	Lack of investment; Lack of budget; Lack of request for equipment	Reduction of intervention capacity	Technical
A22.Lack of dredging	Lack of strategy to increase or maintain the port's capacity.	Reduction of incoming ships of more and more tons; Stranding of ships on the sandbar of the bottom of the sea; Port's loss of competitiveness; Damage to the ship's fuselage by dragging.	Technical
A23.Pilot Related error	Overconfidence, Failure to follow procedures, Lack of supervision of the pilot's action.	Dangerous maneuvers; Clash between ships and against infrastructure; loss of assets; strokes.	Huma Made Errors
A24.Handling and storage of dangers goods	Lack of knowledge, instruction, or guide for handling explosive charges; Negligence.	Spills; explosions; Inhalation of toxic substances; Dissipation into the atmosphere.	Environmental
A25.Destruction of terminal assets	Intentional actions; kidnapping; theft; negligence; accidents.	Destruction of the Port's assets; Stopping of activities; Loss of life; Wounds.	Port Security
A26.Lack of Port KPI	Failure to introduce the need to project performance indicators in the department.	Omission of knowledge of progress, gaps; behavior and trends.	Business
A27.Lack of HAZID and HAZOP drills program	The non-scheduling of a hazard identification (HAZID) and, hazard and operability (HAZOP) conduction program.	Lack of knowledge of the risks related to the operationalization of the Port and the updating of knowledge of these.	Safety Management
A28.Lack of SIL	Failure to introduce industrial concepts to	Lack of knowledge of the probability of occurrence of a dangerous	Technical

studies	quantify the level of risk reduction.	event due to lack of knowledge of non-compliance and nature of failure of a component.	
A29.No respect for probhiting signals for cigarrets.	Lack of punishment, security not prepared to adverse, Port authority does not impose stakeholders.	Explosions; Port reputation.	Safety Mangement
A30.Lack of Emergency Plan based o lessons learned from other accidents	Lack of initiative to create models of lessons learned based on occurrence records.	Lack of creation of contingency plans.	Safety Management
31. Lack of aerial vigilance for drone attack.	Lack of technical and budgetary capacity	Deliberate drone attacks on Porto	Port Security
32. Earthquake	Natural Disaster	From the lowest to the catastrophic.	Natural Disaster

The hazards can be represented in structured Risk Criteria based on codes (Figure 8) to be represented in the AHP analysis in the next chapters, where:





Where:

R – Hazard Code	Hazard Criteria
R1	Environmental
R2	Human Made Errors
R3	Technical
R4	Port Security
R5	Natural Disaster
R6	Business
R7	Safety Management

Figure 8: Risk Criteria base on codes.

4.3.1. Risk Criteria Description

4.3.1. Environmental Risk Criteria

Environmental risk criteria in the present thesis its related to the main activities that release substances in port of Matola that could lead to an environmental accident, occupational health and safety for workers and communities' exposure. The coal and chromium minerals in Matola Port are managed as fine substances and they are potential transported by wind leading to occupational exposure and deposition of the same substances under the sea channel. Communities around Matola Port are also exposure to the dust of this minerals. As a logistic infrastructure the port movement its dominated entrance e leaving of ships and trucks and port facilities it accommodates many stakeholders and must of them use, they cars, this is potential source of gas emission. Beside minerals the other substance managed in port facilities is hydrocarbons (LPG, Gasoline, Diesel), moving from ships, storage in tanks in port facilities stakeholders then transported from this to tank trucks. These substances are potential explosive and the facilities that are used to transport, storage may be corrupted for any reason and a spill occur on land or sea.

According to (Merl, 2014) , the main gases related to port gases emissions are NOx, CO2, CH4, CO and in ports have been linked to bronchitis symptoms, respiratory issues, asthma, coronary heart disease and depression. The major concern of dust emission is the emission it's the PM2.5 and PM10 particles size that according to Merl.O.; (2014); Shipping Emission in Ports; International Transport Forum. Paris, France, PM emissions are responsible for approximately 60,000 cardiopulmonary and lung cancer deaths annually. Beside inhalation the dusty have impact on visibility, sometimes a large amount its released when minerals are being managed and a large mass covers the atmosphere creating conditions in which the infrastructures close to these operations or neighboring infrastructures cannot be see. Troubled eyes are a common feature in dust-affected areas in Port of Matola and one the biggest claims around workers from Fuel Port Terminal in addition to difficulties in breathing

A study from (Ayar, Erboy, Yazgan, & Ugrnas, 2017), suggests that the systemic effect of coal mine dust in ocular structures is not evident, however, direct contact with coal mine dusty leads to a decrease in tear function tests.

As mentioned before chromite is other source of dusty in Matola Port, and a study from (Das Prasad & Singh, 2011)**,** point the inhalation of chromite and dermal exposures as potential induced carcinogenicity among the workers so its essential monitor the exposure of the workers for chromite.

4.3.2. Human Made Errors

Human made errors could be due to Unintentional action (slip or lapse), Intentional action (mistakes, Violation) Skill based performance, Rule-based performance, Knowledge-based performance.

Human made errors could have been a source of the major incidents in port infrastructure, operations, with impact varying from the small scale to severe.

During the internships, an accident occurred in the facilities of the fuel terminal, during the maneuver to attract a ship heading for the coal and chromite terminal, the damage was considerable and affected the structural integrity of the Pier. It caused displacement of the floor of the Pier, collision with the fuel discharge arms that became inoperable during my stay, the collision created conditions for fluids to escape from the unloading arms, the warping of the arms, some screws of the metal structures fixed to the pier floor came out. The pier was closed for some time.

As an intern I could see that the consequences could have a regional scope because through this pier there is also the entrance for fuel in transit to the interland countries in addition to supplying the national market. After verifying the reasons that led to this occurrence, the commission of inquiry concluded that it was due to pilot error.

4.3.3. Technical

Port services are very complex, and any organization must be done to have a better control of activities and procedures to guarantee next better intervention. Dredging is one of main technical issues related to Port availability and business expansion. A maintenance dredging its vital for maintain ideal water depth, other way channels would sand and silt up and ships could not carry full loads and if the channels were not deep enough would increase the ship safety and environment incidents such as grounding and oil spill. A good technical maintenance service must be always kept it up for customers requirements.

The database is very important for risk management. An ideal database its crucial for lesson learned and next better risk management from previous occurrences. The Department of Protection, Safety and Environment (DPSMA) don’t have digital safety database to record the occurrence. Nevertheless, daily reports are made by people local security, and this registration is written in a paper. There is no checklist sample with the major point of concern to orient incident registration. The companies that operate in Port of Matola don t share the occurrence with port authority.

4.3.4. Port Security

Major issues regarding port security are related to human factor that could be intentional, not intentional, poor visibility, external actions, or internal actions. The consequences could range from small to catastrophic. It could be destruction of Port facilities and may also impact the communities around the Port facility, beside impact on the national and regional economy. Port authority must be interventive, to prevent issues related to port security and must considered that this hazard is linked to all other hazards. Improving preventive measures to other hazards will impact on port security.

4.3.5. Natural Disasters

This are hazards events which origin it's out of human control and many times not predictable, its related to nature actions. Meanwhile actions could be taken to reduce the impact. Mozambique it's an offshore country, and in past few years events such earthquakes were felt, and this could impact in port facilities structure. Tsunami is also another potential source of hazard under the port facilities, however because of the construction of the Maputo Bay with the existence of islands across, they allow a natural barrier protection against big tsunami waves, that could be originate either by earthquakes or by storms at open sea. Nevertheless, the climate changes are a fact presently and Mozambique have been under the way of big storm formed under the Mozambique channel that reach the continent, so preventive action are important to take for the impact of this high velocity wind for the facilities under the berths and the staff that work on berth.

4.3.6. Business

The global nature of port operations makes companies susceptible to risks so it's important to companies and port authority to have a strategic communication to have a good joint venture failures analysis for a better port operationalization. On other hand in fuel terminal at DPSMA, Key performance indicators (KPI's) should be implemented, its powerful measurement tool to understand the business performance, it then uses the outcome of this measurement to make any necessary strategic, structural, operational, or other adjustments to improve safety operationalization.

4.3.7. Safety Management

The size and complexity of industrial operation in Port of Matola, together with the nature of the products handled, means that an analysis and control of the risks involved is required. The result from this study allows prioritizing the preventive and corrective measures to minimize the probability of failure or incidents. Port authority safety officer and management must be engaged on accessing all port activities.

Safety management should include assessments of major-accident scenarios occurred to identify the emergency needs based on risk assessments of this accidents. Emergency plans should be done, and everybody involved should be trained and drills should be carried out for the staff.

4.4. Risk Assessment

In the present chapter we will be analyzing the hazards according to the tool proposed, the AHP for risk prioritization.

The risk criteria will be compared to find the weight of each with respect to another. Subsequently, using the same method for risk criteria prioritization, the hazards of the risk criteria priority will be compared, one to another and the highest-ranking hazard from each risk criteria will be treated as the top event for the FTA analysis in risk assessment. The procedures for AHP are presented in the chapter 2.

4.4.1. Analytical Hierarchical Process of Risk Criteria (AHPRC)

The tables below (Table 7 and 8) correspond to the pair-wise matrix and normalized pair-wise matrix for the risks criteria respectively, according to the procedure for AHP in chapter 2. The ratings of the risk criteria were done by Port of Matola experts. They were trained by the author on related linguistic for risk criteria comparison as per the table 3. The terms in each cell from the table below (Table 7) are the ratings resulting from the comparison from risk criteria in the first column with the risk criteria in the first line. The yellow and orange cell display the results based on linguistic comparison from the experts and the red are reciprocal values from the yellow cell.

Table 7 - Pair-wise comparison matrix of the risks criteria.

AHPRC	R1	R2	R3	R4	R5	R6	R7
R1	1	2	7	1	0.2	4	0.3
R2	0.5	1	1	1	0.1	5	1
R3	0.1	1	1	0.5	0.1	2	0.5
R4	1	1	2	1	0.3	5	1
R5	5	7	7	3	1	8	5
R6	0.2	0.2	0.5	0.2	0.1	1	0.1
R7	3	1	2	1	0.2	7	1
Sum:	10.8	13.2	20.5	7.7	2.1	32	8.9

Table 8 - Normalized pair-wise comparison matrix of the risks criteria.

NHRC	R1	R2	R3	R4	R5	R6	R7	NHRC Sum	NHRC Score(priority)	NHRC Score (%)	Eigen Value
R1	0.09	0.15	0.34	0.12	0.09	0.12	0.03	0.97	0.13	13.85	1.50
R2	0.04	0.07	0.04	0.12	0.06	0.15	0.11	0.63	0.09	9.06	1.19
R3	0.01	0.07	0.04	0.06	0.06	0.06	0.05	0.38	0.05	5.53	1.13
R4	0.09	0.07	0.09	0.12	0.15	0.15	0.11	0.81	0.11	11.68	0.89
R5	0.45	0.53	0.34	0.38	0.46	0.25	0.55	2.99	0.42	42.76	0.91
R6	0.02	0.01	0.02	0.02	0.05	0.03	0.01	0.19	0.02	2.77	0.88
R7	0.27	0.07	0.09	0.12	0.09	0.21	0.11	1.00	0.14	14.31	1.28
								Sum:	1	100	
										ʎmax (Eigen Value	7.82

The consistency of the judgement for risk criteria prioritization is:

CI = 0.13; RI = 1.32; CR = 0.1 $\leq$ 0.1 proposed by Saaty, 1990

The figure below (Figure 6), gives the resume of weight in percentage from the normalized table of risk criteria.

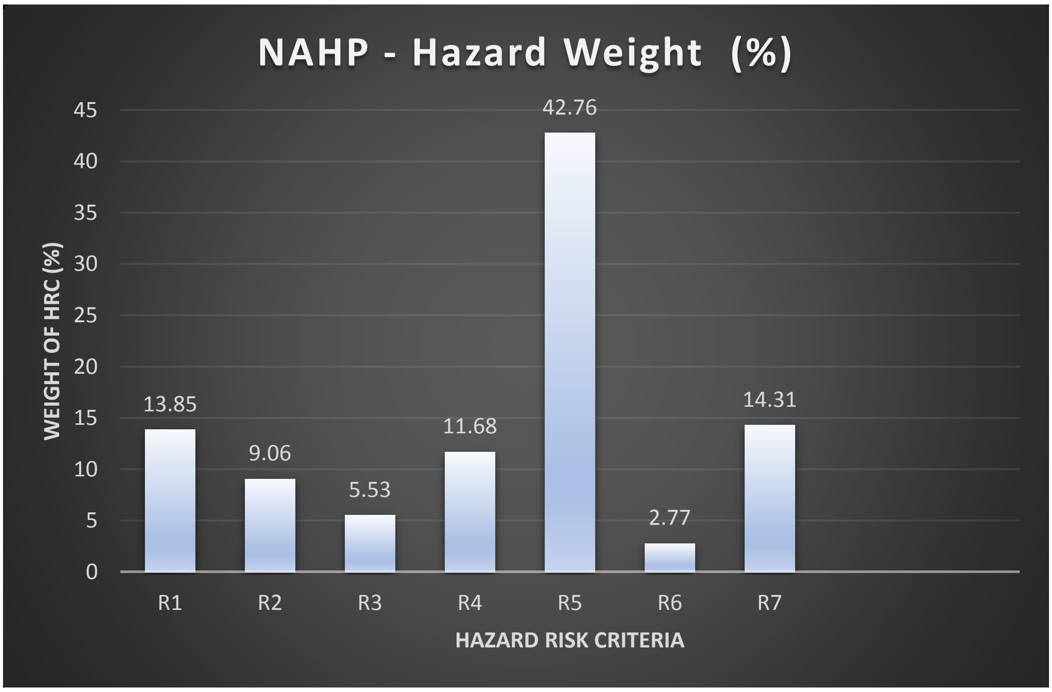


Figure 9: Weight of the Risk Criteria.

The results of risk criteria rank based on percentage weight from AHP procedure are presented in the table below (Table 9).

Table 9 - Risk criteria prioritization.

Number of Order	**Hazard Related Criteria**	**Rank**
R5	Natural Disaster	I
R7	Safety Management	II
R1	Environmental	III
R4	Port Security	IV
R2	Human Made Errors	V

4.4.2. Analytical Hierarchical Process for Priority Risk

The process in this step it will be the same as the previous, nevertheless it will be done for the available risk from each priority risk criteria from table 8.

The tables (Tables 10 and 11) below show the AHP for the for the priority risk criteria R5.

Table 10 - Pair-wise comparison matrix for risk criteria R5.

R5. Natural Disaster	**Storm**	**Tsunami**	**Earthquake**
Storm	1	4	1
Tsunami	0.2	1	0.2
Earthquake	1	5	1
SUM:	2.2	10	2.2

Table 11 - Normalized pair-wise matrix of risk criteria R5.

R5. Normalization Matrix	A6	A20	A32	NR5 Sum	NR5 Score	NR5 Score (%)	Eigen Value (ʎ)
A6. Storm	0.44	0.4	0.45	1.29	0.43	43.29	0.97
A20.Tsunami	0.11	0.1	0.09	0.30	0.10	10.06	1.00
A32.Earthquake	0.44	0.5	0.45	1.39	0.46	46.63	1.02
				SUM:	1	100	
						ʎmax (Eigen Value	3.00

The consistency of the judgement for risk criteria R5 is:

CI = 0; RI = 0.58; CR = 0.01 < 0.1. Indicative of consistent judgement from the experts.

For the risk criteria R7, the AHP is given in the tables (Tables 12 and 13), below.

Table 12 - Pair - wise comparison matrix fo risk criteria R7.

R7. Safety Management	A8	A9	A10	A11	A12	A17	A27	A29	A30
A8. Lack of Fire Drills	1	5	0.2	3	1	0.3	0.2	0.2	0.2
A9. Inexistence of checklist	0.2	1	0.2	1	0.2	0.1	0.1	0.2	0.1
A10. No firefighting reliability checklist	5	5	1	1	1	0.2	0.3	0.2	0.1
A11. Heat detector in relevant facilities	0.3	1	1	1	1	0.2	0.1	0.2	0.2
A12 No fixed gas detectors and combustible detectors	1	4	1	1	1	0.2	0.1	0.2	0.2
A17.Luck of update contingency Plans and Drills	3	7	5	5	5	1	1	1	0.3
A27.Lack of HAZID and HAZOP drill programs	5	7	3	6	6	1	1	1	1
A29. No respect for probhiting signals for cigarrets	5	4	5	5	5	1	1	1	1
30.Lack of Emergency Plan based o lessons learned from other accidents	5	7	6	5	5	3	1	1	1
SUM:	25.5	41	22.4	28	25.2	7.0	5.0	5.0	4.2

Table 13 - Normalized pair -wise comparison matrix for risk criteria R7.

R7. Normali-zation Matrix	A8	A9	A10	A11	A12	A17	A27	A29	A30	NR7 SUM	NR7 Score	NR7 Score (%)	Eigen Value
A8	0.03	0.12	0.008	0.10	0.03	0.04	0.03	0.03	0.04	0.49	0.05	5.45	1.39
A9	0.007	0.02	0.008	0.03	0.009	0.02	0.02	0.04	0.03	0.21	0.02	2.42	0.99
A10	0.19	0.12	0.04	0.03	0.03	0.02	0.06	0.03	0.03	0.61	0.06	6.79	1.52
A11	0.01	0.02	0.04	0.03	0.03	0.02	0.03	0.03	0.04	0.30	0.03	3.39	0.95
A12	0.03	0.09	0.04	0.03	0.03	0.02	0.03	0.03	0.04	0.40	0.04	4.49	1.13
A17	0.11	0.17	0.22	0.17	0.19	0.14	0.19	0.19	0.07	1.50	0.16	16.72	1.18
A27	0.19	0.17	0.13	0.21	0.23	0.14	0.19	0.19	0.23	1.72	0.19	19.18	0.96
A29	0.19	0.09	0.22	0.17	0.19	0.14	0.19	0.19	0.23	1.66	0.18	18.53	0.93
A30	0.19	0.17	0.26	0.17	0.19	0.42	0.19	0.19	0.23	2.06	0.22	22.98	0.97
										SUM:	1	100	
												ʎmax (Eigen Value	10.05

CI = -0.09474; RI = 1.45 ; CR = -0.06533 < 0.1, indicating a consistency judgement.Saaty, 1990, did not point a minimum accepted value to evaluate the consistency, on the other hand, Saifullah (2019) presented CR < 0 an validate the results.

The table below (14 and 15), are for AHP for risk criteria R1.

Table 14 - Pair - wise comparison matrix for risk criteria R1.

R1. Environmental	A1	A2	A7	A24
A1. Gas Emissions	1	0.2	0.1	0.2
A2. Dust Emissions	5	1	0.2	0.2
A7. Oil Spill	7	5	1	3
A24.Handling and storage of dangers goods	5	5	0.3	1
SUM:	18	11.2	1.6	4.4

Table 15 - Normalized pair - wise comparison matrix for risk criteria R1.

R1. Normalization	A1	A2	A7	A24	NR1 SUM	NR1 Score	NR1 Score (%)	Eigen Value
A1	0.05	0.01	0.08	0.04	0.20	0.05	5.10	0.91
A2	0.27	0.08	0.11	0.04	0.53	0.13	13.29	1.48
A7	0.38	0.44	0.59	0.68	2.11	0.52	52.84	0.88
A24	0.27	0.44	0.19	0.22	1.15	0.28	28.75	1.26
					SUM:	1	100	
							ʎmax (Eigen Value	4.55

C.I = 0.1862; RI = 0.9; CR = 0.1 ≤ 0.1

The tables below (Table 16; 17), for AHP of risk criteria R4

Table 16 - Pair - wise comparison matrix for risk criteria R4.

R4. Port Security	A5	A17	A19	A34	A40
A5. Terrorism	1	7	5	1	1
A14.Visibility	0.1	1	0.3	0.3	0.2
A16. collision with the pier	0.2	3	1	1	1
A26. Destruction of terminal assets	1	3	1	1	1
A32. Lack of aerial vigilance for drone attack.	1	5	1	1	1
SUM:	3.3	19	8.3	4.3	4.2

Table 17 - Normalized pair-wise risk matrix for R4

R4. Port Security	A5	A14	A16	A26	A32	NR1 Score (Priority)	NR1. Score% (Priority)	Eigen Value
A5. Terrorism	0.29	0.36	0.6	0.23	0.23	0.34	34.72	1.16
A14.Visibility	0.04	0.05	0.04	0.07	0.04	0.05	5.19	0.98
A16. collision with the pier	0.05	0.15	0.12	0.23	0.23	0.16	16.13	1.34
A26. Destruction of terminal assets	0.29	0.15	0.12	0.23	0.23	0.20	20.91	0.90
A32. Lack of aerial vigilance for drone attack	0.29	0.26	0.12	0.23	0.23	0.23	23.02	0.96
					SUM:	1	100	
							ʎmax (Eigen Value	5.36

CI = 0.436401831; RI = 0.9; CR = 0.48 > 0.1. This judgment is not consistent.

The tables below (Table 18; 19), for AHP of risk criteria R2

Table 18 - Pair - wise comparison matrix for risk criteria R2**.**

R2. Human Made Errors	A3	A22	A26	A31
A3.Muskelethal Disorder (MSD)	1	0.3	0.2	0.1
A22.Lack of judgment for potential risk	3	1	1	0.1
A26.Skills based error	5	1	1	0.1
A31.Pilot Related error	9	7	7	1
SUM:	18	9.3	9.2	1.3

Table 19 - Normalization pair-wise matrix for risk criteria R2.

R2 Normalization	A3	A19	A20	A24	NR2 Score (Priority)	NR2 Score% (Prior-ity	Eigen Value
A3. Muskelethal Disorder (MSD)	0.05	0.03	0.02	0.07	0.04	4.81	0.86
A18.Lack of judgment for potential risk	0.16	0.10	0.10	0.10	0.12	12.11	1.13
A19.Skills based error	0.27	0.10	0.10	0.10	0.14	14.89	1.37
A23.Pilot Related error	0.50	0.75	0.76	0.71	0.68	68.16	0.95

SUM:	1	100	[redacted]
		λmax (Eigen Value	4.32

CI = 0.1; RI = 0.9; CR = 0.1 $\leq$ 0.**1**

The high risk from each risk criteria are:

- Event (1) - Earthquakes - From Natural Disaster Risk Criteria.
- Event (2): Lack of Emergency Plan based o lessons learned from other accidents – From Safety Management Risk Criteria.
- Event (3): Oil Spill in Pier Fuel Terminal - From Environmental Risk Criteria.
- Event (4): Terrorism – From Port Security Risk Criteria.
- Event (5): Pilot Related Errors – From Human Related Error Risk Criteria.

4.4.3. FMEA

FMEA, or Failure Mode and Effects Analysis, is a systematic approach for identifying and analyzing potential failures or errors in a system, process, or product, and determining their potential impact on the system. The FMEA analysis will be conducted for the last four events above identified. The natural disaster event will not be assumption of the following thesis for FMEA. The above table shows the FMEA proposed for the priority risks identified in the AHP.

Table 20: FMEA

Potential Failure	Potential Causes	Potential Effects	P	S	D
Inadequate preparations for events (ex: natural); Failure to respond effectively to fire or explosion; Lack of communication among stakeholders during emergency; Failure to evacuate; Inadequate training	Lack of risk assessment and planning; Insufficient allocation of resource; Complacency; Lack of communication and collaboration among	Loss of life; Injury; Disruption of public service; Environmental contamination; Damage to reputation	Medium	High	Medium

or equipment for first responders.	stakeholders				
Bomb explosion; Active shooter; Kidnaping.	Inadequate security measures and protocols	Loss of life; Injury; Damage to infrastructure; Psico-trauma.	Medium	High	Low
Miscommunication; Fatigue, stress, or medical issues.	Human error or judgement; workload or time pressure; Environmental factors	Accidents or crashes; property damage; Reputation damage; Delays.	Medium	High	Medium
Equipment malfunction; Human error or negligence handling the equipment; Natural disaster.	Inadequate maintenance and inspection to equipment; Insufficient emergency plan and resource; Poor communication among stakeholders.	Environment contamination; harm to marine life and ecosystem; Health to workers and residents; Financial and legal liability.	Medium	High	High

4.4. 5. Fault Tree Analysis (FTA)

Through AHP, five events were extracted for FTA from priority risk criteria and that will be the top event.

However, in the five priority events, the earthquakes, because it's natural disaster hazard will not be target in the present thesis for FTA. Terrorism its related to Port security and because its relevance regarding current national affairs, where Mozambique has been the target of terrorist attacks, an assessment of the level of security of Port of Matola fuel terminal will be carried, beside an FTA. The security risk assessment for fuel terminal will be according to the assumption of the ISPS code that defines levels of countermeasures in case of a terrorist attack for Ports.

Other case for FTA it will be for the top event of risk criteria R7, instead use the high ranked event as per AHP we will proceed with the event ‘Cigarrets smoking inside the Port of Matola’, it’s the third in the R7. Because of the recurrent practice even under the eyes of Port security and in places where tank trucks are parked even close of tank storage.

The suggested FTA is in figures below (Figure 7, 8, 9).

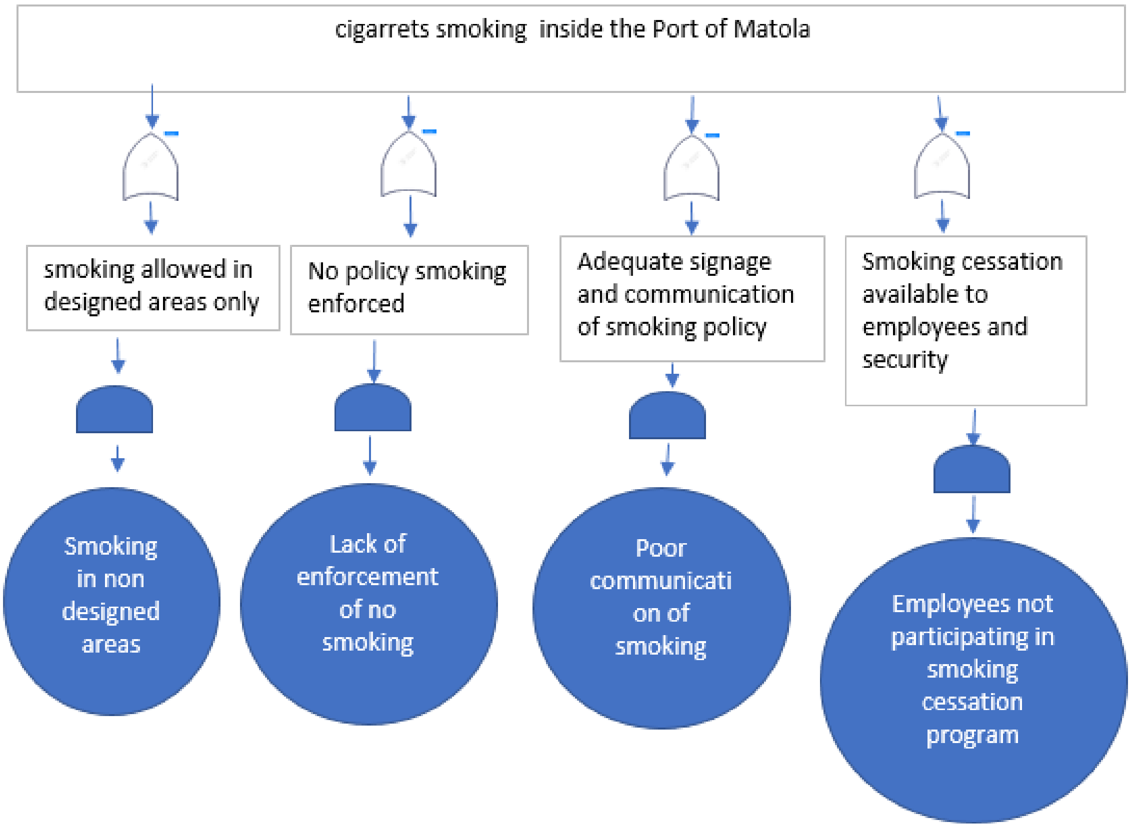


Figure 10: FTA for the top event - Cigarrets smoking inside the Port of Matola

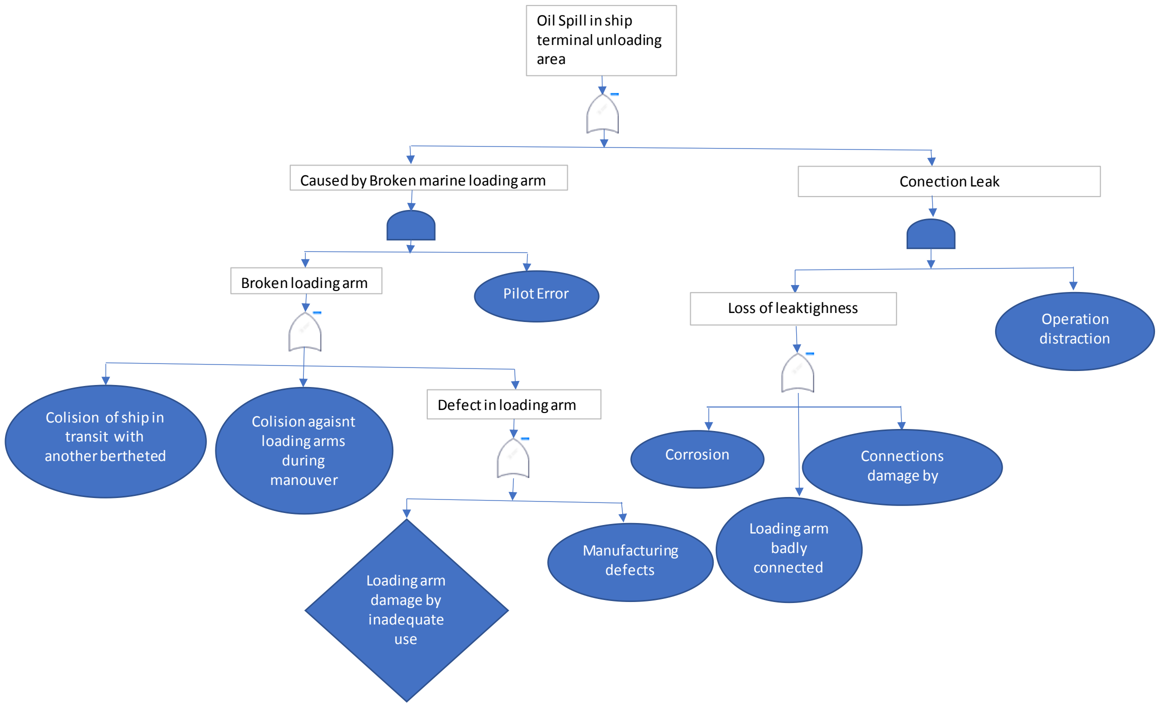


Figure 11: FTA for the top event: Oil spill in ship terminal unloading area

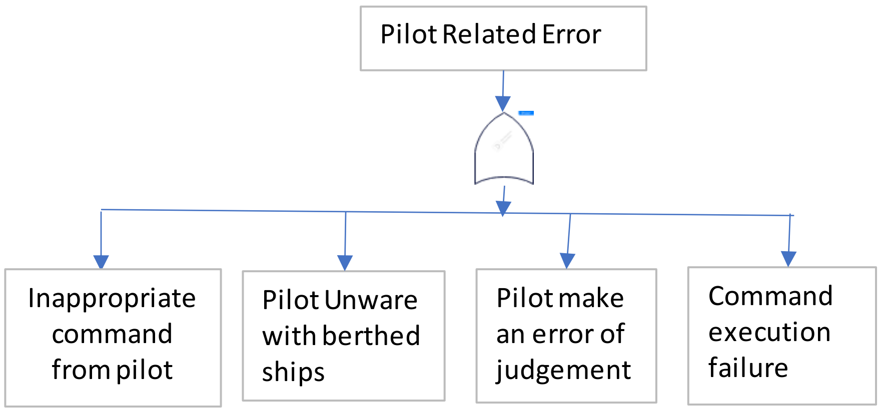


Figure 12: FTA for the top event - Pilot Related Error

4.4.6. Security Level of Port of Matola as per ISPS code

Many systems face security risks. To properly protect these systems, it is important to gauge relative security risk of different systems, so that more resources will be used to protect systems with higher risk.

For the case of Port Security, terrorism is the main issues to concern as per risk prioritization and, at Port of Matola this is taken seriously. In the advent of 11/01 WTC terrorism attack, the IMO organization created the ISPS code for port security and, Mozambique as member of IMO organization adopted the ISPS code.

The relevance of this study is justified because of a terrorist attack at Port facilities can lead to a severe impact on health and safety of people, economy, environmental damages as well as fatalities due to the hazardous nature and quantity of fuel handled at Port of Matola facilities**.**

The ISPS code gave the assumption in which Port authority must introduce to guaranty security for the ships and the Port. The proposition for this chapter is to access the level of security of Port of Matola according the established with the ISPS code and beside the level this also include the countermeasures and recommendations tailored from ISPS Code (Table 20).

Table 21 - Level and countermeasures and recommendations tailored from ISPS code (Adapted from ISPS code, 2003).

Security risk status	**Actual points status**	**ISPS Security Countermeasures**	**Security risk treatment (recommendation)**
Low	<25	Level 1	The security risk is low. Maintain awareness without excessive concern
Moderate	25 – 48	Level 2	A moderate security risk is present. Review and upgrade existing procedures. Maintain awareness without excessive concern
High	49 – 72	Level 3	Identify risk-drivers that can be reduced with reasonable controls. Work with law enforcement agencies to enhance security
Extreme	>72	Level 3+ state of high alert	Initiate aggressive risk-reduction activity, in conjunction with consultation with law enforcement agencies

One of the widely used techniques for gauging risk in Port terminals is the Security Risk Factor Table (SRFT) model, the fact that it is successful seems to indicate that this model indeed reflects the actual risks (Rivera, Zapata, & Kreinovich, 2014).

The main elements from the SRFT are present in the table (Table 21), demonstrated in the study of (Rahaman, Motlagh, & Al Rashid, 2020).

Table 22 - SRFT main elements for acess the Port security level (Adpated from Rahaman, Motlagh & Al Rashid, 2020).

Security risk factor	Linguistic scales for rating security risks factor			Security auditor's Ratings / Judgment.
Site Location	Rural	Urban	High density	
Visibility status of ships and storage tanks	Not Visible	Less Visible	High Visible	
Processed gas and liquid chemicals storage	Medium	Large	Very large	
Imported crude oil and natural gas storage	Medium	Large	Very Large	
Tanker ships traffic	Low	Medium	High	
Site's ownership	Private	Public/Private	Government	
Presence of terrorist groups in region	Low quantity	Medium quantity	Large quantity	
Worst Impact on site	Low	Moderate	Severe	
Worst impact off-site	Low	Moderate	Severe	
History of security incidents in site	Nil	Few	Frequent	
Meteorological conditions	Good	Moderate	Bad	
Target identification - chemical - by terrorists:				
CW (Chemical Weapon) agents	None	Minimum	Present	
Listed chemical concern	None	Minimum	Present	
Chemicals of extreme toxicity	None	Minimum	Present	
Existing security measures:				
Access control from land	High Level	Ordinary	Poor/Ordinary	
Access control from sea	High Level	Ordinary	Poor/Ordinary	
Perimeter protection	High Level	Ordinary	Poor/Ordinary	
Mitigation potential	High Level	Ordinary	Poor/Ordinary	
Proper lighting (All over the	High Level	Ordinary	Poor/Ordinary	

port)				
Use of metal detector / X-ray/ CCTV (at entrance and all critical location)	High Level	Ordinary	Poor/Ordinary	
Pre-arrival security control of ships.	High Level	Ordinary	Poor/Ordinary	
Security inspection of ships in terminals, before cargo operation begins.	High Level	Ordinary	Poor/Ordinary	
Employees preparedness, awareness trainnings	Well Prepared	Average	Poor	
Reliability and status of readiness of emergency units, e.g, health, safety, security and environment	Well Prepared	Average	Poor	

In the SRFT the results are based on what the expert judgment can see from the Port actual characteristics or security risk factor as per the SRFT table. However, for a more accurate judgment to the linguistic scales for rating security risk factor in the SRFT, the risk assessment linguistic variables (very low, low, medium, high, very high) (Table 16) can be integrated. The risk assessment linguistic variables are attributed in each column of the linguistic scales for rating security risk factor parameter of the SRTF, from scale of low in the first column, medium in the second column and the high in the last column ((to be seen in the SRFT results table for Port of Matola). On other hand, the linguistic variables are associated to certain premises under the risk assessment assumption, and they are the occurrence likelihood (P) and severity (S) as showed in the table below (Table 21). The definition of P and S is presented in the same table as per (ABS, 2003)**.** The same author mentioned, for S, it can be divided into three aspects including 'Damage to economic (SEC)', 'Loss of life (SLI)', and 'Damage to environment (SEN)'.

Numerical judgments its must accept by the management and because of this the linguistic variables could be transformed into numbers and this could be done by using the Fussy Set Theory (FZT), to provide precise numerical judgements about the criteria of each security risk factor (Jiang, Lu, Qu, & Yang, 2021)**.**

The FST can provide number under two types of environments, the trapezoidal and the triangular numbers. For the present work will be using the trapezoidal fuzzy number. The explanation behind the theory of fuzzy numbers will not be a focus in the work. Therefore, a linguistic variable and the Trapezoidal Fuzzy Number (TFN) can be related as showed in table (Table 21).

Table 23 - Relationship between linguistic variables and Trapezoidal Fuzzy Numbers (TFN).

Grade	Occurrence Likelihood (P)		Severity (S)				Trapeizodal Fuzzy Number (TFN)
				SEC	SLI	SEN	
Low	Very Low	<10%	Slight	<20%	No Injuries	<5%	(0.00; 0.00; 1; 2)
	Low (L)	10% - 35%	Minor	20% - 39%	Minor Injuries	5%-19%	
Medium	Medium	36% - 64%	Moderate	40%-59%	Injuries	20%-39%	(1.0; 2.0; 3.0; 4.0)
High	High	65% - 90%	Critical	60% - 80%	Major Injuries	40%-65%	(3.0; 4.0; 5.0; 5.0)
	Very High	>90%	Catastrophic	>80%	Loss of Life	>65%	

From the table above it can be seen that the TFN is a set of four numbers.

This numbers are a result of the combination between the occurrence likelihood (P) and the severity (S), and this is represented mathematical by the following equation (4), from (Jiang, Lu, Qu, & Yang, 2021).

$$FRS = P \ x \ S \qquad (4)$$

Equation 4: Fuzzy Risk Score (FRS).

Where:

FRS = Fuzzy Risk Score

Because the Fuzzy Risk Score (FRS) is a set of numbers, it's not applicable for rating the risk security factor in the SRFT, the ideal is to be one number. The number to be carried is the correspondent number, the trapezoidal fuzzy of number *M* = (*l*,*m*,*n*,*u*), used to transform the set of number into crisp numbers also called defuzzification.

The mathematical operation for '*M* 'in a trapezoidal fuzzy environment is accordind to equation (5), from (Jiang, Lu, Qu, & Yang, 2021).

$$M = \frac{1}{3}\frac{(u+n)^2 - (u*n) - (l+m)^2 + (l*m)}{(u+n-m-l)} \qquad (5)$$

Equation 5: Trapezoidal Fuzzy Number.

Once the value of '*M* 'is available for each risk security factor in the SRFT the resulting sum for all will be the used find the level of Port Security and this is done by matching the result of total *'M'* to the interval of actual points status of ISPS Code (Table 20).

4.4.6.1. Application of SRTF, RALV and TFN for access the Security Level in Port of Matola

The table below (Table 23) summarize the characteristics of the fuel terminal in Port of Matola.

Table 24 - Characteristics of fuel terminal of Port of Matola…

Fuel Terminal
Tugs and mooring boats
Pipelines
Manifolds
Unloading Arms
Guardrooms
Blocks for Employees
Car Parking
Fire Brigades
Administrative Building
Port Control and Pilots
Ports State Control
Gates
Generator

After the portrait of petroleum terminal under the management of CFM – Direction from Port of Matola we follow through SRFT for access the port security level.

The result SRFT for the case study is adapted from the the SRFT from the table 15 accord to the actual characteristics observed. The result of combination of RALV and TFN are also present the result SRFT (Table 18). The calculation '*M'* was done under excel sheet.

Table 25 - SRFT for Port of Matola – Petroleum Terminal.

Security risk Factors	Range of Security / Linguistic Variables			Security Ratings / by experts	Defuzzyfication Scores *(M)*
	Low	Moderate	High		
Port of Matola Location	Rural	Urban	High Density	Urban	2.5
Visibility Status	Not Visible	Less Visible	High Visible	Less Visible	2.5
Site Ownership	Private	Public/Private	Government	Public/Private	2.5
Tanker Ship Traffic	Low	Medium	High	High	4.2
Presence of Terrorist Group in Region	Low quantity	Medium Quantity	Large Quantity	Medium Quantity	2.5
Worst Impact Onsite/Port Facility	Low quantity	Moderate	Severe	Severe	4.2
Worst Impact Off-site/Port Facility	Low	Moderate	Severe	Moderate	2.5
History of security incidents in port	Nil	Few	Frequent	Nil	0.7
Metorological Conditions	Good	Moderate	Bad	Good	0.7
Target Identification chemical by terrorist:					
Chemical Weapon (CW) agents	None	Minimum	Present	None	0.7
Listed Chemicals of Concern	None	Minimum	Present	None	0.7
Chemical s of Extreme Toxicity	None	Minimum	Present	None	0.7
Existing Security Measures:					
Acess Control from Land	High Level	Ordinary	Poor Ordinary	Poor Ordinary	4.2
Acess Control from Sea	High Level	Ordinary	Poor Ordinary	Ordinary	2.5
Perimeter Protection	High Level	Ordinary	Poor Ordinary	Ordinary	2.5
Mitigation Potential	High Level	Ordinary	Poor Ordinary	Poor Ordinary	4.2
				Total Score:	38.2

The summation of *'M'* its 38.2-point status. This value it's in the interval of 25 – 48 of point status of the ISPS Code countermeasures. The interval is of level 2, meaning that, a moderate security risk is present.

4.5. Risk Mitigation Alternatives

In the previous chapters potential risks criteria affecting the Matola Port Terminal with focus to the fuel terminal were identified. Then a risk-based model was implemented for comparisons of the risk criteria and prioritization. In a later stage the most significant risk criteria were analyzed individually using the same method for risk prioritization and port security level were accessed according to ISPS Code definitions. To complete the proposed risk management framework, it is required to mitigate the identified risk criteria. This chapter intends to introduce a number of risk mitigation strategies to be applied at Port of Matola to mitigate the priority risk criteria.

The motivation to follow the strategy for mitigation alternatives of this work, refers to the need for an integrated port assurance paradigm which will include quality, safety and security concerns and requirements. The quality, safety and security systems will rely on selection of international procedures such as ISO and Standards from IMO.

There are many different ISO Standards, and sometimes it can be hard to understand which ones are the most suitable for a business. While some are industry-specific, many of the most popular standards are broad-reaching and can be implemented into an organization, no matter what sector it is.

Below will be presenting the selection of some ISO standards wild used in many industries and that could also be accommodate in maritime ports such as the case of study Port of Matola.

4.5.1. International Standards Alternatives for Quality, Safety and Security Management Systems for Mitigation of Risk Criteria for Port of Matola.

According to international quality, safety and security standards, the adoption of a quality, safety and security management system is a strategic decision for an organization. The design and implementation of an organization's quality management system is influenced by a) its organizational environment, changes in that environment, and the risks associated with that environment; b) changing needs, c) specific goals; d) the products it supplies, e) the processes it employs, f) its organizational size and structure (Perreira, Garcia, & Oliveira Jesus, 2017).

For the present thesis the list of quality, safety, and security management system to be applied are founded to be a support for prevention and mitigation alternatives of the risk criteria identified in the data collection chapter (Chapter 6).
The quality, safety and security management systems that are founded to be suitable for the priority risk criteria are: ISO 9001, ISO 14001, ISO 29001, ISO 27001, ISO 7010, ISO 28000, and ISO 45001.

4.5.1.1. ISO 9001 (Quality Management)

The most popular family of standards is ISO 9000. This is a family of fourteen quality management standards. ISO 9001:2015 details how to put a quality management system (QMS) in place to better prepare your organization to produce quality products and services. It is customer-focused and places an emphasis on continuous improvement and top management processes that extend throughout the organization.
The ISO 9000 document has undergone many revisions throughout the history of the standard, to ensure that it is as efficient and relevant as possible. The standard was updated in 2015 and now places a greater emphasis on risk management. The standard is broadly focused and can be used in any organization in any sector, regardless of its size or complexity.
This standard provides a set of systems and principles that bring together an organization’s business objectives and marketing plan. When this is embedded in competency management plan, every employee understands how their actions benefit the customer experience. It allows processes to be put into place to continually review and improve an organization. To achieve certification in ISO 9001, a business must demonstrate a strong management system with a process approach, which means that it has a step-by-step sequence of actions. Day-to-day operating procedures and systems are documented.

4.5.1.2. ISO 29001 (Oil / Gas)

This standard is for all organizations working within the oil and gas industry supply chain. All requirements for ISO 29001 are generic and intended to be applicable to all organizations, regardless of the size and product provided. The oil, gas, and petrochemical industry can inflict significant damage on people and the environment if improperly managed. Therefore, a high level of operational integrity, as well as best practices and processes are needed to ensure safe operations. This standard provides the platform and method for reaching these high standards and ensuring safe operations.

ISO 29001 is completely aligned with ISO 9001. It incorporates best practices and risk management for the way organizations implement quality management requirements for the design, development, production, installation, and service of products for the oil and gas industries. Competency management will ensure that competency requirements for audits and certification in these specific management systems have been met.

4.5.1.3. ISO 27001 (Information Security)

This family of standards concerns information technology, with the goal of improving security and protecting company assets. 27001 is a management-based system that specifies a minimum set of policies, procedures, plans, records, and other documented information that is needed to become compliant. This can be monitored through a competency management program. Not only does this standard provide organizations with the necessary know-how for protecting valuable data and information, but it also provides certification which proves to customers and partners that it safeguards its data. ISO 27001 is a process for managing risks through the implementation of security controls.

4.5.1.4. ISO 14001 (Environment)

ISO 14000 is a family of standards relating to the environment. It includes multiple standards. ISO 14001:2015 is the most popular in the family and is the only one in which an organization can be certified.

ISO 14001 is concerned with how processes interact with the environment. The first step is to determine the competence, skills, and abilities, required for a person to perform a job function while avoiding potential environmental impacts. Then after identifying these competencies, people must be found with these competencies to fill the positions and then properly trained. Then all employees must be made aware of how their tasks can lead to identified environmental impacts. ISO 14001 specifies that you should keep records to show that competencies have been achieved through education, training, or experience.

4.5.1.5. ISO 7010 (Safety)

Prescribes safety signs for the purposes of accident prevention, fire protection, health hazard information and emergency evacuation. Makes use of plates with illustrations of signs. Signaling plates indicate direct or indirect risk. The simplification of symbols is one of the objectives of the ISO 7010 regulation in areas at risk.

4.5.1.6. ISPS CODE (Security)

The International Ship and Port Facility (ISPS) code was introduced in 2004 to help detect and prevent security incidents on ships and at port facilities. Addresses the port facility security assessment issue, development of port facility security plan (including countermeasures), and the skills and knowledge required of the personnel involved.

4.5.1.7. ISO 28000 (Security)

ISO 28000 is a major security initiative designed to improve the monitoring of freight flows, combat smuggling and other criminal activities and to respond to the threat of terrorist attacks. In doing so, its mandate is to create a safe and secure international supply chain regime.

ISO 28000 can be used by a broad range of organizations - small, medium, and large - in the manufacturing, service, storage, and transportation sectors at any stage of the production or supply chain.

This standard complements all international security legislative codes such as ISPS Code at port terminals (Fairnie, 2011).

4.5.2. Summary of Proposed Mitigation aAlternatives for Risk Criteria.

The summary of quality, safety and security management systems for mitigation alternatives considered to be applied in Port of Matola it's in the table below (Table 25). In the first column of the table the standards are being introduced, in columns 2 and 3 the mandatory and voluntary nature of the systems is provided, and in columns 4–8 the four categories (quality/safety/health and security) are provided.

Table 26 - Summary of quality, safety, and security management systems.

Quality/Safety Approaches	Standard Category						
	Implementation		Quality	Safety		Health	Security
	Mandatory	Voluntary		Environment	Human	Human	
ISO 9001		√	√				
ISO 29001		√	√				
ISO 27001		√					√
ISO 14001		√		√			
ISO 7010		√		√	√		
ISO 28000		√					√
ISPS CODE	√						
ISO 45001					√	√	

The evaluation output of risk assessment could be used to support in decision to purchase orders and contracts for one or another QSSMS to be used in Port.

The table below (Table 20) suggest the comparison of risk assessment linguistic variables and the minimum QSSMS requirement.

Table 27 - Risk assessment linguistic variables and minimum quality, safety, and security system requirement.

Risk Status	Minimum quality, safety, and security system requirement
Very Low	ISO 9001
Low	ISO 9001; Meet some requirement for ISO 7010, ISO 14001, and ISO 45001; Requirement for ISPS CODE.
Moderate	ISO 9001, ISO 14001, ISO 45001, ISPS CODE, ISO 7010 (when possible); Meet some requirement for ISO 29000 (when possible), ISO 28000 (when possible), ISO 27001 (when possible)
High	ISO 9001, ISO 14001, ISO 45001, ISPS CODE, ISSO 7010, ISSO 29001, ISO 27001

The following approach can be considered for the table above:

- Where status for the identified risk is very low the requirement for ISO 9001:2015 certification could be applied across all risk levels.
- Where risk status is low or moderate, ISO 9001:2015 certification might not be available to be applied to all risk, it would need to supplement with additional certification and meet the requirement for some certifications.
- When the risks are high the organization may seek for a combined ISO certification to avoid multi-risks to provide the organization with a higher level of assurance.

4.5.3. Integrated Management Systems (IMS)

The implementation of international standards for risk prevention and mitigation it's a cost task for an organization or company. This process is generally combined with Cost-Benefit Analysis (CBA) for optimal decision-making (UNCTAD, 2006).

Beside looking at implementation of one at time, the QSSMS can also be integrated creating an integrated management system (IMS).

According to (Muzaimi, Chew, & Hamid, 2017), the integration is a combination that consolidates the internal management practices into one system. The benefit as resulting from the implementation of IMS are the improvement of business focus, a holistic approach to managing business risk, reduce the clash between individual management systems, minimize duplication and bureaucracy, more effective and efficient internal and external audits, and simpler facilitation of the requirements of any new management system standard that the organization wishes to adopt

The most popular IMS is the integration of the systems that are focused on quality, environment, and occupational health and safety. The integration consists of three main management systems: ISO 9001, ISO 14001, and ISO 45001 (Figure10). And this IMS is considered to be the ideal for port of Matola.

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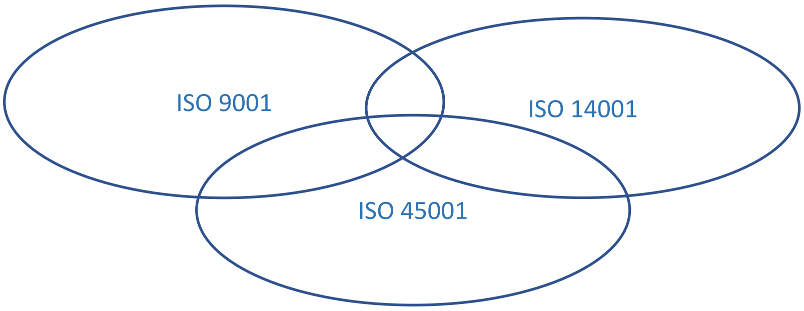

Figure 13: Suggested IMS for Port of Matola.

5. Conclusion

An effective risk management framework was proposed for the use of port of Matola.
For the assessment of the risk, it was proposed a AHP model.
The strengths of AHP are that reduces the burden on experts, and it enables consistency analysis of the comparisons and weights the risk criteria in a systematic, flexible, and reliable way.
By using the AHP, the assessment information of the Seven risk criteria was aggregated, to generate their final safety ranking. The prioritization is as follow R5, R7, R1, R4, R2, R3 and R6. However only the five according to the priority were used in the next steps of the proposed management framework.
To provide more reliable results FMEA were added to provide the impact of failure modes, the occurrence and detection for the priority risk according to AHP.
The results obtained in risk management through the AHP model are in accordance with the conditions placed to assess the consistency of the judgment, which suggests that these results can be used to plan risk responses at the port of Matola.

The SRFT with integration of risk assessment linguistic variables and TFSN were the tools used to assessment of security of port of Matola. The result presents a moderate risk, a level 2 risk point status from ISP code for Port of Matola.
This level suggests the port authority should review and upgrade existing procedures, maintain awareness however without excessive concern.

For mitigation purpose of priority risk criteria for port of Matola, an integration of quality, health, safety, security, and Environment management systems, is most important strategies for the company to ensure survival and savings (time, cost, and resources) in today's competitive and strictly regulated port activity.

The adoption of an integrated quality management system, safety, security, health and environment, its more viable, as it avoids the duplication of tasks of management and allows an organization to effectively share information resources and infrastructure, human, material and financial, and also provides important guidelines for the company, and strengthens its positioning in the international market and recognition by other companies, especially for meeting the requirements of stakeholders .

6. Recommendation

Development a digital program that integrate the risk management framework to help port authority to make rational safety decision.

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