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Integration of Occupational Health and Safety Management System with the Quality Management System: Case Study BCX Lda.

A Dissertation by

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Integration of Occupational Health and Safety Management System with the Quality Management System: Case Study BCX Lda.

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DECLARATION OF DOCUMENT ORIGINALITY

"I declare that this dissertation has never been submitted to obtain any degree or in any other context and is the result of my own individual work. This dissertation is presented in partial fulfilment of the requirements for the degree of Master in Health, Safety and Environment, from the Universidade Eduardo Mondlane".

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Abstract

The Quality Management System, although it is a very effective model for improving internal processes with a view to customer satisfaction, when the concern is to control occupational risks, prevent accidents and occupational diseases at work, as well as improve Occupational Health and Safety (OH&S) processes, is shown to be inadequate.

In order to respond to the need to maintain good safety and health conditions at work, many organizations use to integrate the two systems, the quality management system and the Occupational Health and Safety management system, essentially aiming to create and implement policies, procedures, establish and maintain controls of system components with an impact on work safety.

The lack of an initial gap analysis that integrates these three visions, namely functional, structural and behavioral during the process of development and implementation of Management Systems can lead to failure in the process.

This report describes and applies a series of adapted and strategically integrated technical-scientific tools such as Failure Modes, Effects, and Criticality Analysis (FMECA), Fault Tree Analysis (FTA), Systemic Cindynogenic Deficits (SCD) and Gap Analysis to, together, generate a detailed overview of OH&S conditions in the study area and provide subsidies for the treatment of deviations from good practices and recommendations of the Reference Standard ISO 45001:2018.

The results of the FMECA and FTA application, shows that the feared events without looking at the specificities, are related to OH&S issues. Each of these occurrences can be dealt with through the implementation of OH&S management procedures and/or safe work procedures, that is, it is necessary to set up policies and a team to manage the health and safety conditions and aspects.

In the OH&SMS design/development has aspects that should not be neglected, such as engagement plan of Interested Parts (IP), good communication and feedback practice between management and workers, attribution of responsibilities in the design of the management system process, PDCA approach.

In the OH&SMS Implementation process among other aspects, should be considered as important, the need to have an engagement plan for Stakeholders, Staff training and compliance with adopted safety procedures, Internal Audits execution, risk-based approach, team specialized in the analysis of deficiencies, and correct management of non-conformities.

Based on the proposed action plan would be needed at least 71 working days for the implementation of the OH&S Management System following the ISO 45001 :2018 requirements.

Key words: Management System, integration, Gap Analysis, Safety

Resumo

O Sistema de Gestão da Qualidade, embora seja um modelo bastante eficaz para a melhoria dos processos internos visando a satisfação do cliente, quando a preocupação é controlar os riscos ocupacionais, prevenir acidentes e doenças ocupacionais no trabalho, bem como melhorar a Saúde e Segurança Ocupacional (SSO), mostra-se inadequado.

Para responder à necessidade de manter boas condições de segurança e saúde no trabalho, muitas organizações recorrem à integração dos dois sistemas, o Sistema de Gestão da Qualidade e o Sistema de Gestão da Segurança e Saúde Ocupacional, visando essencialmente criar e implementar políticas, procedimentos, estabelecer e manter os controlos dos componentes do sistema com impacto na segurança do trabalho.

A falta de uma análise inicial de lacunas que integre estas três visões, nomeadamente funcional, estrutural e comportamental durante o processo de desenvolvimento e implementação de Sistemas de Gestão pode levar ao insucesso do processo.

Este relatório descreve e aplica uma série de ferramentas técnico-científicas adaptadas e estrategicamente integradas, como, a Análise de Modos de Falha, Efeitos e de Criticidade (*FMECA*), Análise de Árvore de Falhas (*FTA*), *Systemic Cindynogenic Deficits (SCD)* e Análise de Lacunas para, em conjunto, gerar uma visão detalhada das condições de SSO na área de estudo, fornecer subsídios para o tratamento de desvios às boas práticas e recomendações da Norma de Referência ISO 45001:2018.

Os resultados da aplicação *FMECA* e *FTA* mostram que os eventos temidos, sem olhar para as especificidades, estão relacionados à questões de SSO. Cada uma dessas ocorrências pode ser tratada por meio da implementação de procedimentos de gestão de SSO e/ou procedimentos de segurança do trabalho, ou seja, é necessário estabelecer políticas e uma equipe para gerir as condições e aspectos de saúde e segurança.

No Processo de desenvolvimento do Sistema de Gestão de Saúde e Segurança Ocupacional há aspectos que não devem ser negligenciados, como, Plano de Engajamento das Partes Interessadas, boas práticas de comunicação e *feedback* entre a gestão e os trabalhadores, atribuição de responsabilidades no processo de desenvolvimento do sistema de gestão, abordagem PDCA.

No processo de Implementação do Sistema de Gestão de Saúde e Segurança Ocupacional entre outros aspectos, deve ser considerado como imprescindível, a necessidade de ter um Plano de

Engajamento para as Partes Interessadas, Treinamento da equipe e cumprimento dos procedimentos de segurança adotados, Realização de Auditorias Internas, abordagem baseada em riscos, equipe especializada na análise de deficiências, e gestão correta de não conformidades.

Com base no plano de acção proposto seriam necessários pelo menos 71 dias úteis para a implementação do Sistema de Gestão de Saúde e Segurança Ocupacional seguindo os requisitos da ISO 45001:2018.

Palavras-chave: Sistema de Gestão, integração, *Gap Analysis*, Segurança

If we don't change our way of thinking, we won't be able to solve problems that we create with our current ways of thinking.

Albert Einstein

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Abbreviations

Binf.	Lower limit (for the class)
Bsup.	Upper limit (for the class)
CA	Criticality analysis
DCRCS	Degree of Compliance with Requirements- Ccurrent Situation
DCRDS	Degree of Compliance with the Requirements-Desirable Situation
Fk	Cumulative frequency
fk	frequency
FMEA	Failure Modes and Effects Assessment
FMECA	Failure Modes, Effects, Causes and Criticality assessment
FTA	Fault Tree Analysis
I&A	Incidents and Accident per
ICT	Information and Communication Technology
ILO	International Labor Organization
IP	Interested Parts
ISO	International Standardization Organization
NASA	National Aeronautics and Space Administration
OEM	Original Equipment Manufacturer
OH&S	Occupational Health and Safety
OH&SMS	Occupational Health and Safety Management System
QMS	Quality management System
SCD	Systemic Cindynogenic Deficit
SME	Small and medium-sized enterprise
SSC	Subsystem component
Vx	Coefficient of Global variation
Vx^*	Realistic Coefficient of variation

CHAREPTER 1: Introduction

In this chapter, the following sections describe the context of this research, the objectives of the study are defined and the research problem is justified.

1.1. Context

The focus of quality management models is to develop, implement, standardize, maintain and continually improve the quality of processes, products and services. The most used model for this purpose is the International Standardization Organization (ISO) model, implemented through the ISO 9000 series standards (Quirós & Justino, 2013). Although it is a very effective model to improve internal processes with a view to customer satisfaction, when the concern is to control occupational risks, prevent work accidents and occupational diseases, as well as improve Occupational Health and Safety (OH&S) processes, the model proved to be unsuitable (Pacheco, 2019).

An organization is responsible for the safety and health of its workers and others who are affected by its activities. This responsibility includes the promotion and protection of physical, psychological and mental health (ISO, 2018).

The Occupational Health and Safety Management System (OH&SMS) aims to provide a framework for the management of Occupational Health and Safety (OH&S) risks, that is, to prevent work-related injuries and health problems and to provide a safe and healthy workplace. (ISO, 2018).

” An OH&S management system to be effective, must be developed, implemented, evaluated and continuously improved in accordance with the guidelines of the Standard. It must be aligned with the organization's objectives and contribute to their achievement. The main objective of the management system should be to achieve and increase safety through the:

- Consistent fulfilment of all requirements for the management of the organization;
- Description of the necessary and systematic planned actions in order to provide the indispensable confidence that all these requirements are met;
- Ensuring that health and safety, quality and production requirements are not addressed in separate forums, to help avoid possible negative impacts on the management system” (IAEA, 2013).

All the benefits of OH&SMS implementation become reality when the phases for its implementation are properly carried out.

Mourougan and Sethuraman (2017) present an approach to the implementation of the quality management system that adapts well to the needs of OH&SMS implementation. According to this authors, the development process involves six main phases:

Phase 1: Initial Gap Assessment. This is called Gap analysis

Phase 2: Preparation of the Action Plan for the Implementation

Phase 3: Implementation

Phase 4: Audit and System analysis

Phase 5: Certification

Phase 6: Communication with stakeholders

This study focuses on the application of phases 1 and 2 only. In phase 1, we will be evaluating the current state of the organization regarding the compliance with the requirements of the Standard (ISO 45001:2018). The results of this evaluation will be used as a reference for the planning and development of the OH&SMS in the study organization (actions referring to phase 2).

The initial review (Phase 1) will focus on the organization's operations and processes, helping to determine what already exists about policies and procedures to deal with, for example the external service providers in terms of contracts and suppliers, integration of the OH&SMS into the organization's business processes, compliance with legal and other requirements, performance assessment and monitoring of the OH&SMS. The organization’s current and existing practices will also be evaluated, considering:

- Leadership and Commitment.
- Hazard Identification and Assessment.
- Hazard Control.
- Workplace Inspections.
- Competence and Training of the Worker.
- Accident Reporting and Investigation.
- Emergency Response Planning.

This research project took place at BCX Lda. BCX is a company specialized in providing information and communication technology products, services, and solutions such as cloud computing, print management, applications, business communication, data center, energy efficiency, information security, Retail IT, systems integration, and desktop services.

1.2. Research problem

The ISO 9001:2015 Standard provides a set of requirements that, when well implemented, ensure the reliability that the organization is able to consistently provide products and services that meet the needs and expectations of its customers.

The Quality Management System (QMS), although it can favour and increase stakeholder satisfaction, allows addressing risks and opportunities related to the organization's context and objectives, improving the organizational system, achieving maximum efficiency and internal control (Viadiu, 2006 *Apud* Pacheco, 2019).

The search for customer satisfaction, and the achievement of maximum efficiency without the integration of OH&S in production processes, generates a strong gap in terms of work safety, that is, greater exposure of employees to risks with the potential to cause damage to health, and even material losses.

The **Figure 1** below illustrates non-conformities verified in the study area, and were divided into seven categories (Electrical Devices, Safety Signalling, Fire Fighting Devices, Waste Management, Cleaning and Organization, Infrastructure and Equipment Management, Other Findings).

The category “other remarks” is the one with the highest percentage among the categories of nonconformities and accounts for 26%. The set of non-conformities included in this category are: Use of inappropriate PPE, lack of a culture of identification and assessment of potential risks related to routine and non-routine activities, failure to carry out inductions or safety dialogues, lack of recording accidents.

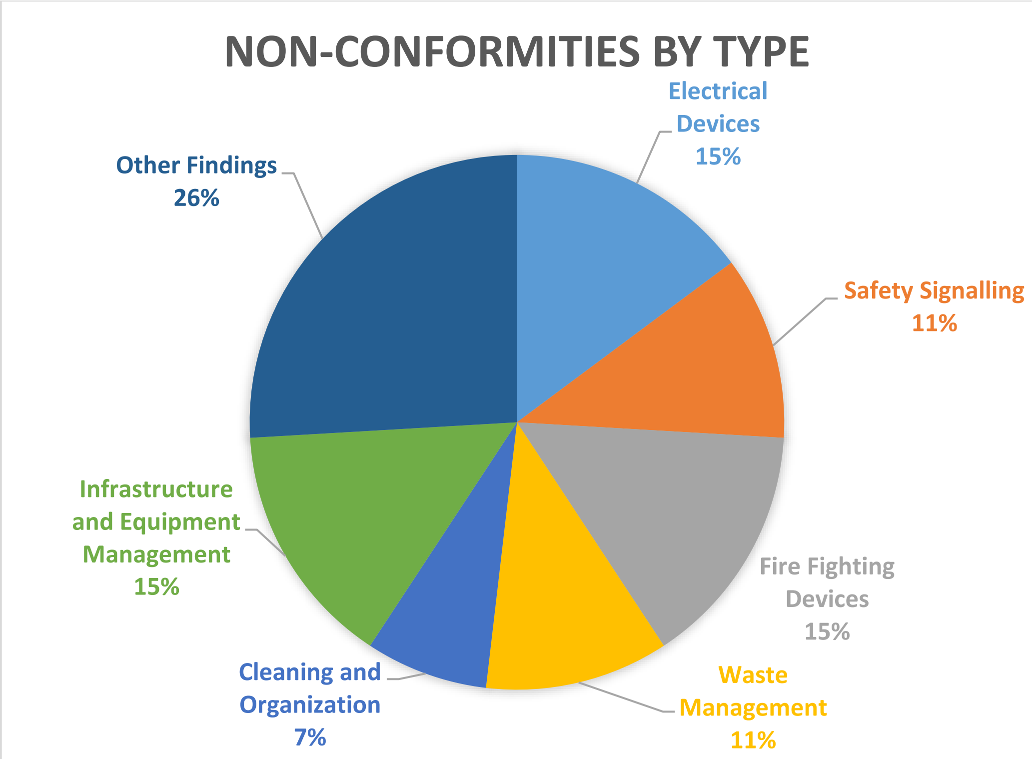


Figure 1: Non-conformities identified in the study area

The OH&SMS is a tool that allows identifying, evaluating, controlling, and monitoring problems that may be related to the safety of employees and production processes.

To implement the standards required by the ISO Management Systems Standards, most organizations tend to survey gaps/deviations between their current state and the requirements of the Standard they intend to implement. This procedure is essential for estimating resources and the level of effort required for the implementation of the Standard and give an overview of what can from the current practices be reused in the system. Hence, this procedure it is commonly referred to as gap analysis and it is often complex (Valdevit & Mayer, 2010).

The lack of use of an approach in the implementation of management systems that allows to highlight which areas at the organization need improvements to qualify for ISO, leads to wasting time, money and increases the likelihood of making mistakes.

Bering in mind that there is a need to generate a list of findings and valuable initial information for the management systems integration process, including to measure the progress of the Management System Implementation Action Plan, the following research questions are posed:

1. **What is the importance of the initial diagnosis for the successful implementation of the Occupational Health and Safety Management System, for certification purposes?**

2. **How to assess the level of compliance with the requirements of the Occupational Health and Safety Management System (SGSSO) at BCX Lda, for the purpose of certification by the ISO 45001:2018 Standard?**
3. **How can OH&S Management processes be integrated into the Quality Management System and production processes?**

1.3. Motivation

The changes that have been happening in the last decades in the world have led organizations to implement the Quality Management System, in response to the need to adopt new business strategies to face competition and increasing customer demands. However, the International Labour Organization (ILO) presents unsatisfactory indicators for this trend of increasing quality standards. Thus, the ILO estimates that at least 2.3 million women and men around the world are affected by work-related accidents or illnesses every year, which corresponds to 6,000 deaths every day. Work-related illnesses are the most common cause of death among workers. It is estimated that hazardous substances alone, cause 651 279 deaths per year (ILO, 2022).

In addition to the need to differentiate themselves in the market by optimizing their processes, organizations also need to demonstrate to stakeholders that occupational health and safety issues are being addressed and considered in their daily activities. As a result, organizations of all types around the world, to avoid strategic and competitive implications, are now focusing on achieving good performance in the field of occupational health and safety (OH&S).

The need to integrate the requirements of the ISO 45001:2018 Standard into the existing Management System arises from the concern to prevent accidents at work and occupational diseases cases, as well as to improve OH&S processes. The integration of the requirements of the ISO 45001:2018 Standard in the existing Management System, can bring advantages in addition to the correct management and monitoring of occupational risks and continuous improvement of Health and Safety conditions in the work environment, it can reduce the cost of the final product, by the reduction of interruptions in the production process, reduction of absenteeism and accidents and/or occupational diseases (Quelhas *et al*., 2003).

The ISO Occupational Health and Safety Management Standard (ISO 45001: 2018) is applicable to all types and sizes of organizations and defines specific OH&S requirements to enable any organization to develop and implement policies and objectives that consider legal requirements and good practices (ISO, 2018).

The existence of gaps in meeting the requirements of the Standard is at the origin of deficiencies in compliance with the basic principles of occupational safety and health within many organizations, that is, failures in the Occupational Health and Safety Management System. And, for organizations that seek certification, the deficient survey of these gaps in the initial phase (Phase 1) of implementation of the management system tends to generate waste of resources, as well as failures in the developed system.

Conducting conformity assessment based on the gap analysis approach can optimize efforts to reach the required or desirable level of compliance with the requirements of the Standard, and mainly allow to highlight flaws present in the organization regarding OH&S. Once the gap analysis process is effectively completed, it allows the organization to better focus its resources (financial, human and technological) on these identified areas to improvement.

This study is related to assessing the level of compliance with the OH&S requirements in relation to the ISO 45001:2018 Standard (Gap Investigation) at BCX Lda., followed by the design of an action plan for the process of integrating the QMS and OH&SMS that optimizes the resources (financial, human, and technological) of the organization in the implementation process.

1.4. Research Objective

1.4.1. General objective

General objective of this study is announced as:

- To evaluate the effectiveness of the quality management system in improving OH&S conditions in the work environment at BCX Lda.

1.4.2. Specifics objectives

- To describe the current situation of the system with characterization of its strengths and weaknesses.
- To perform system gap analysis based on the requirements of ISO 45001:2018.
- To identify the risks in the OH&SMS development and implementation processes.
- To propose an action plan to integrate the Occupational Health and Safety Management System with the Quality Management System.

CHAREPTER 2: Literature review

In this chapter, in the sections that follow, the theoretical framework of the theme of this research is made, and some important concepts are described.

2. Occupational Health and Safety Management System (OH&SMS)

The OH&SMS ISO 45001:2018 as other ISO management system standards, is based on the PDCA cycle (Plan-Do-Check-Act), and uses risk-based thinking approach as a method of identifying risks and opportunities in all parts of the cycle to improve performance and minimize negative outcomes.

The OH&SMS is a tool designed to create a safe and healthy work environment by decreasing the incidence of injury and illness in the employer's operation. The level of detail, the complexity, the extent of documented information and the resources needed to ensure Successful implementation of the system will depend on a number of factors, such as (AlbertaGoberment, 2009; ISO, 2018):

- Management commitment to the system.
- The organization's context (e.g. number of workers, size, geography, culture, legal requirements and other requirements).
- Effective allocation of resources.
- High level of employee participation.
- The scope of the organization's OH&SMS.
- The nature of the organization's activities and the related OH&S risks.

Although the scope and complexity varies according to the size and type of workplace, the following elements are the basic components of an OH&SMS, and are all very much interdependent (AlbertaGoberment, 2009).

1. Management Leadership and Organizational Commitment
2. Hazard Identification and Assessment
3. Hazard Control
4. Work Site Inspections
5. Worker Competency and Training
6. Incident Reporting and Investigation
7. Emergency Response Planning
8. Program Administration

2.1. Key success Factor

The implementation of an OH&SMS is a strategic and operational decision for an organization. The success of the OH&S management system depends on leadership, commitment and participation from all levels and functions of the organization (ISO, 2018).

The OH&SMS implementation and maintenance, its effectiveness and its ability to achieve its intended outcomes are dependent on a number of key factors, which can include (ISO, 2018).

a. Top management leadership, commitment, responsibilities and accountability.
b. Top management developing, leading and promoting a culture in the organization that supports the intended outcomes of the OH&S management system.
c. Communication.
d. Consultation and participation of workers, and, where they exist, workers' representatives.
e. Allocation of the necessary resources to maintain it.
f. OH&S policies, which are compatible with the overall strategic objectives and direction of the organization;
g. Effective process(es) for identifying hazards, controlling OH&S risks and taking advantage of OH&S opportunities.
h. Continual performance evaluation and monitoring of the OH&S management system to improve OH&S performance.
i. Integration of the OH&SMS into the organization's business processes.
j. OH&S objectives that align with the OH&S policy and take into account the organization's hazards, OH&S risks and OH&S opportunities.
k. Compliance with its legal requirements and other requirements.

2.2. Occupational Health and Safety Management System Scope

According to ISO (2018) the ISO 45001: 2018 specify the requirement to an OH&SMS, and it is applicable to any organization that wishes to establish, implement, and maintain an OH&S management system to improve occupational health and safety, eliminate hazards and minimize OH&S risks (including system deficiencies), take advantage of OH&S opportunities, and address OH&S management system nonconformities associated with its activities.

The Standard is applicable to any organization regardless of its size, type, and activities. It is applicable to the OH&S risks under the organization's control, considering factors such as the context in which the organization operates and the needs and expectations of its workers and other interested parties.

This Standard does not state specific criteria for OH&S performance, nor it prescriptive about the design of an OH&S management system (ISO, 2018).

This Standard enables an organization, through its OH&S management system, to integrate other aspects of health and safety, such as worker wellness/wellbeing.

This Standard does not address issues such as product safety, property damage or environmental impacts, beyond the risks to workers and other relevant interested parties (ISO, 2018).

This Standard can be used in whole or in part to systematically improve occupational health and safety management. However, claims of conformity to this Standard are not acceptable unless all its requirements are incorporated into an organization's OH&S management system and fulfilled without exclusion (ISO, 2018).

2.3. OH&SMS Implementation process

Mourougan & Sethuraman (2017) present an approach to the implementation of the quality management system that adapts well to the needs of OH&SMS implementation. According to these authors, the development process involves six main phases:

I. Phase 1-Initial Gap Assessment-Gap analysis

The initial gap assessment of the organization gives a complete overview of the current status of the management system (Mourougan & Sethuraman, 2017).

The gap analysis technique determine the steps to be taken to move from the current state to a desired future state. It is a good approach that can be taken to clearly identify which clauses of the ISO standard are not being fully addressed (or not addressed) and to develop corrective actions (WMO, 2017).

Therefore, the main objective of this first step is to determine, based on a careful analysis of the organization's documents and records, existing processes and their implementation, whether the requirements of the standard are being met, and also which documents, records, processes are missing and how can be generated.

II. Phase 2-Preparation of the Action Plan for the Implementation

The Action Plan is prepared based on the information generated in the initial gap assessment. This plan helps to make changes and implement improvements step by step (Mourougan & Sethuraman, 2017).

The objective of this phase is to transform the outputs of the previous phase into an action plan that will solve the identified gaps, that is, this phase will result in a draft of the Management System specifications, with defined responsibilities.

III. Phase 3- Implementation

At the Implementation phase shell be implemented the changes in accordance with the developed action plan (Mourougan & Sethuraman, 2017). That is, at this stage it will be necessary to develop the necessary documentation, processes, etc. at the same time implementing those requirements that were defined as necessary in the previous phase.

Therefore, the main purpose of this phase is to implement the plan developed in the previous phase.

IV. Phase 4- Audit and System analysis

There are different techniques that can be used to measure the system effectiveness, for example: interviews with managers, staff and / or other stakeholders, surveys, analysis of documents generated during the system implamentation, and the observation and random control of document activities (Hernad, J.M. C. & Gaya, C. G., 2013)

The main purpose of this phase is to measure the system effectiveness, identifying any weaknesses with the purpose of correcting them. Once implemented the system, must be defined an evaluation plan including evaluation criteria (Hernad, J.M. C. & Gaya, C. G., 2013)

This phase helps to measure whether the changes implemented in the previous phase had the desired effect on the processes, inputs and outputs that the organization considers important.

V. Phase 5-Certification

The Certification process it is the process through which the certification body, after an audit of the organization's compliance with normative requirements, assigne a certificate corresponding to the Standard by which it was audited (Mourougan & Sethuraman, 2017).

VI. Phase 6: Communication with stakeholders

The organization at this stage communicates with relevant stakeholders in different ways at its disposal to show not only the certificate but also show them the results with pride on how well the organization manages its processes and continuously improves them (Mourougan & Sethuraman, 2017).

2.3.1. Mandatory Documents according to ISO 45001:2018

For the ISO management system to be considered fully implemented, some mandatory requirement must be met, the table below shows the mandatory documents and records.

Table 1: Mandatory documents and records

Mandatory documents	Clause
Scope of the OH&S management system	4.3
OH&S policy	5.2
Responsibilities and authorities within the OH&SMS	5.3
OH&S process for addressing risks and opportunities	6.1.1
Methodology and criteria for assessment of OH&S risks	6.1.2.2
OH&S Objectives and plans for achieving them	6.2.2
Procedure for emergency preparedness and response	8.2
Mandatory records	**Clause**
OH&S risks and opportunities and actions for addressing them	6.1.1
Legal and other requirements	6.1.3
Evidence of competence	7.2
Evidence of communications	7.4.1
List of external documents	7.5.3
Plans for responding to potential emergency situations	8.2
Results on monitoring, measurements, analysis and performance evaluation	9.1.1
Maintenance, calibration or verification of monitoring equipment	9.1.1
Compliance evaluation results	9.1.2
Internal audit program	9.2.2
Internal audit results	9.2.2
Results of management review	9.3
Nature of incidents or nonconformities and any subsequent action taken	10.2
Results of any action and corrective action, including their effectiveness	10.2
Evidence of the results of continual improvement	10.3

Source: NM ISO 45001:2018

The above are the documents and records that are required to be maintained for the ISO 45001 Occupational Health and Safety Management System, however, it is not prohibited to maintain or use other documents or records, provided that the organization has identified them as necessary to ensure that the management system remains functional, is maintained and continuously improved.

2.3.2. Benefits of the Occupational Health and Safety Management System implementation

The ISO 45001:2018 Standard can help any organization to achieve the intended outcomes of its OH&S management system, consistent with the organization's OH&S policy and other criteria established by it. The benefit of the implementation of OH&S management system include but not limited to the following (ISO, 2018):

a. Continual improvement of OH&S performance.
b. Fulfilment of legal requirements and other requirements.
c. Achievement of OH&S objectives.
d. Improve the efficiency of processes through the application of risk-based thinking and the PDCA cycle.
e. Promotion of worker participation in hazards identification, elimination or reducing of risks by implementing controls integrated with other business process.
f. Provides a systematic approach for senior leadership to assess OH&S risk and opportunities.
g. Enables to integrate the ISO 45001 because of the high-level structure of 'Annex SL' with other ISO standards like ISO 9001 Quality and ISO14001 Environmental management systems.

2.4. Gap analysis Approach

According to Murray, J. P., (2000) the Gap analysis process can be seen as a way to measure the distance (i.e., the gap) between where a particular item currently stands and where it should be, to better meet the organization's needs.

This approach provides the company with insight into areas for improvement, also offers a low-cost, rapid way to address specific areas of difficulty. By using the output of the gap analysis, it is possible to develop the list of findings and action plan (Murray, J. P., 2000) (Keen, R., 2022).

The requirement to make the gap analysis process work include four steps detailed above:

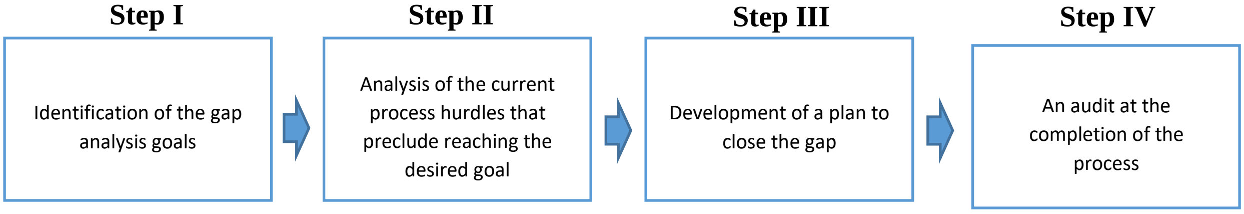


Figure 2: Gap analysis process steps (adapted from Murray, J. P., 2000)

I. Identification of the gap analysis goals- This step will allow define the tool to be used to assess the gap.
II. Analysis of the current process hurdles that preclude reaching the desired goal- This stage will allow the analysis of the current situation regarding certain requirements and will provide subsidies for the development of the action plan.
III. Development of a plan to close the gap- The Action Plan will allow to close the gaps between the process's status and attainment of the desired goal.
IV. An audit at the completion of the process- The audit should determine if the goals have been met, and if those who used the process now understand it, making its future use more productive.

2.5. Definition of a System

According to Vesely, W. E., *at al.*, (1981) a system is a deterministic entity comprising an interacting collection of discrete elements. From the definition, a system is made up of parts or subsystems that interact keeping the System itself functional, so it is possible to perceive that any failure in one of the components (subsystem or element) of the System ends up affecting it in part or in general, that is, ends up changing in a way. Understanding this principle is very important because it allows us to better define strategies, make decisions that result from the analysis of the components of the system that keep it functional.

When carrying out any analysis of a system, it is assumed that there is a clear definition of its limits. It is therefore very important to establish resolution limits, that is, to establish the external and internal limits of the system to be analysed. It is quite useful in the resolution perspective, to define subsystems or also to divide the subsystems into elements, the choice of system limits guarantees better understanding of analysis (Vesely, W. E., *at al*., 1981).

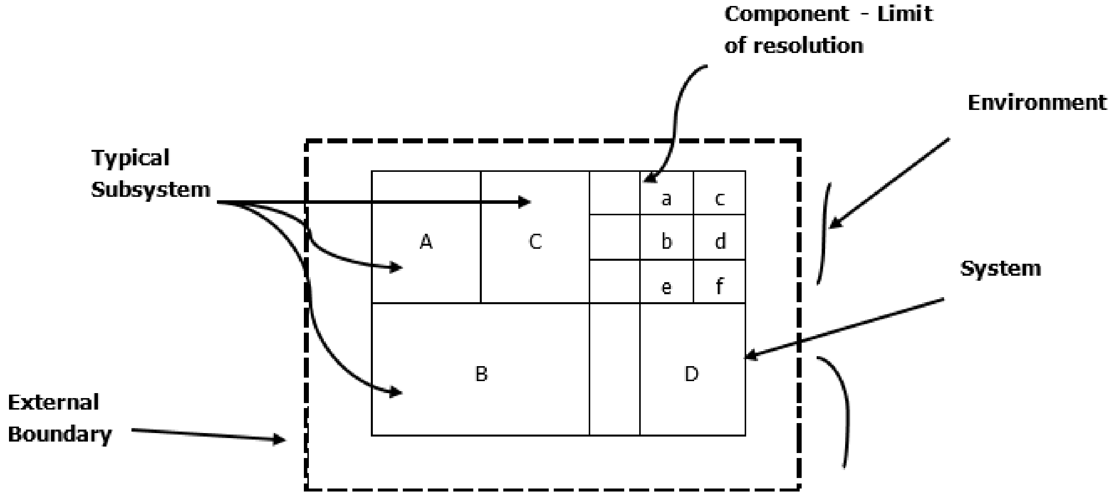


Figure 3: System definition: Internal and External Boundary. Adapted from Vesely, W. E., at al., (1981)

2.5.1. Approaches to system analysis

There is two generics approaches to system analysis: inductive and deductive:

2.5.1.1. Inductive Approaches

Induction constitutes reasoning from individual cases to a general conclusion. When the analysis starts from particular fault or initiating condition and attempt to ascertain the effect of that fault or condition on system operation, we are constructing an inductive system analysis (Vesely, W. E., *at al.*, 1981).

There is many inductive system analysis methods developed. Examples of this method are: Preliminary Hazards Analysis (PHA), Failure Mode and Effect Analysis (FMEA), Failure Mode Effect and Criticality Analysis (FMECA), Fault Hazard Analysis (FHA), and Event Tree Analysis (Vesely, W. E., *at al.*, 1981).

2.5.1.2. Deductive Approaches

Deduction constitutes reasoning from the general to the specific. In a deductive system analysis, we postulate that the system itself has failed in a certain way, and we attempt to find out what modes of system/component behavior contribute to this failure. Fault Tree Analysis (FTA), is an example of deductive system analysis (Vesely, W. E., *at al.*, 1981).

2.5.2. Failure Mode, Effects and Criticality Analysis (FMECA)

The Failure Mode, Effects and Criticality Analysis (FMECA) is a reliability evaluation/design technique originally developed by the National Aeronautics and Space Administration (NASA) to improve and verify the reliability of space program hardware, the technique is very useful to examine the potential failure modes within a system and its equipment, in order to determine the effects on equipment and system performance. The FMECA is composed of two separate analyses, the Failure Mode and Effects Analysis (FMEA) and the Criticality Analysis (CA) (Borgovini, R. *at al.,* 1993).

2.5.2.1. Failure Mode and Effects Analysis (FMEA)

The analyst performing a functional FMEA must be able to define and identify each system function and its associated failure modes for each functional output. The failure mode and effects analysis is completed by determining the potential failure modes and failure causes of each system function.

2.5.2.2. Criticality Analysis (CA)

The criticality analysis (CA), like the FMEA. The CA produces a relative measure of significance of the effect a failure mode has on the successful operation and safety of the system. The CA is completed after the local, next higher level and end effects of a failure have been evaluated in the FMEA (Borgovini, R. *at al.,* 1993).

"To perform a quantitative criticality analysis, it is necessary to have the completed FMEA as well as information on the system such as system mission, definition of failures, severity categories and part failure rate information" (Borgovini, R. *at al.,* 1993).

2.5.2.3. Benefits resulting from application of FMECA Technic

According to Borgovini, R. *at al.* (1993) The FMECA provides valuable information for maintainability, safety and logistic analysis:

- Determines the effects of each failure mode on system performance
- Provides data for developing fault tree analysis and reliability block diagram models
- Provides a foundation for qualitative reliability, maintainability, safety and logistics analyses
- Provide estimates of system critical failure rates
- Provide a quantitative ranking of system and/or subsystem failure modes

2.5.3. Fault Tree analysis (FTA)

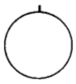
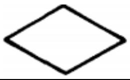
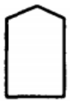
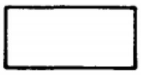
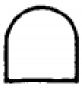
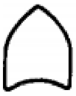
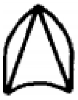
Fault tree analysis (FTA) is a deductive system failure analysis (logic diagram which follows multi-causality principle) which focuses on one particular undesired event (top event) and which provides a method for determining causes of this event (Vesely, W. E., *at al.,* 1981).

According to Vesely, W. E., at al. (1981) it is important to Careful chose the top event for the success of the analysis. The Top event cannot be too general (the analysis become unmanageable) or too specific (the analysis does not provide a sufficiently broad view of the system).

2.5.3.1. Symbology-The Building Blocks of the Fault Tree

According to Vesely, W. E., at al. (1981) the main symbols used to build FTA diagram are presented in Table 2 below.

Table 2: Fault Tree Symbols

	PRIMARY EVENT SYMBOLS
	**Basic Event-** Describes a basic initiating fault (primary failure)
	**Conditioning event** - Specific conditions or restrictions that apply to any logic gate (used primarily with PRIORITY AND and INHIBIT gates)
	**Undeveloped Event** - An event which is not further developed either because it is of insufficient consequence or because information is unavailable.
	**External Event** - An event which is normally expected to occur
	INTERMEDIATE EVENT SYMBOLS
	A fault event that occurs because of one or more antecedent
	GATE SYMBOLS
	**AND** - Output fault occurs if all of the input faults occur
	**OR** - Output fault occurs if at least one of the input faults occurs
	**EXCLUSIVE OR** - Output fault occurs if exactly one of the input faults occurs
	**PRIORITY AND** - Output fault occurs if all of the input faults occur in a specific sequence
	**INHIBIT** - Output fault occurs if the (single} input fault occurs in the presence of an enabling condition
	TRANSFER SYMBOLS
	**TRANSFER IN** - Indicates that the tree is developed further at the occurrence of the corresponding TRANSFER OUT
	**TRANSFER OUT** - Indicates that this portion of the tree must be attached at the corresponding TRANSFER IN

2.5.3.2. Benefits resulting from application of FTA Technic

According to Andrews, J. & Moss, B., (2002) the Fault Tree Analysis:

- Gives the logic path beginning with the undesirable event. Focuses the attention of the analyst on one undesired system failure mode which is usually that identified as the most critical with respect to the desired system function.
- Diagram can be used to help communicate the results of the analysis to peers. It is particularly useful with multidisciplinary teams with some members who may be unfamiliar with the numerical performance measures.
- Gives qualitative and quantitative results that together provide the decision makers with an objective means of assessing the adequacy of the system design.

2.5.4. Systemic Cyndinogenic Deficit (SCD)

According to Kervern, G. Y. (1995) the term Cindynics is derived from "Kindunos" the Greek word for danger and refers to the new science of hazard identification. It is also called “**science of danger**”

Cindynics' approach sets out to identify the causes and find ways to avoid crises, that is, the objective pursued is to identify the vulnerability of these situations in order to reduce it from the source and thus limit the risks and their consequences at a human, material, economic, environmental level, etc (Rouaud, Julien 2017).

By applying the Cindynics approach, it is possible to identify all potential sources of risk existing in the system in order to preemptively implement action plans to reduce them so that the system achieves its objectives.

The Cindynicians established based on the systematic survey of post-accident/disaster reports, a list of 10 empirical Systemic Cindynogenic Deficits (SCDs), because the analysis of the catastrophes showed that the 10 cindynogenic factors were present and were permanent causes (Kervern, G. Y. 1995) (Rouaud, Julien 2017a):

- 4 factors are cultural by nature,
- 2 factors are organisational,
- 4 factors are managerial.

According to Rouaud, Julien (2017a) the list of the 10 empirically established S.C.D is as follows:

1. S.C.D 1 - Cultural - Conviction of absence of danger
2. S.C.D 2 - Cultural - Aversion for complexity
3. S.C.D 3 - Cultural - Non-communication attitude

4. S.C.D 4 - Cultural - Non-attention to the outside world
5. S.C.D 5 - Organisational - Production dominates risk-management
6. S.C.D 6 - Organisational - Dilution of accountability
7. S.C.D 7 - Managerial - No post-accident informations storage and processing
8. S.C.D 8 - Managerial - No risk-management methodology
9. S.C.D 9 - Managerial - No training for risk Management/safety personal
10. S.C.D 10 - Managerial - No preparation for crisis management

According to Rouaud, Julien (2017a) the presence of 3 or 4 S.C.D in a system is sufficient to generate an important accident or a catastrophe.

CHAREPTER 3: Methodology

In this chapter and sections that follow, the methodology used to develop this research is described.

3. Methodology Approach

To meet the expectation about the project, which is the development of an action plan for the process of integrating the QMS and OH&SMS, deductive and inductive analyses will be developed, based on bibliographic research, associated with field work (Site inspections/internal audits).

The proposed methodology will consist of four phases:

- **Phase 1**: Literature review
- **Phase 2**: Preparation of the Gap Analysis questionnaire
- **Phase 3**: Data collection
- **Phase 4**: Definition of the strategy to solve the gaps - Preparation of the Implementation action plan.

Data collection will be based on the application of qualitative and quantitative methods, as shown in the diagram below.

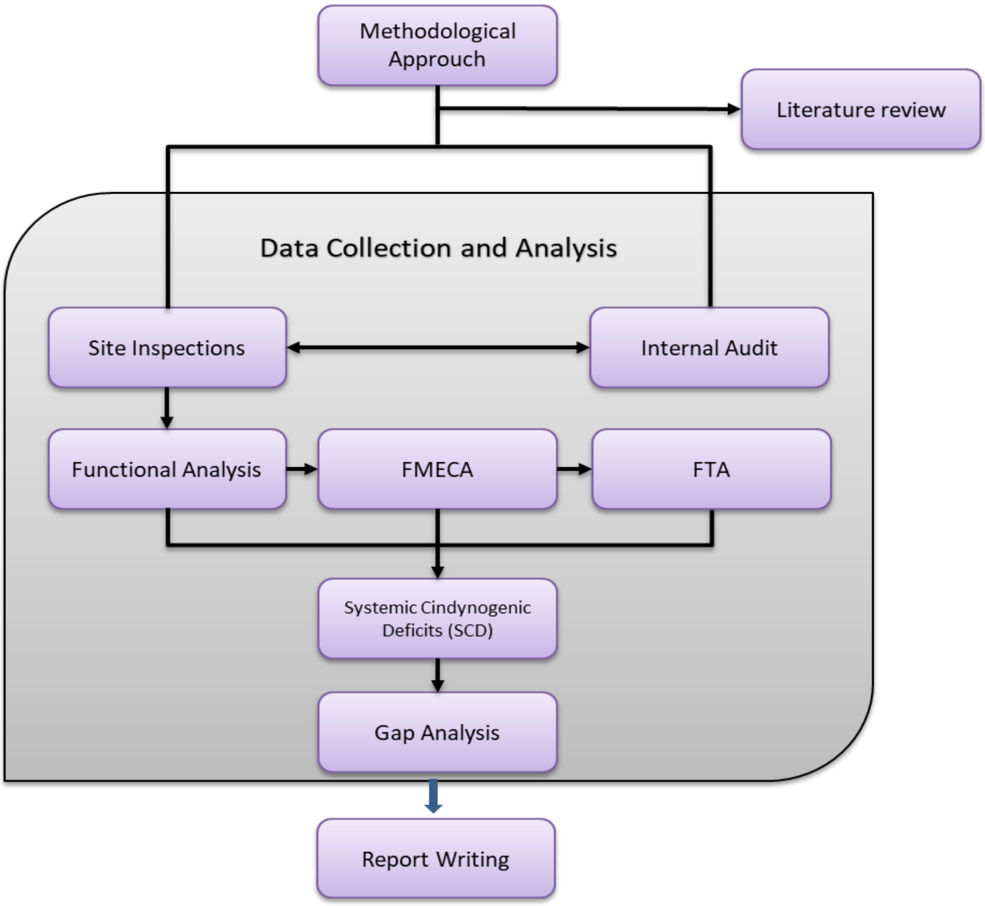


Figure 4: Methodological Approach

Each of the phases is described below.

3.1. Phase 1: Literature review

This phase is vital in the development of this research, it is where the fundamentals to develop the research will be obtained.

3.2. Phase 2: Preparation of the Gap Analysis questionnaire

The Gap Analysis Form is essentially a list of well-structured questions, developed based on the requirements contained in the ISO 45001:2018 Standard. This Form will be used to systematically verify the existence of evidence of compliance with the requirements contained in the Standard. A rating scale will be defined for each question. The assignment of classification will be based on judgment and evidence of the degree of compliance with the requirements of the ISO 45001:2018 Standard.

Table 3: Rating Scale of Compliance with Standard Requirements

Evaluation criteria				Description
NA	Not applicable	0		Requirement Intentionally Ignored
NC	Non-compliance	1	(red)	There is no evidence or elements leading to the fulfilment of the requirement, that is, nothing is done
P	Partial Compliance	2	(yellow)	Partially Satisfied or in Progress
L	Largely fulfilled	3	(light green)	There is evidence(s) of a thorough and systematic approach to meeting the requirement. There are some shortcomings regarding the fulfilment of the requirement, i.e. done but not sufficiently documented
F	Fully Fulfilled	4	(dark green)	There is evidence(s) of a thorough and systematic approach to meeting the requirement. There is no significant deficiency related to the requirement, that is, requirement satisfied and sufficiently documented

Source: Adapted from ISO/IEC 33020: 2015

The application of the questionnaire will generate a list of existing documents and/or required by the Standard as documented information, as well as the quantification of the Level of compliance with the requirements of the Standard.

3.3. Phase 3: Data collection and system analysis

This phase will be carried out in three steps. And in this phase, the integrated assessment of the management system will result in an overall analysis of OH&S conditions and practices, that is, verification of the existence of documentation, processes and practices required explicitly or implicitly in the Standard.

3.3.1. Activity 1: Initial system analysis

It will be based on the development of functional analysis. It is aimed at assessing the risks and opportunities of implementing the OH&SMS in the Organization.

Next, the description of the System to be studied will be made, as well as the survey on the ground of the Hazards, non-conformities or deviations in the Good Practices of OH&S in the work environment. The assessment of the identified risks will be based on a 5x5 matrix according to the following Formula:

$$R = P \; x \; S \qquad (\mathbf{1})$$

3.3.2. Activity 2: Application of the Gap Analysis questionnaire

The application of the questionnaire will be via direct interviews with key personnel in the organization (leadership and employees).

3.3.3. Activity 3: Situational analysis in relation to OH&S practices

The quantitative analysis of OH&S practices and conditions will be by applying two different tools: The Failure Modes, Effects, and Criticality Analysis (FMECA) and Fault Tree Analysis (FTA) tools for relevant failures or feared events; and as a complement to the OH&S situational analysis will be applied the qualitative tool Systemic Cindynogenic Deficits (SCD).

3.3.3.1. FMECA Criticality assessment

To assess the Criticality will be used de following formula:

$$Criticality \; = \; \boldsymbol{S}everity \; X \; \boldsymbol{F}requency \; X \; \boldsymbol{C}ontrol \qquad (\mathbf{2})$$

3.3.3.2. FTA Probabilistic and statistical analyse

For n input events attached to the OR-gate, if the equivalent Boolean expression is $= A1 \; + \; A2 \; + \; A3 + \ldots + An$. In the terms of probability, the equation will be:

$$P(Q) \; = \; P(A) \; + \; P(B) \; - \; P(A \cap B) \qquad (\mathbf{3})$$

The probability of an occurrence resulting from the combination of 3 events will be determined using the formula below:

$$P(A \cup B \cup C) \; = \; P(A) + P(B) + P(C) - P(A \cap B) - P(B \cap C) - P(A \cap C) + P(A \cap B \cap C) \qquad (\mathbf{4})$$

For n input events to an AND-gate, the equivalent Boolean expression is $Q = A1 \ x \ A2 \ x \ A3 \ldots$

$$P(Q) = P(A) \ x \ P(B) \ x \ P(C) \tag{5}$$

3.3.3.3. Systemic Cindynogenic Deficits (SCD)

Systemic Cindynogenic Deficits (SCD) will be used to analyse the risks in the processes of System Design and implementation of the OH&SMS, investigating cultural, organizational and managerial deficiencies (limiting to having an effective OH&SMS).

3.4. Phase 4: Definition of the strategy to solve the gaps- Elaboration of the Implementation action plan.

The main objective of this phase is to define the best approach to use in the implementation process, the documented information that needs to be developed and/or edited to meet a certain requirement of the standard. The plan to be drawn up will naturally take into account the nature of the organization, type of activities carried out, organizational culture.

The results collected by the implementation of the approaches and techniques of the previous stages will serve as a basis to identify where the principles, good practices and procedures of Health, Safety and Environment were not considered or were not adequately addressed to take into account in future improvement actions. During this step, many other documents will be reviewed to ensure consistency and integrity in assessing the implementation of Occupational Health and Safety principles.

At the end, the results will be interpreted and compared with the Standard Requirements (ISO 45001:2018) and good practices with a view to developing new safety guiding principles, or improving existing principles. The results of this proposal will be presented in tables and diagrams to better analyse, qualify and quantify the results that the indicators will provide.

3.1. Study Limitations

- Lack of a database of probabilities or occurrence history that would lead to the deduction of probabilities, which could help for a more accurate analysis of the facts.

CHAREPTER 4: Description of the study area

In this chapter, the following sections describe the location of the study area, as well as the description of the main activities and processes existing therein.

4. Location of the study area

Business Connexion Mozambique BCX is a company that was established in 2005, located at , Av. Av. Mártires da Machava, N 1352, Maputo-Moçambique, with almost 144 employees.

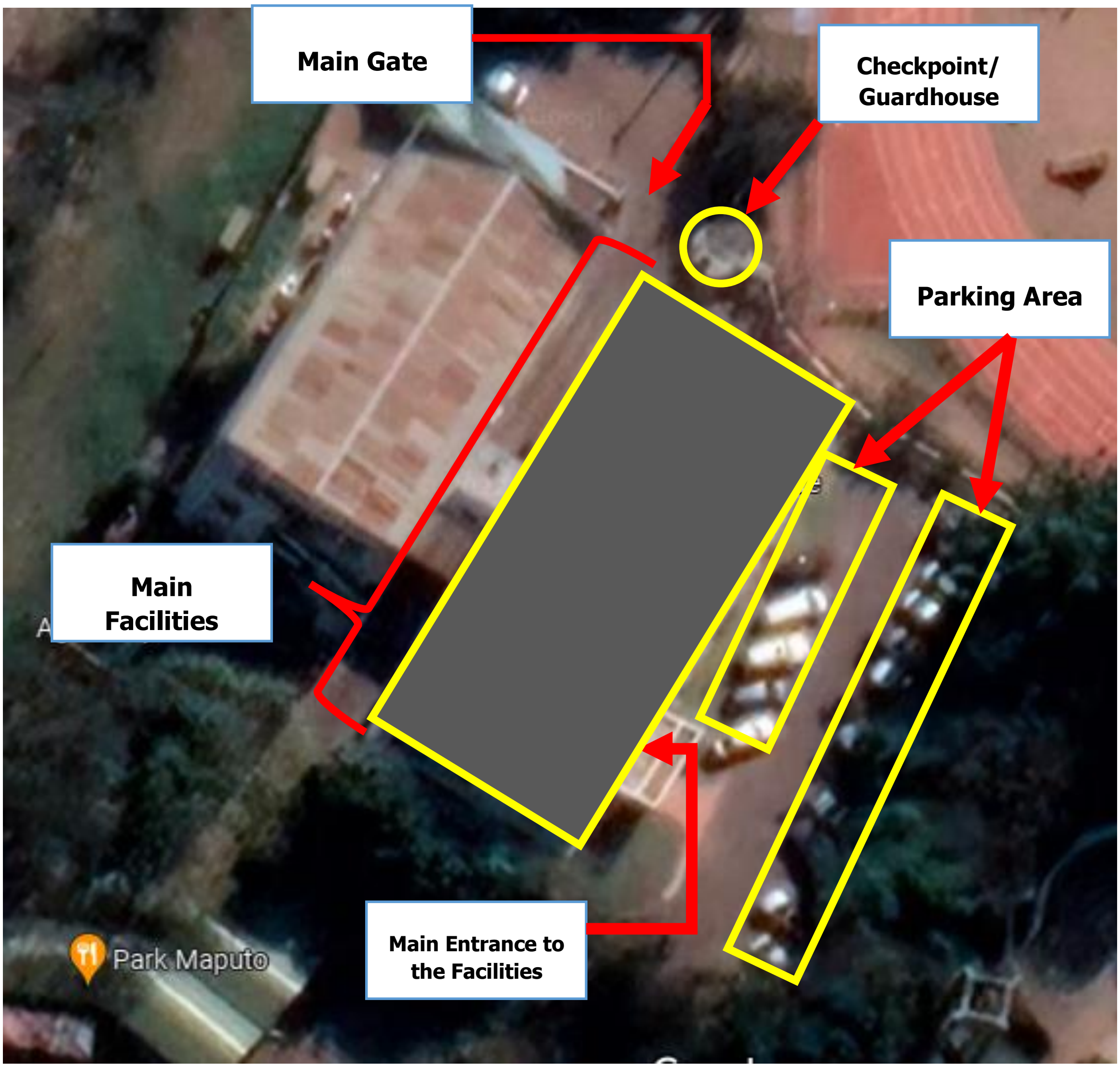


Figure 5: Location of the study area

4.1. Description of activities

BCX Lda, is a company specialized in providing information and communication products and technologies, services, and solutions such as, print management, applications, business communication, data center, energy efficiency, information security, print management, Retail IT, systems integration, and desktop services.

BCX operates across all business arenas:

Table 4: areas of expertise

Industry Insights	*Technology Insights*
- Finance Sector *- Education Sector* *- Government Sector* *- Healthcare Section* *- Manufacturing* *- Mining Sector* *- Retail Sector*	*- Big Data Analytics* *- Cloud Solutions* *- Converged Connectivity* *- Digital Transformation* *- Internet of Things & M2M* *- Mobility Solutions* *- Security Solutions* *- Unified Comms & Collaboration*

4.2. Main processes

It should be noted that the company under study has a certified quality management system since September 10, 2013.

The Main existing processes address the requirements for design, development and support, of information and communication technology (ICT) services, provision and support ICT products.

According to the gap analysis data, in the company under study, there are procedures and records described in the **Table 5** under the management of four departments or areas, Human resources, Operations, Finance & Commercial, Sales & Marketing.

Table 5: Existing Internal Processes & Records

ISO Requirements			
Mandatory	**Processes type**	**Non-Mandatory**	**Processes type**
Monitoring and measuring equipment calibration records		Project Management Procedure	Support Procedure
Records of training, skills, experience and qualifications		Business Processes	Support Procedure
Records about customer property		Sales Procedure	Support Procedure
Record of nonconforming outputs			
Internal audit procedure	Nuclear Procedure		
Results of internal audits			
Results of corrective actions			
Procedure for management review	Nuclear Procedure		
Customer satisfaction evaluation			
Procurement Procedure	Support Procedure		

Org. Structure			
Procedure for management of nonconformities and corrective actions	Nuclear Procedure		
Context of the organization			
Addressing risks and opportunities			
Procedure for competence, training and awareness	Nuclear Procedure		
Procedure of equipment maintenance and measuring equipment	Nuclear Procedure		
Document and record control			
Procedure for design and development	Nuclear Procedure		
Quality Objectives			

(Source: By the Author)

Based on the data above, it can be said in a generalized way that there are two major processes that contribute to the achievement of the organization's objectives. The nuclear processes, that provide conditions for the supply of products and services as well as management of the ISO management system and the Support processes, which provide elements for the good performance of nuclear processes.

The processes interaction can be represented and summarized by scheme on the **Figure 6** below.

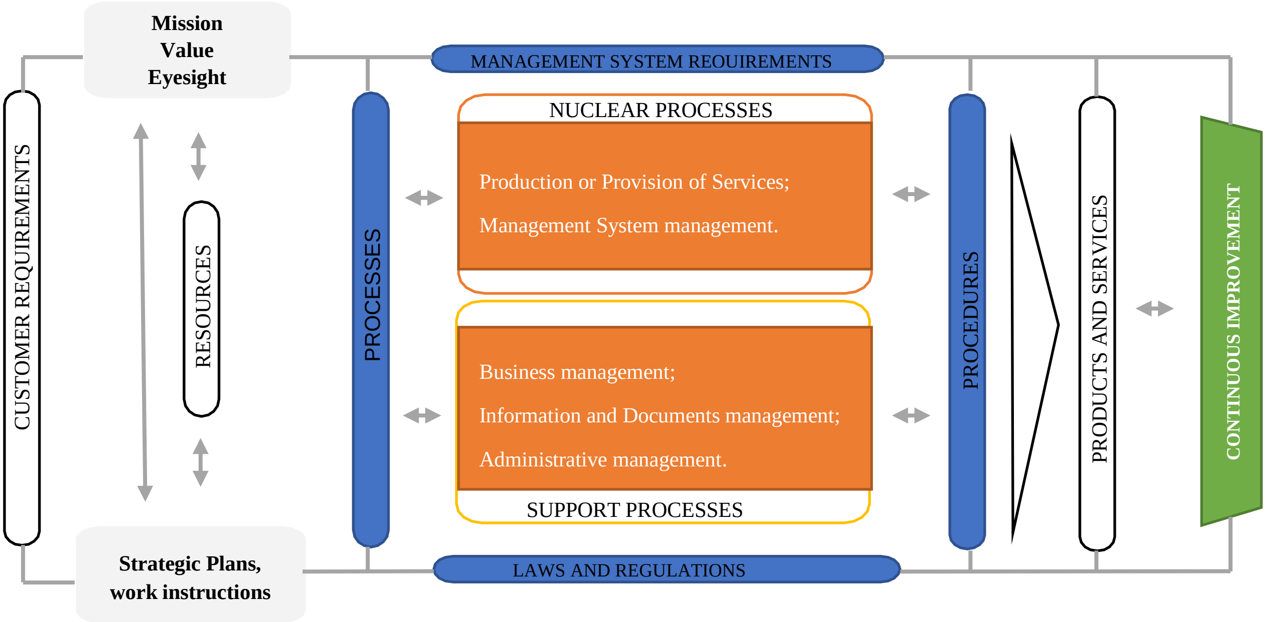


Figure 6: Scheme of processes interaction (Source: By the Author)

CHAREPTER 5: Presentation and discussion of results

In this chapter, the following sections present and discuss the results referring to the OH&S surveys carried out in the study area, in order to develop the OH&SMS implementation Plan.

5. System Analysis

5.1. System definition and it components

1. Purpose and the limits of this system

For a better understanding of the System under study as a whole, its components and interaction are described below. However, the actions of the OH&S management system implementation project will only cover the subsystem components and Elementary system, but, it is to be expected that the positive effects of actions in these two fields are reflected in the system as a whole.

The company that proposes to develop and implement the occupational health and safety management system based on the ISO 45001:2018 standard is a IT services and products provider, whose activities are basically the importation and selling of hardware and software belonging to the area of information technology, as well as the supply, installation and management of information technology infrastructure. Below are described its components, and the schematic representation is through **Figure 7**.

1.1. Definition of the system and it components

1.1.1. System

The system in question is resultant of interaction between BCX, costumer's needs, products and technologies Provider/people (infrastructure Monitoring, IT professionals, whether developers, system administrators), the Acquisition process (Procurement) and all necessary aspect and conditions to make the product or technology arrive to the customer (Logistic) as well as all the organisms responsible for monitoring of the IT services and establish fees and polices for Implementing the tax protocols on the entire system activity (Tax authorities and Customs). The result of this Interaction is the one that allows that technologies are put at the service of customers.

1.1.2. Elementary system

1.1.2.1. SE1- People

People are one of the most important thing. Is the human element that is responsible for all other parts of the IT system and it operation (IT professionals, whether developers, system administrators, or network administrators) among the other responsibility they analyse organization's needs and determine which hardware and software will do the job.

1.1.2.2. SE2- Tecnology

Tecnology is set of instruments, methods and processes specific to any art, craft or technique. Correspond to all activities offered by the IT infrastructure.

1.1.2.3. SE3- Process

Process mapping comes up as an important because, Identifying the inputs and outputs of a process also helps to understand if it is working as it should. After all, by understanding the delivery, it is possible to define what information will be used to generate it, what Hardware or Software to use

1.1.3. Interface

For this system, the interface is established in the connection between the Express need, procurement, or process, logistical aspects, infrastructure and Internet Network, whose functionality is to ensure the continuity of the system until the product or service reaches the client or being provided.

1.1.4. Subsystem

The combination of the four components of this Subsystem dictate whether the product will reach its destination or applicability to the client: transportation costs, cargo integrity, functionality, etc.

1.1.4.1. Component 1 (SSC1)

The **procurement** is the main process that guarantee the acquisition of the technology, product or service that are put at the service of customers.

1.1.4.2. Component 2 (SSC2)

For the entire system to work is important to consider logistical aspects, this consideration ensure that the best means of transport is being used, and that is being moved the greatest number of goods, in the shortest time and at the lowest possible cost. In this way, it can be said that attending to logistical aspects ensures the transport of products with a guarantee of cargo integrity, within the agreed time and at a possible low cost.

1.1.4.3. Component 3 (SSC3)

Infrastructure consists of all the technological devices that make it possible to carry out a certain activity, computer and smart TV facilities, Hardware, Software.

1.1.4.4. Component 4 (SSC4)

Internet Network it is up to connect and support all of the organization's technological devices. It is the network that allows everyone involved in the processes to have access to IT resources and systems.

1.1.5. Environment

The interactions or failures in the interactions of the aforementioned components generate a series of reactions in the environment with the objective of reestablishing the proper functioning of the entire system, on the other hand the environment influences the way the entire system is controlled.

The **Government, Tax Authorities** define / determine or monitor, respectively, compliance whit fiscal legislation and operation procedures in the territory regarding to IT uses. **Customs** duty is a tariff or tax imposed on goods when transported across international borders.

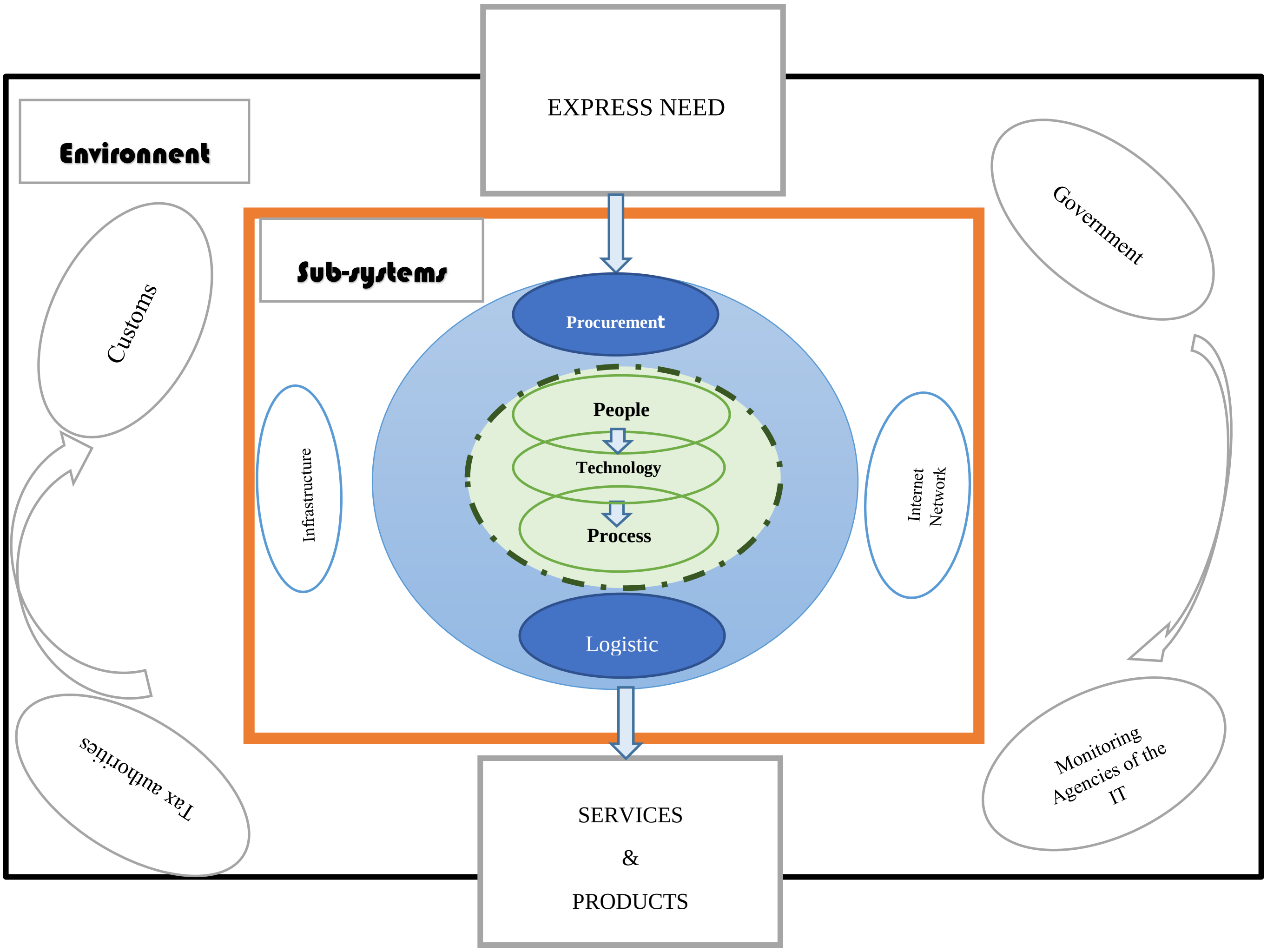


Figure 7: Components of case study System (Source: By the Author)

5.2. Environment analysis- Internal and external

As seen in section 5.1 above, the definition of the System to be analysed allows a better understanding of the interaction of the different elements that contribute to or condition the delivery of the product or provision of services by the organization to its customers. However, for the purposes of this study, it is also important to know in more detail which elements of the internal or external environment of the study company can be used to achieve the intended purpose, which is implementation of the OH&SMS.

The SWOT analysis below (**Table 6**) gives any overview of the current status regarding to the main STRENGTHS, WEAKNESSES, OPPORTUNITIES, and THREATS that can obviously affect the company performance and also the existing management system (ISO 9001:2018) and also the intended (ISO 45001:2018).

The loss or failure to attract critical staff (personnel with the necessary skills to perform key activities or operations) may result in the inability to provide services to clients, as a mitigation measure, compensation and benefits may be reviewed (consider extraordinary compensation options) or continued internal skills development.

The existing opportunity related to the Increasing Multi nationals investment (coal oil gas), as expected demand from local services provider behind competence, safety integrity insurance that is, secure operations and workers safety. So, in order to well use this shell be implemented and maintained operational the OH&SMS.

In other hand the implementation of an OH&SMS could also help to reduce or limit the increasing competition treat impact on the Company business.

For the process of implementing ISO 45001:2018, it is possible to take advantage of the fact that the organization already has an ISO system in place (ISO 9001:2015), so that some elements can be used to complement ISO 45001: 2018 implementation process. Since the ISO standards have the same structure, the so-called annex SL[1]

[1] Section of the ISO/IEC Directives part 1 that prescribes how ISO Management System Standard standards should be written

Table 6: SWOT analysis about the study area

	STRENGTHS	WEAKNESSES
INTERNAL ANALYSIS	• Skilled workforce; • Original Equipment Manufacturer Certification (OEM certification); • Long standing operation with strong services culture/ portfolio • Existence of branches in almost all provinces of the country • Good infrastructures for operations • ISO 9001:2015 certification • ITIL V4 certification	• Lack of diversification from body shop/managed services; • Lack of Strategic account management; • Staff turnover coupled to general market skills scarcity; • Non-compliance to indigenization drive; • Loss or failure to attract critical staff may result in the inability to provide services to clients; • Lack of ISO 45001 certification; • 100% ownership by SA may negatively impact BCX Mozambique to secure future government contracts or international businesses with major impact on Oil & Gas sector.
	OPPORTUNITIES	**THREATS**
EXTERNAL ANALYSIS	• Increasing Multi nationals investment (coal oil gas) • Aggregator of choice (onestopshop) • Increasing Small and medium-sized enterprises (SME) segment • Technology convergence Citizen services	• Loss of highly skilled resources to competition and multi nationals • Increasing competition • Cloud computing • Changing landscape (Rules and regulations indigenization) • Political instability may affect the ability to conduct and grow business

(Source: Adapted from BCX, 2020)

5.3. Functional analysis

This Functional analysis will allow to highlight the main service and constraint functions of the system, and the octopus diagram shows the different interactions between the different elements that influence the product (OH&SMS) and vice versa.

This sort of information will help on the definition of the Specification or requirements for the OH&SMS to be implemented.

The organization's expectations in terms of the requirements it wants its management system to meet are translated in the **Table 7**.

Table 7: Main service and constraint functions

#	Function
SF1	Improves processes and information management
SF2	Protect employees and assets
SF3	Improves planning and communication
cF1	Reduces occupational risks
cF2	Increases the safety culture
cF3	manage resources

Source: By Author

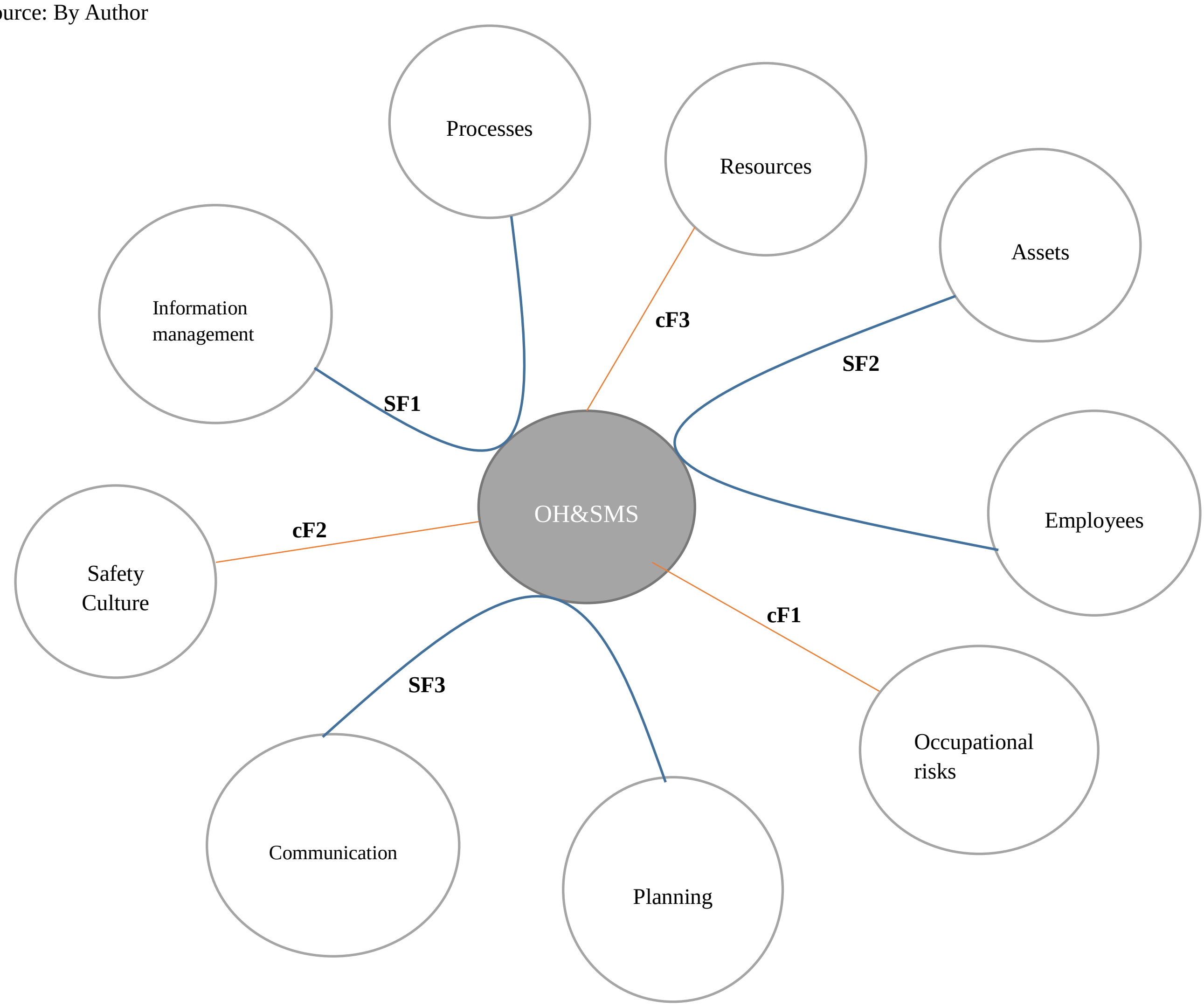


Figure 8: Functional analysis octopus diagram (Source: By Author)

5.3.1. Specification of Services and constraint Functions

The system components must be able to guarantee that all the resources available for its operation contribute to the correct management of information, processes in the fulfilment of the intended objectives.

The Table 8 below shows the level of efficiency expected of an OH&SMS by the leadership of the organization where the OH&SMS will be implemented and by other interested parties.

The management system must be able to improve processes and information management, protect employees and assets, improve planning and communication, increase safety culture, reduce occupational risks.

For the functionalities identified, the importance classification criteria vary from Important to Vital. On the other hand such functionalities are barely negotiable or non-negotiable as can be seen in the tables below (See Table 8 & Classification Criteria

Table **9**).

Table 8: Specification of Services and constraint Functions

#	Title	K	Criteria	Level	F
SF1	Improves processes and information management	5	Number of processes managed (P)	P >20	1
			Number of information managed (I)	I > 20	1
SF2	Protect employees and assets	5	Number of incidents and accident per year (I&A)	I&A < 2	2
SF3	Improves planning and communication	4	Percentage of planned executions (PA)	PA=100%	1
			Communication efficiency CE (%)	CE=100%	1
cF1	Must reduce occupational risks	5	Percentage of hazards managed Pe (%)	Pe=100%	0
cF2	Must increases the safety culture	4	Efficiency of awareness AE (%)	AE=100%	2
cF3	Must manage resources	3	Resource management efficiency RE (%)	RE=100%	2

(Source: By Author)

K - Importance criteria, allows to define a hierarchy among the functions

F - Flexibility, the flexibility class is given by the user to express the possibility to negotiate the levels

Table 9: Classification Criteria

K	Description		F	Description
1	useful		0	Not negotiable
2	necessary		1	Could be negotiable
3	important		2	Negotiable
4	very important		3	Very negotiable
5	vital			

5.4. Site Survey- Nonconformities and Hazards identification

The data presented below results from the assessment of the potential hazards existent on study area, a part resulting from the system and another part related to errors or human behaviour, in other words, the applied approach aims to identify conditions with a potential to cause accidents or create failures in the system. The logic behind the process is similar to the preliminary hazard analysis however applied to obtain a general overview of safety conditions.

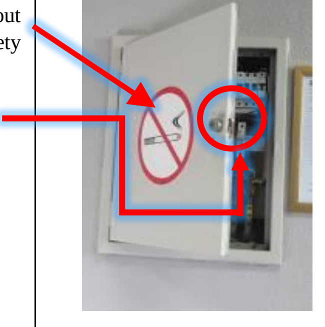
The **Table 10** below shows nonconformities and potential hazards identified at the study area. 27 non-conformities were identified, and categorised into seven categories (Electrical Devices, Safety Signalling, Fire Fighting Devices, Waste Management, Cleaning and Organization, Infrastructure and Equipment Management, Other Findings).

In quantitative terms the category “other Findings” is the one with the highest percentage among the categories of nonconformities established, totalling 26%. This category includes non-conformities such as: Use of inappropriate PPE, lack of a culture of identification and assessment of potential risks of routine and non-routine activities, failure to carry out inductions or safety dialogues, lack of recording incidents or accidents.

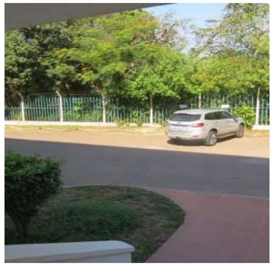
After the category other findings, the categories Electrical Devices, Fire Fighting Devices, and Infrastructure and Equipment Management are those with the highest percentage, around 15% each.

The non-conformities below were classified according to the previously defined evaluation criteria (see appendix II).

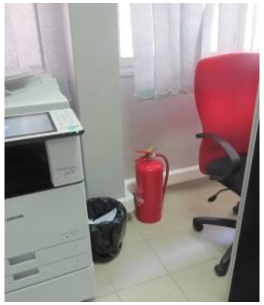
Table 10: Hazard identification and risk assessment

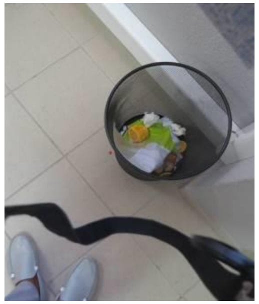
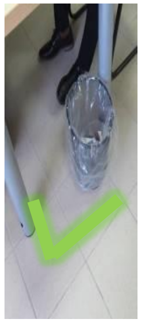
i	Location	Hazards and Risks identification			Normative Requirement	Risk assessment			Measure to apply	Risk assessment		
		Hazard or Nonconformity Description	Questionable item	Risk		P	S	R		P	S	R
	Electric Devises											
1	First flow	Circuit breakers not labelled making it difficult to use or manage emergency situations Electrical panels without secondary protective cover for the circuit-breaker module Electrical panel without circuit labelling		• Exposure • Reduced responsiveness in an emergency due to lack of breakers labeling; • Eletrocition	• ISO 45001:2018 requirement 5.2 & 6	3	5	15	• Introduction of electrical devices management procedures: ○ Protection and Isolation procedures ▪ Protect the electrical panels properly and label it.	1	5	5
2	First flow	Electrical panels without corresponding hazard/safety signs Damaged locking device		• Exposure Lack of proper sinaling end mantainace of electric devises incrising the potencial for eletrocution	• ISO 45001:2018 requirement 5.2 & 6	4	5	20	• Introduction of isolation/procedures ○ Provide the correct signage corresponding to the risk of electrocution ○ Perform the proper maintenance or replacement of the electrical panel locking device	2	3	6

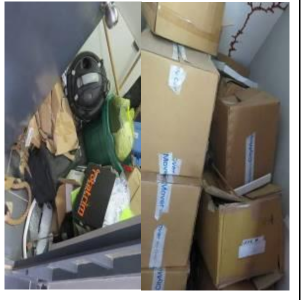
i	Location	Hazards and Risks identification			Normative Requirement	Risk assessment			Measure to apply	Risk assessment		
		Hazard or Nonconformity Description	Questionable item	Risk		P	S	R		P	S	R
3	ground floor-main warehouse	Cables with inadequate insulation (no protection)		• Exposure ○ Eletrocution	• ISO 45001:2018 requirement 5.2 & 6	4	5	20	• Isolation ○ It is necessary to adopt preventive measures against potential emergency situations, in which case it is necessary to use conventional connectors and isolation of exposed parts	2	5	10
4	First flow-corridor to oper space	• Extension-socket device on the table affecting order and tidiness increasing short-circuit potential		• Exposure ○ Eletrocution	• ISO 45001:2018 requirement 5.2 & 6	3	5	15	• Training and implementation of safe working procedures ○ It is necessary to ensure that suitable devices are used in corresponding spaces, not only under the pretext of order and tidiness but also to reduce the potential for short circuits to occur	1	5	5
	Safety Signaling											

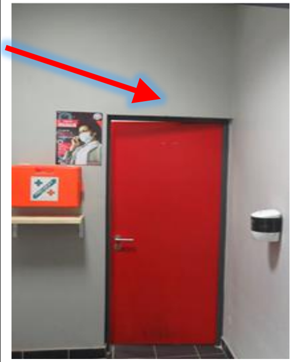
i	Location	Hazards and Risks identification			Normative Requirement	Risk assessment			Measure to apply	Risk assessment		
		Hazard or Nonconformity Description	Questionable item	Risk		P	S	R		P	S	R
5	ground floor	Lack of safety/emergency signage		• Exposure ○ Increased death potential due to lack of elements for safe evacuation	• ISO 45001:2018 requirement 5.2 & 6	3	3	**9**	• Implementation of safety Procedures ○ It is necessary to start with the process of placing emergency signs in all compartments in use in the BCX, and this sign must have an arrow indicating the direction, or direction until the exit of the building ○ Development of an emergency plant	2	3	**6**
6	Yard	No vertical or horizontal traffic signs. Pedestrian circulation zone not demarcated. Emergency Meeting point that does not facilitate the evacuation process.		• Exposure ○ Vehicle collision ○ pedestrian running over	• ISO 45001:2018 requirement 5.2 & 6	3	4	**12**	• Implementation of safety procedures and supervision ○ Start the signalling process (to ensure greater understanding of traffic directions, parking area) ○ Placing of obligatory signposts for parking in the rear ○ It is necessary to signal areas for the exclusive use of pedestrians ○ It is necessary to establish a new meeting point that is strategic for emergency evacuation, has no risk of falling objects, tripping or falling at the same height (Preferably close to the entrance gate).	2	3	**6**

i	Location	Hazards and Risks identification			Normative Requirement	Risk assessment			Measure to apply	Risk assessment		
		Hazard or Nonconformity Description	Questionable item	Risk		P	S	R		P	S	R
7	yard	Fire hose point without signalling		• Exposure • Inefficient responsiveness	• ISO 45001:2018 requirement 5.2 & 6 • Decree No. 30/2003 of 1 July	3	2	6	• Training • Fixation of signs indicating the point of existence of fire hose	2	2	4
	Firefighting devices											
8	Ground floor- main warehouse	Smoke detectors do not work when flammable material is also stored on site.		• Inefficient responsiveness • Material and infrastructure damage or lost	• ISO 45001:2018 requirement 5.2 & 6	**3**	**5**	**15**	• Implementation of safety procedures ○ Develop a maintenance plan for fire detection and prevention devices ○ Ensure that there is a control center / fire panel that keeps all detectors active and monitorable;	2	2	4
9	Yard	Non-operational firefighting equipment		• Inefficient responsiveness	• ISO 45001:2018 requirement 5.2 & 6	3	4	12	• Maintenance program development and implementation ○ Ensure the operation of hoses through periodic tests and maintenance ○ Ensure hoses are connected to a reservoir that can continuously supplies water for at least 10 minutes ○ Ensure that the pressure in the hoses is at least 1000 liters per minute	2	4	8

i	Location	Hazards and Risks identification			Normative Requirement	Risk assessment			Measure to apply	Risk assessment		
		Hazard or Nonconformity Description	Questionable item	Risk		P	S	R		P	S	R
10	First flow-corridor to oper space	Deliberately placed fire extinguisher		• Inefficient responsiveness		2	2	4	• Training • Implementation of safety procedures ○ Fixing the fire extinguisher at a height that ensures good visibility by the user (average height of 1.2m)	2	2	4
11	First flow-corridor to WCs	Few first aid kits for building features		• Inefficient responsiveness		2	2	4	• Training • Place other Kits in strategic locations • Ensuring that Kits are inspected at periods to be defined by the organization • Ensure that the list of emergency contacts including Fire, Police and others is available and visible.	2	2	4
Waste Management												

i	Location	Hazards and Risks identification			Normative Requirement	Risk assessment			Measure to apply	Risk assessment		
		Hazard or Nonconformity Description	Questionable item	Risk		P	S	R		P	S	R
12	First flow- corridor to oper space	Labels fixed in a position that makes them difficult to read, making it impossible to correctly dispose of waste		• Poor waste manangerment practices ○ Deliberate introduction of waste into garbage cans	• Decree No. 94/2014 of 31 December - Regulation on the Management of Solid Urban Waste • ISO 45001:2018 requirement 5.2 & 6	2	2	4	• Supervision • Label containers properly in a point of easy visibility for the user • Start the training and awareness process on the need for waste separation by types	2	2	4
13	First flow- open space	Mixture of waste with recycling potential		• Exposure • Poor waste manangerment practices ○ Increased potential for contamination of waste collection and packaging personnel	• Decree No. 94/2014 of 31 December - Regulation on the Management of Solid Urban Waste • ISO 45001:2018 requirement 5.2 & 6	3	3	6	• Supervision • Training ○ Start the education/training process on the correct disposal of waste in accordance with good practices	2	2	4
14	First flow- open space	• Waste container without protective plastic	 	• Increased potential for contamination of waste collection and packaging personnel	• Decree No. 94/2014 of 31 December - Regulation on the Management of Solid Urban Waste	2	2	4	• Implementation of safe working procedures. • Make sure that all containers have the protective plastic to contain residues; • Ensuring that the plastic has sufficient strength to contain the waste, preventing contamination of the container and facilitating the process of removing waste safely by the operator	2	2	4
Cleaning and organization												

i	Location	Hazards and Risks identification			Normative Requirement	Risk assessment			Measure to apply	Risk assessment		
		Hazard or Nonconformity Description	Questionable item	Risk		P	S	R		P	S	R
15	Ground floor	Poor cleaning and housekeeping		• Contamination/Exposure to an unhealth environment	• Decree No. 94/2014 of 31 December - Regulation on the Management of Solid Urban Waste • NM ISO 45001:2018 requisito 5.2; 6	3	3	9	• Training ○ Ensure correct storage or disposal of unnecessary material in the organization at risk of creating unhealthy conditions, or that favor the occurrence of accidents	2	2	4
16	Ground floor	Inadequate packaging of waste considered hazardous (Lamps)		• Contamination/Exposure to hazzard material	• Decree No. 94/2014 of 31 December - Regulation on the Management of Solid Urban Waste • Decree No. 83/2014 of 31 December - Regulation on the Management of Hazardous Waste • ISO 45001:2018 requirement 5.2 & 6	3	4	12	• Training • It is necessary to develop and implement a waste management program (which contains the characterization of the waste produced, forms of management and final destination)	2	4	8
Infrastructure and equipment management												

i	Location	Hazards and Risks identification			Normative Requirement	Risk assessment			Measure to apply	Risk assessment		
		Hazard or Nonconformity Description	Questionable item	Risk		P	S	R		P	S	R
17	ground floor- warehouse	• Poor infrastructure management	 	• Exposure to unsefe conditions ○ Increased potential for theft or damage to movable property; ○ Loss of costomers propertys	• ISO 45001:2018 requirement 5.2; 6; 8.1.2 - 8.1.2.3	3	3	9	• Implementation of safe working procedures ○ Ensuring correct and periodic maintenance of infrastructure, especially devices with greater probability of interaction with workers.	2	2	4
18	First flow	• The absence of indicative names of the work areas, sections or departments		• Exposure lack of areas identification	• ISO 45001:2018 requirement 5.2; 6; 8.1.2 - 8.1.2.3	2	2	4	• Conditions must be created to name all areas, departments or sections (It is necessary to name the work areas not only under the pretext of guaranteeing a good aesthetic appearance, but also under the pretext of facilitating the intervention of people external to BCX in case of an emergency situation)	2	2	4
19	First flow- Open space	• Poor management of infrastructure/equipment with the potential to cause a tripping hazard • Lack of manteinance	 	• Exposure to trip and fall hazard	• ISO 45001:2018 requirement 5.2; 6; 8.1.2 - 8.1.2.3	4	4	16	• It is necessary to ensure that there are no exposed cables in access areas, for which it is possible to apply gutters or ensure their correct maintenance and signal	2	4	8
20	Ground flow	• Unidentified and incorrectly stored LADDER		• Exposure to Trip hazzard	• ISO 45001:2018 requirement 5.2; 6; 8.1.2 - 8.1.2.3	4	4	16	• Supervision ○ Ensuring that all work material is stored properly and in places established for this purpose	2	4	8

i	Location	Hazards and Risks identification			Normative Requirement	Risk assessment			Measure to apply	Risk assessment		
		Hazard or Nonconformity Description	Questionable item	Risk		P	S	R		P	S	R
Other findings												
21	Ground flow	• Workers in the operational area without a protective uniform; • Central warehouse operators without PPE		• Exposure with potential for burns	• ISO 45001:2018 requirement 5.2; 6; 8.1.2 - 8.1.2.3	3	4	12	• It is necessary to ensure that at least the employees who enter the repair area have a protective uniform with long sleeves; • It is necessary to provide the minimum protective equipment necessary for warehouse operations (gloves, boots, glasses, uniform, helmet)	2	4	8
22		• Lack of emergency planning; • Lack of emergency drilling Lack of emergency procedures;		• Probability of an accident	• ISO 45001:2018 requirement 5.2; 6; 8.1.2 - 8.1.2.3	4	4	16	• It is necessary to define criteria for the management of potential emergency situations; Execution of emergency drills and recording of executions	3	3	9
23		• Non execution of Safety induction		• lack of safety culture ○ Accident	• ISO 45001:2018 requirement 5.2; 6; 8.1.2 - 8.1.2.3	4	4	16	• It is necessary to submit to an induction all visitors, new employees on the functioning of the organization, the security conditions and the policies to be followed	3	2	6
24		• Non-existence of Hazard Identification Tool and Risk Assessment by Work Areas		• Lack of hazzard manangerment ○ Acident	• ISO 45001:2018 requirement 5.2; 6; 8.1.2 - 8.1.2.3	3	4	12	• Implementation of safe working procedures ○ There must be created a risk identification and assessment tool/ model to be updated as needed.	2	2	4
25		• Health and safety committee not created		• Lack of hazards management ○ Accident recurrence	• ISO 45001:2018 requirement 5.2; 6; 8.1.2 - 8.1.2.3	2	3	6	• Implementation of safe working procedures ○ It is necessary to establish a team to manage the conditions and aspects of health and safety, generally	1	3	3

i	Location	Hazards and Risks identification			Normative Requirement	Risk assessment			Measure to apply	Risk assessment		
		Hazard or Nonconformity Description	Questionable item	Risk		P	S	R		P	S	R
									composed of a worker representative, a representative of the management and a safety technician			
26		• Non execution of Safety dialogs/safety toolbox		• Poor safety culture accident ○ Accident recurrence	• ISO 45001:2018 requirement 5.2; 6; 8.1.2 - 8.1.2.3	3	4	12	• Training • Implementation of safe working procedures ○ It is necessary to establish a periodicity in the execution of dialogues on security aspects	1	3	3
27		• Incident and accident record		• Lack of hazards management • Accident recurrence	• ISO 45001:2018 requirement 9	4	4	16	• Implementation of safety procedures • It is necessary to continuous monitoring of health and safety performance indicators	2	4	8

(Source: By Author)

5.4.1. Pareto Diagram of the Main Nonconformities and Observed Hazards

With the Pareto Diagram below, it is possible to better visualize the critical categories of the main nonconformities and hazards identified in the study area in terms of risk level. The category with a high risk level is “Other Findings” with 29.8%, followed by the “Electrical Devices” category with 23.18%, the two combined produce a percentage of almost 53% of the non-conformities and hazards identified. In the process of resolving nonconformities, these two categories should be prioritized. The category “Other Findings” is behind the critical or key non-conformities and hazards, which in this context it is logical, since this category encompasses principles and procedures that, if implemented, would be fundamental for the non-occurrence of most non-conformities and hazards.

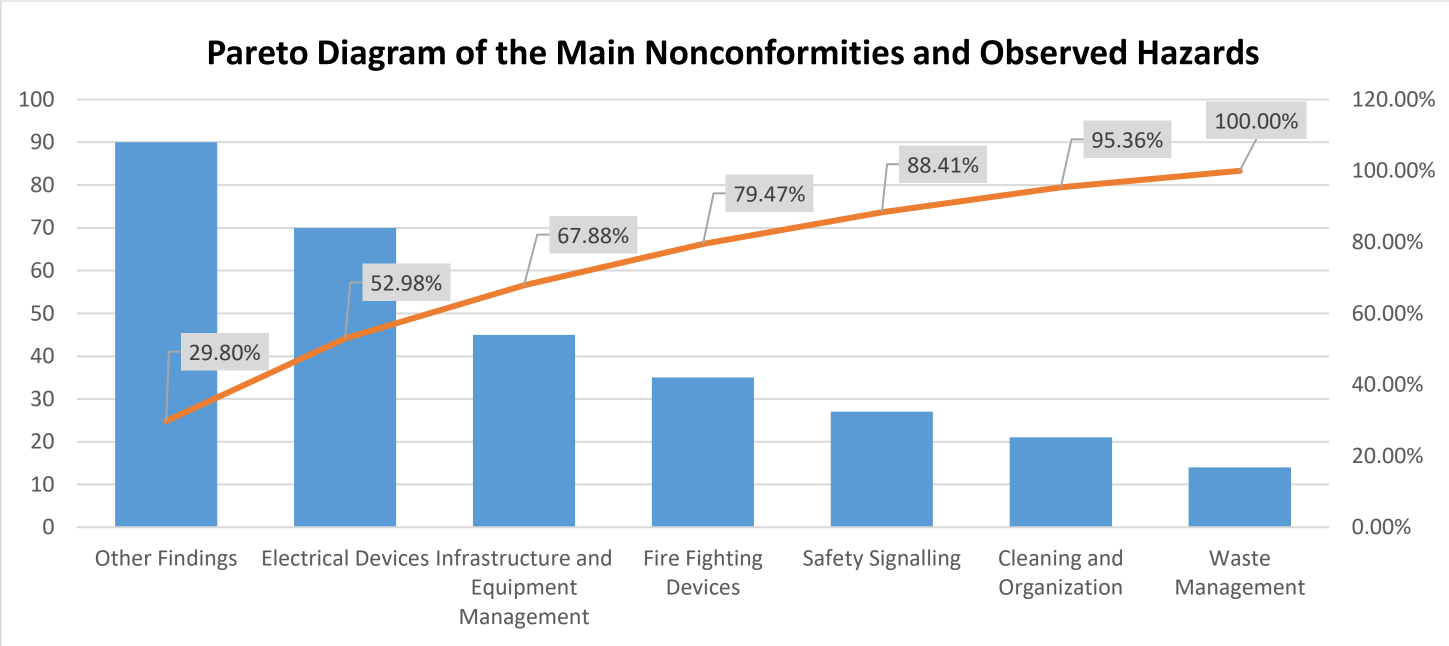


Figure 9: Pareto Diagram of the Main Nonconformities and Observed Hazards (Source: By Author)

5.5. FMECA for relevant failure or feared events

The feared events were analysed based on the FMECA tool, some of which resulted from the preliminary analysis presented in Table 10 above, being that they were identified a total of 6 processes or areas for analysis, namely, Yard, Reception, Fire prevention and fighting, Electricity supply, Facilities and client data security, Emergency evacuation. The Table 11 below therefore presents a complementary analysis where the main potential causes and failure modes are presented.

The criticality analysis was based on the criteria presented in appendix III.

As shown in Table 11 below all the feared events without looking at the specificities are related to OH&S issues. Each of these occurrences can be dealt with through the implementation of OH&S management procedures and/or safe work procedures, that is, it is necessary to set up policies and a team to manage the health and safety conditions and aspects, generally composed of a representative of the workers, a representative of the management, Safety manager and a safety officer.

Table 11: FMECA for relevant failure or feared events

Process/area	Component	Functions	Failure modes	Possible causes (internal and external)	System effects	Severity	Frequency	Control	Criticality
Yard	Sidewalks	Circulate	Sliding	Frost, heavy rain	Fall and injury	2	2	6	24
	Car park	Park a vehicle	Blocking access	Broken down car	Dissatisfaction of users				
		Walking access to vehicles		Accident	Injury or death of a person	10	2	4	80
Reception	Waiting room	Allow customers to wait	Heating system failure	Damaged air conditioner	Customers wait in the heat: Discontent Costumers/users	2	6	2	24
	Mobile chairs	Allow customers and worker to seat	Defective seats	Lack of maintenance	Discontent Costumers/users	2	6	4	48
			Defective seats	And of life time use	Ergonomic problems	6	6	4	144
Fire prevention and fighting	Smoke detectors	Detect fire outbreaks	Damaged fire detection sensor	Lack of maintenance	Fire & loss of property	10	6	6	360
			Smoke detector without battery	lack of maintenance	Alert system failure	10	6	6	360
	Hydrant	Put out fire	mechanical failure	Lack of maintenance	Fire & loss of property	8	4	6	198
				Damaged opening mechanism	Fire & loss of property	8	4	6	198
	Water tank	Water storage for fire fighting	Reservoirs without water	Reservoirs connected to other water supply systems	Fire & loss of property	8	6	4	192

Process/area	Component	Functions	Failure modes	Possible causes (internal and external)	System effects	Severity	Frequency	Control	Criticality
	Piping	Water transport	Collapse of the firefighting system	Improper sizing of the reservoir capacity or water leakage	Inability to fight fire, with potential for major material damage and victims	6	4	4	96
			Cutted pipe	Piping with inadequate characteristics/end of life	Water leak / inability to fight fire	6	4	4	96
	Fire extinguisher	Put out fire starts	Damaged fire extinguisher trigger	Lack of maintenance	Loss of property	8	6	4	198
				inappropriate use	Loss of property	8	6	4	198
			Expired fire extinguisher	Lack of maintenance	Fire & loss of property	8	4	4	128
			Disability in fire fighting	Bad sizing of the quantity and distribution of Fire extinguishers	A small fire turns into a large fire	8	4	2	64
Electricity supply	Electric cables	conduct electricity	Sort circuit	System overload, cable heating, bare cables	Equipment damage	8	8	4	256
	circuit breakers	Control of the electrical system	Overload	Bad sizing	Malfunction of equipment connected to the electrical system	8	8	4	256
Facilities and client data security	Lockers	Lock, property protection	Non-operational handle	lack of maintenance	loss of security	4	4	2	16
	Servers	Information storage, systems sharing, backup	Heating	Lack of room cooling	Malfunctioning, non-operational storage system	4	6	2	48
	CCTV	Provide real-time image of the existence or not of deviations	Do not provide image	Damaged cameras, cut cables	Reduction of the security level in the installations	6	6	4	144
Emergency evacuation	Maximum distance to travel to a safe exit	Optimize escape time	Distance Very large approximately 90m, compromising the safety of workers in an emergency	Non-implementation of safe areas with access to exits in order to reduce the distance in case of emergencies	Panic and Victims	8	6	4	192

Process/area	Component	Functions	Failure modes	Possible causes (internal and external)	System effects	Severity	Frequency	Control	Criticality
	Minimum number of exits	Optimize the evacuation process	Evacuation conditioning during an emergency	Failure to implement exits for evacuation purposes in emergency situations	Panic and Victims	8	6	4	192
	Emergency stairs	Escape route (vertical escape route)	Evacuation conditioning during an emergency	Poor sizing of steps, lack of handrail	People fall during evacuation/victims	10	10	4	400

(Source: By Author)

5.6. FTA for relevant feared events

Based on the main findings resulting from the FMECA above, three main feared events were defined that are believed to be the origin/conditions for the occurrence of failures in an OH&S management process. The FTA aims to identify the root causes of the feared events, in order to obtain information to develop measures that prevent the occurrence or eliminate the risk.

5.6.1. FTA for Non-operational OH&SMS

Below is represented the fault tree for OH&SMS Non-Operationality, the tree contains 3 levels and has 4 antecedents whose interaction can potentially leads to the top event. The causes that precede the top event are described below and they are all related to human factors:

- System design failure;
- Lack of resource;
- Lack of employee engagement;
- Failure to plan to meet regulatory requirement.

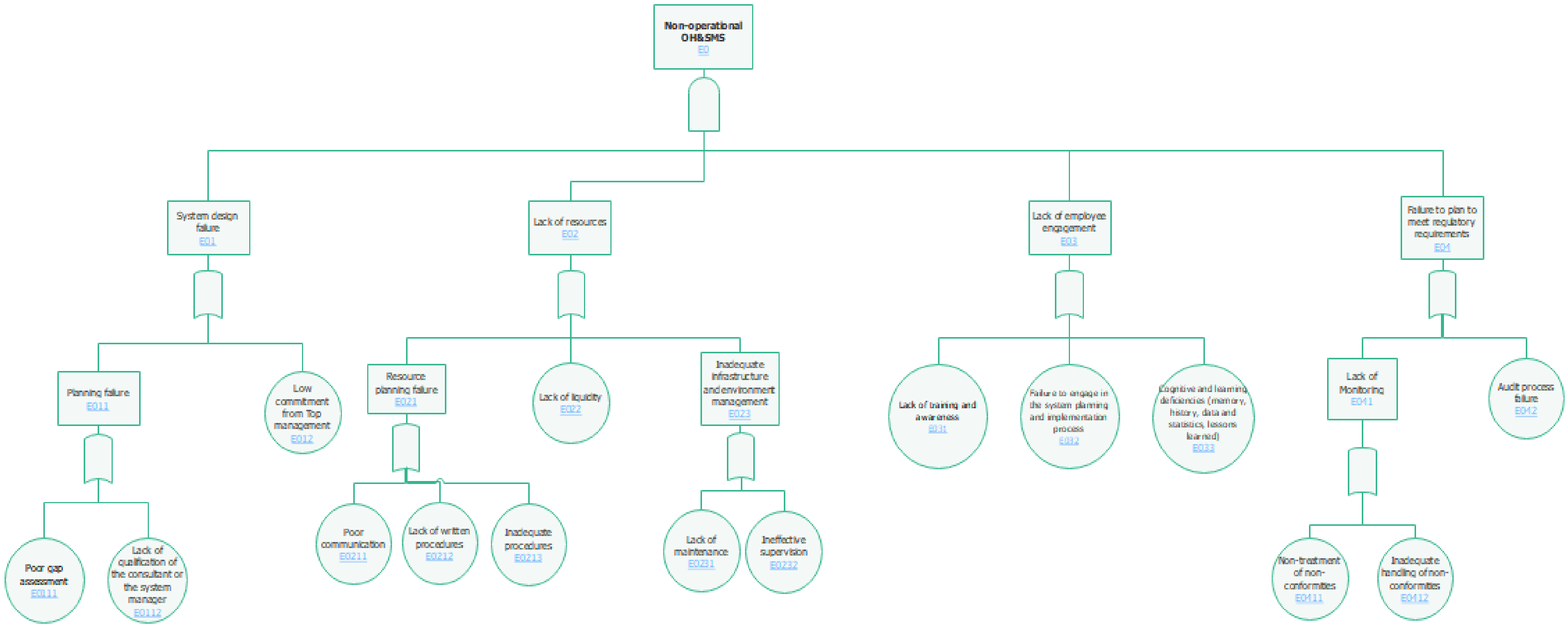


Figure 10: FTA for Non-operational OH&SMS (Source: By Author)

5.6.1.1. Mathematical description of the event

The **Table 18** in appendix V-A show the parameters for calculating the probabilities of Non-operational OH&SMS. The defined test questions were based on the author's criteria and the law of probability was defined based on the root cause factor, which in turn was defined based on the root cause. For this top event was defined 15 root causes.

The Figures 11 and 12 below show the results of the homogeneity test, based on below Histogram is possible to see that the sample is not homogenous. The Histogram (**Figure 11**) shows also the range of probability of occurrence of the top event, which is between 3.9% and 5.4 %.

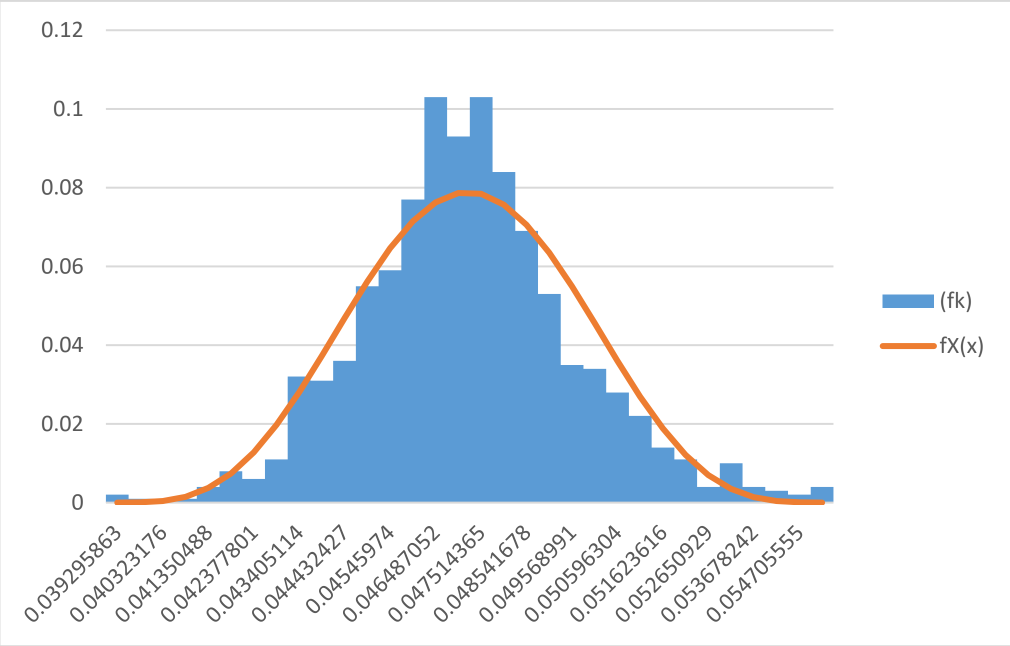


Figure 11: Homogeneity study (Source: By Author)

The homogeneity test also shows that the data under analysis obey at least two laws of probability. One part obeys the Beta 1 law and the other the GAMMA law. The data also show a good relationship with each other of about 93%.

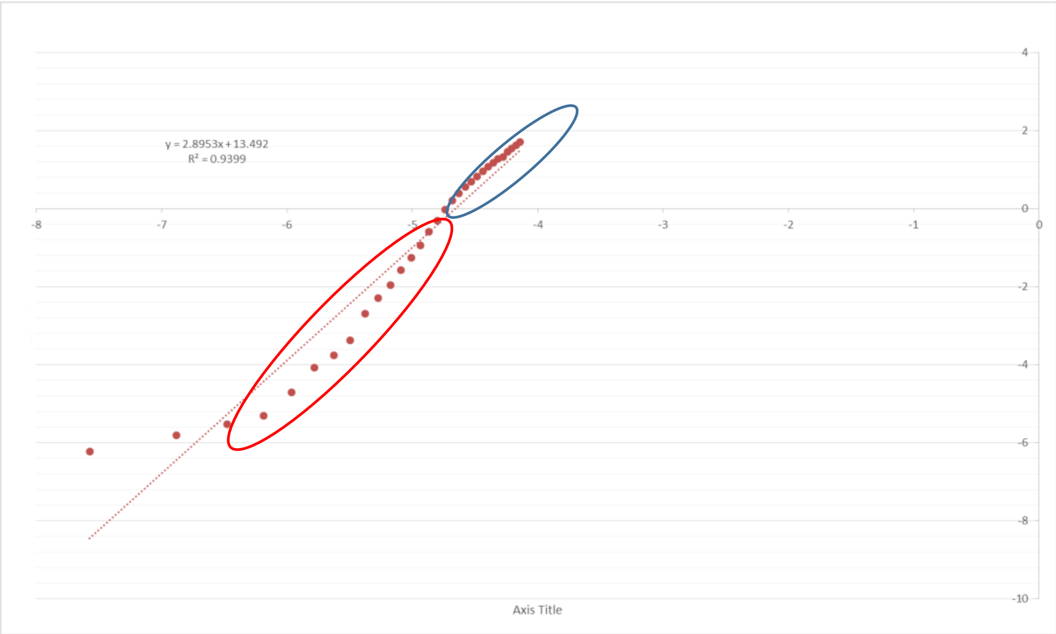


Figure 12: Correlation graphic- Inability to put out fire (Source: By Author)

As can be seen in **Figure 13**, there are some branches that theoretically do not have much influence on the top event, as is the case of sytem Design failure, Failure to plan to meet the regulatory requirement this branches that can be considered discardable a priori, however, it is essential to reassess based on experience and other ways of analyzing the authenticity or applicability of the branche elimination approach. However, the mathematical issues highlighted the object of study the ISO 45001: 2018 Standard, is quite precise about the fundamental importance the comitment of the top manangerment with the manangement Sytem or the need of do audits.

It is also possible to see from the results below, as expected, which weighs for the effectiveness of the top event, the existence of resources at all levels (adequate installations, maintenance).

The poor communication, as can be seen, has a weight of around 82% in the resource planning Failure. And one other important root cause is the lack of treatment of non-conformities which impact in 50% on the lack of monitoring.

Therefore, in order to reduce the risk of having a non-operational Management System, it is necessary to correctly manage or treat the following root causes:

- E0111- Poor gap assessment
- E012- Low commitment from Top management
- E0211- Poor communication
- E0231-Lack of maintenance
- E0232- Ineffective supervision
- E033- Cognitive and learning deficiencies (memory, history, data and statistics, lessons learned)
- E0411- Non-treatment of non-conformities
- E0412- Inadequate handling of non-conformities
- E042- Audit process failure.

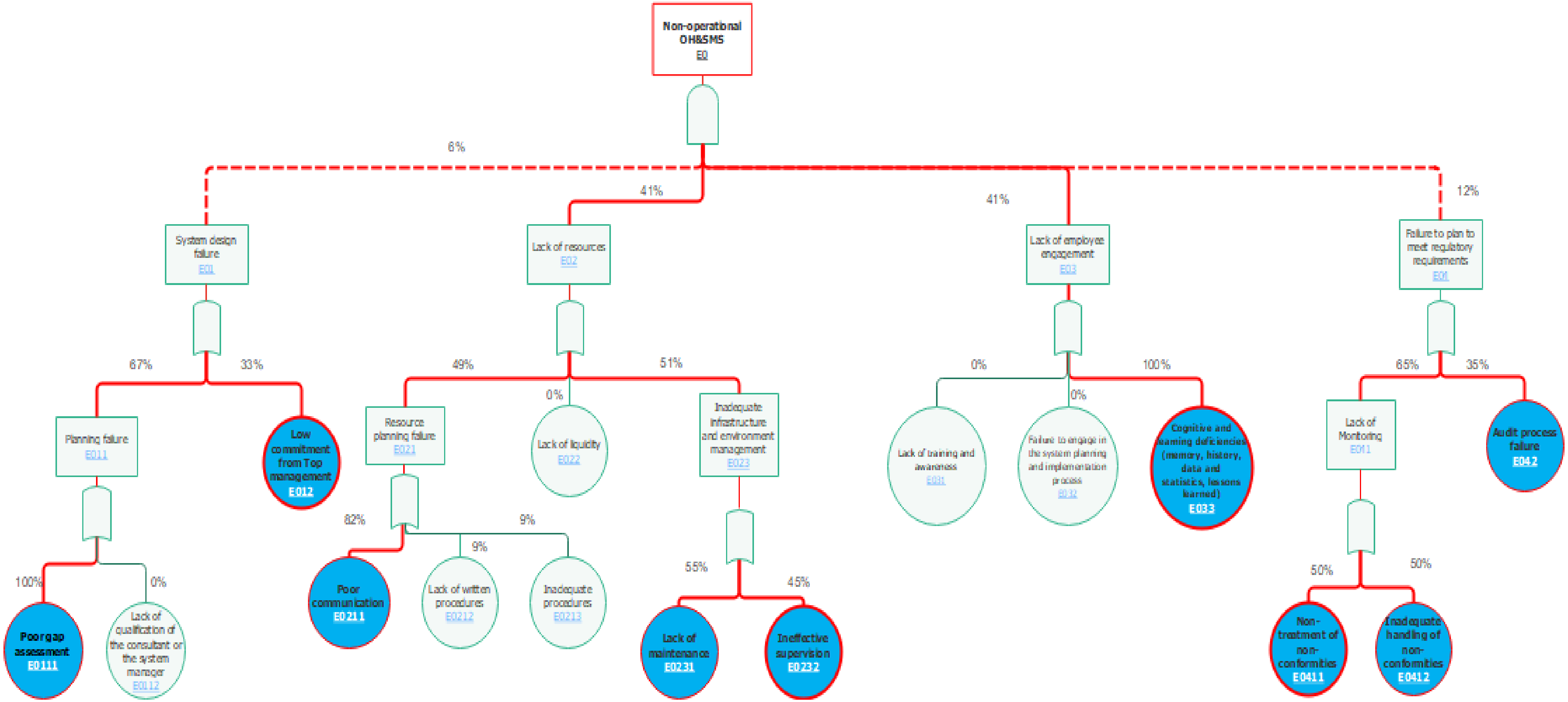


Figure 13: Non-operational OH&SMS Critical Paths (Source: By Author)

According to the provisions above, there are three types of risk families (the risk family corresponds to a set of risks that obey a certain pattern) that compete for the realization of the top event, as can be seen from the graph in the **Figure 14** below.

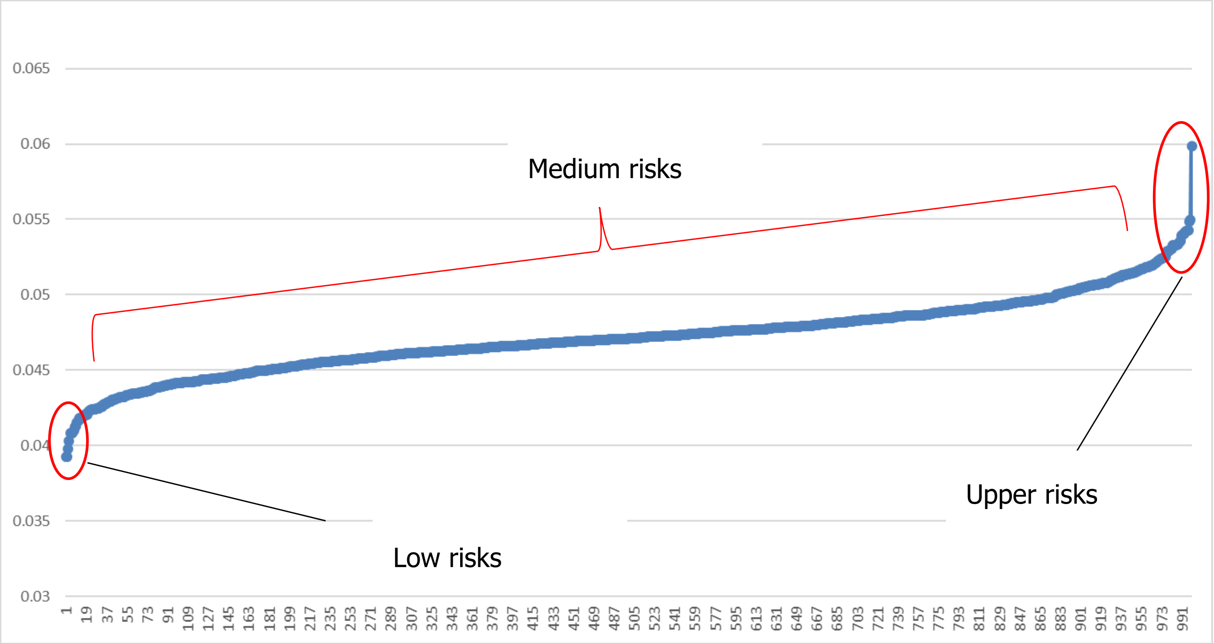


Figure 14: Family of risks that contribute to Non-operational OH&SMS (Source: By Author)

The following root causes correspond to the low risk family:

- E0112, E0213, E0212, E022, E031, E032

The following root causes correspond to medium risks family:

- E012, E0231, E0232, E0411, E0412, E042

The following root causes correspond to upper risks family:

- E0111, E0211, E033

According to the importance shown in the analysis of the fault tree above, an action plan was defined for the causes with the greatest influence on the top event, as can be seen in **Table 12**.

Table 12: Actions to be taken to reduce the feared event (Non-operationality of the OH&SMS) Probability

Ref.	Root cause	Root cause factor	Action to be taken
E0111	Poor gap assessment	Human error	Assign an expert with in-depth knowledge of the gap assessment technique
E012	Low commitment from Top management	Human error	Provide a map based on the type of activity carried out in the company on the direct and indirect, short and long-term costs of not implementing occupational health and safety procedures and the impacts on the brand, products and services provided
E0211	Poor communication	Human error	Define a communication procedure with a clear definition of what, how, when to communicate
E0231	Lack of maintenance	Mechanical stress	Define and implement a maintenance program for each component of the infrastructure under the organization's management
E0232	Ineffective supervision	Human error	Assign positions based on qualifications and technical skills
E033	Cognitive and learning deficiencies (memory, history, data and statistics, lessons learned)	Human error	Define and implement a staff training and development program
E0411	Non-treatment of non-conformities	Human error	Define accountability criteria for the person responsible for implementing actions to deal with non-conformities
E0412	Inadequate handling of non-conformities	Human error	Define an action plan and a monitoring plan for each non-conformity, also define for each non-conformity criteria for evaluating the performance or effectiveness of the measures to be implemented
E042	Audit process failure	Human error	Define and implement an Audit program and Plan

(Source: By Author)

5.6.2. FTA for Inability to put out fire

The below FTA is for Inability to put out fire, the FTA contains 3 levels and has 3 antecedents whose interaction can potentially leads to the top event. The causes that precede the top event are described below and they are all related to mechanical stress:

- Smoke detector failure;
- Inoperational Hydrant;
- Fire extinguisher inoperative;

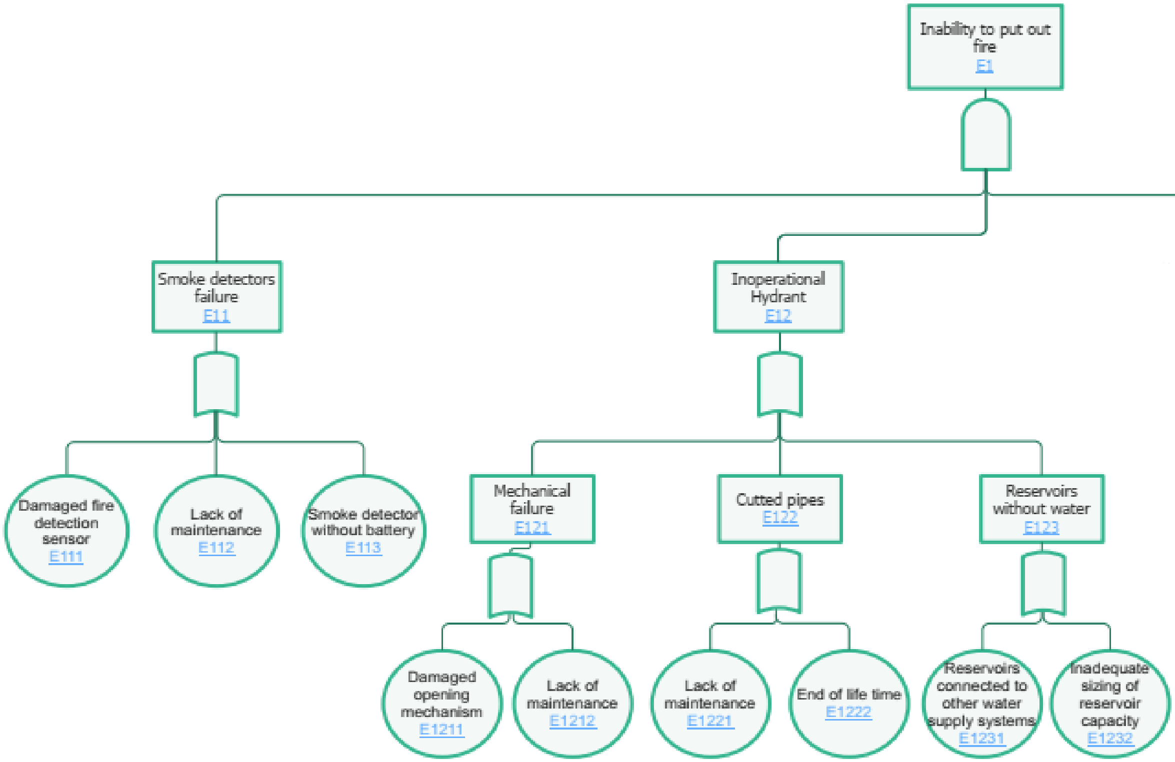


Figure 15: FTA of Inability to put out fire (Source: By Author)

5.6.2.1. Mathematical description of the events

The **Table 20** in appendix V-B define the parameters for calculating the probabilities of Inability to put out fire. The defined test questions were based on the author's criteria for calculating the probabilities.

The law of probability was defined based on the root cause factor, which in turn was defined based on the root cause.

The Figure 16 and 17 below show the results of the homogeneity test, based on below Histogram is possible to see that the sample is not homogenous. The range of probability of occurrence of the top event, based in the Histogram (**Figure 16**) is between 3.9% and 6.4 %, that is, the probability of occurrence of the top event is very low, which may not correspond to reality.

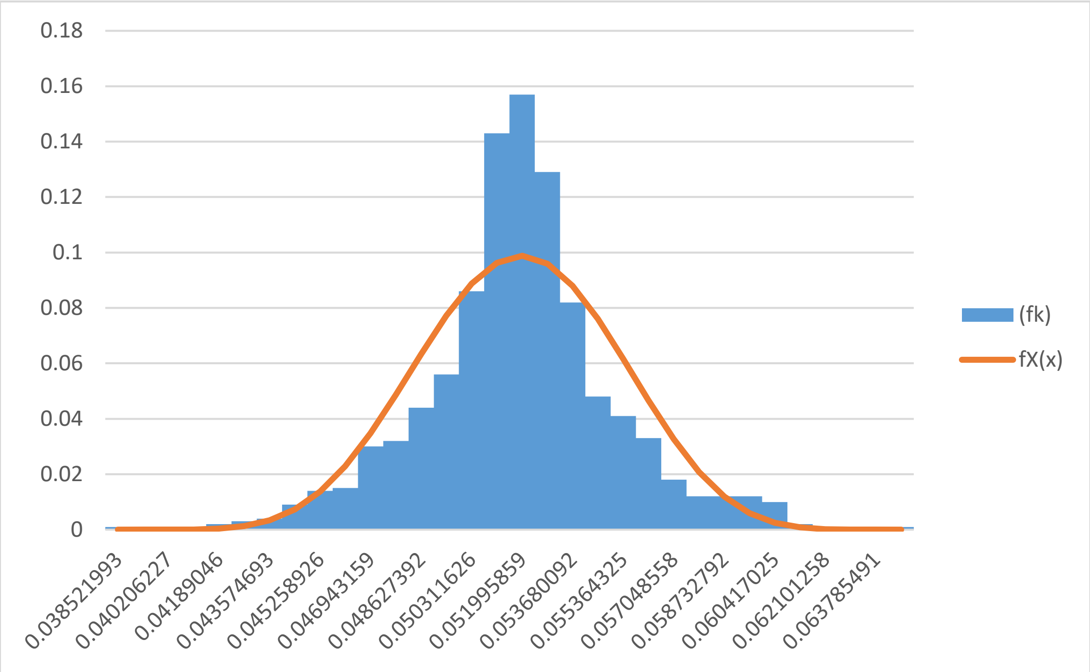


Figure 16: Histogram-Homogeneity study (Source: By Author)

Although the data show a good correlation of around 94%, the graphical presentation makes it possible to verify two opposite concavities, that is, two sets of data. One set obeys BETA 1 Law and another BETA 2 Law.

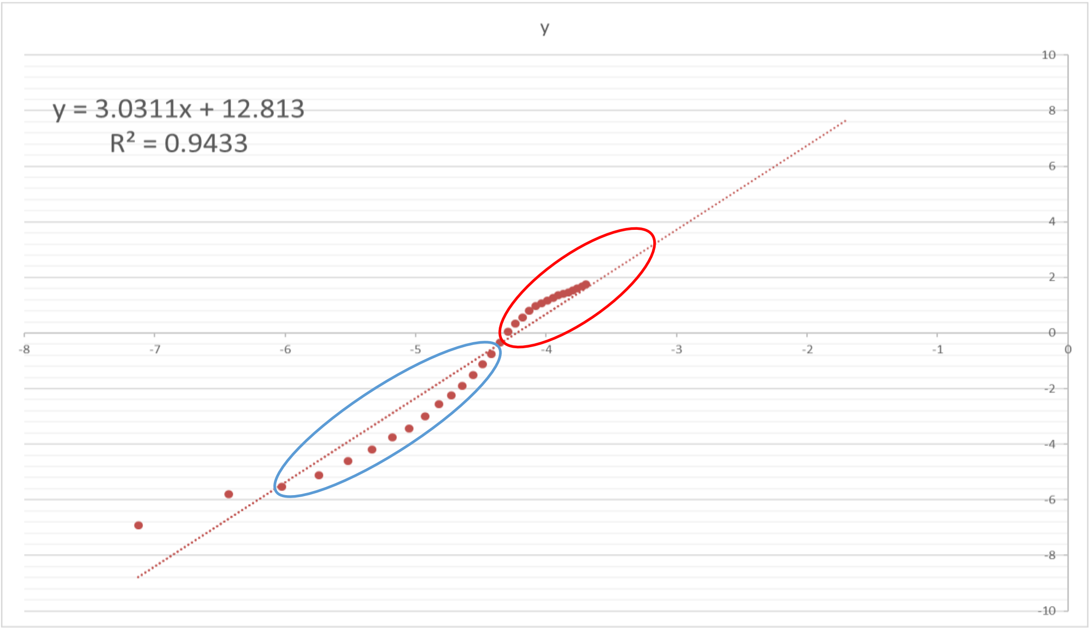


Figure 17: Correlation graphic- Inability to put out fire (Source: By Author)

According to the fault tree the immediate causes that contribute more to the Inability to put out fire is Inoperational Hydrant (49%) and Fire extinguisher inoperative (48%).

Most of the root causes identified are related to mechanical stress. Which brings us to the need to have and implement a maintenance plan for all fire detection and fighting devices. This aspect can very well be resolved by establishing procedures and clearly assigning responsibilities for monitoring or managing them.

Another aspect to consider that is evident in the fault tree is to keep the critical devices (hydrant system) in a dedicated system, that is, not interconnected to others that are not for crisis management. According to the fault tree, one of the root causes with an impact on the functioning of hydrants is the fact that the Reservoirs are connected to other internal water supply systems.

Therefore, in order to reduce the risk of having Inability to put out fire, it is necessary to correctly manage or treat the following root causes:

- E111-Damaged fire detection sensor
- E1211-Damaged opening mechanism
- E1231-Reservoirs connected to other water supply systems
- E131-Damaged fire extinguisher
- E133-Lack of maintenance

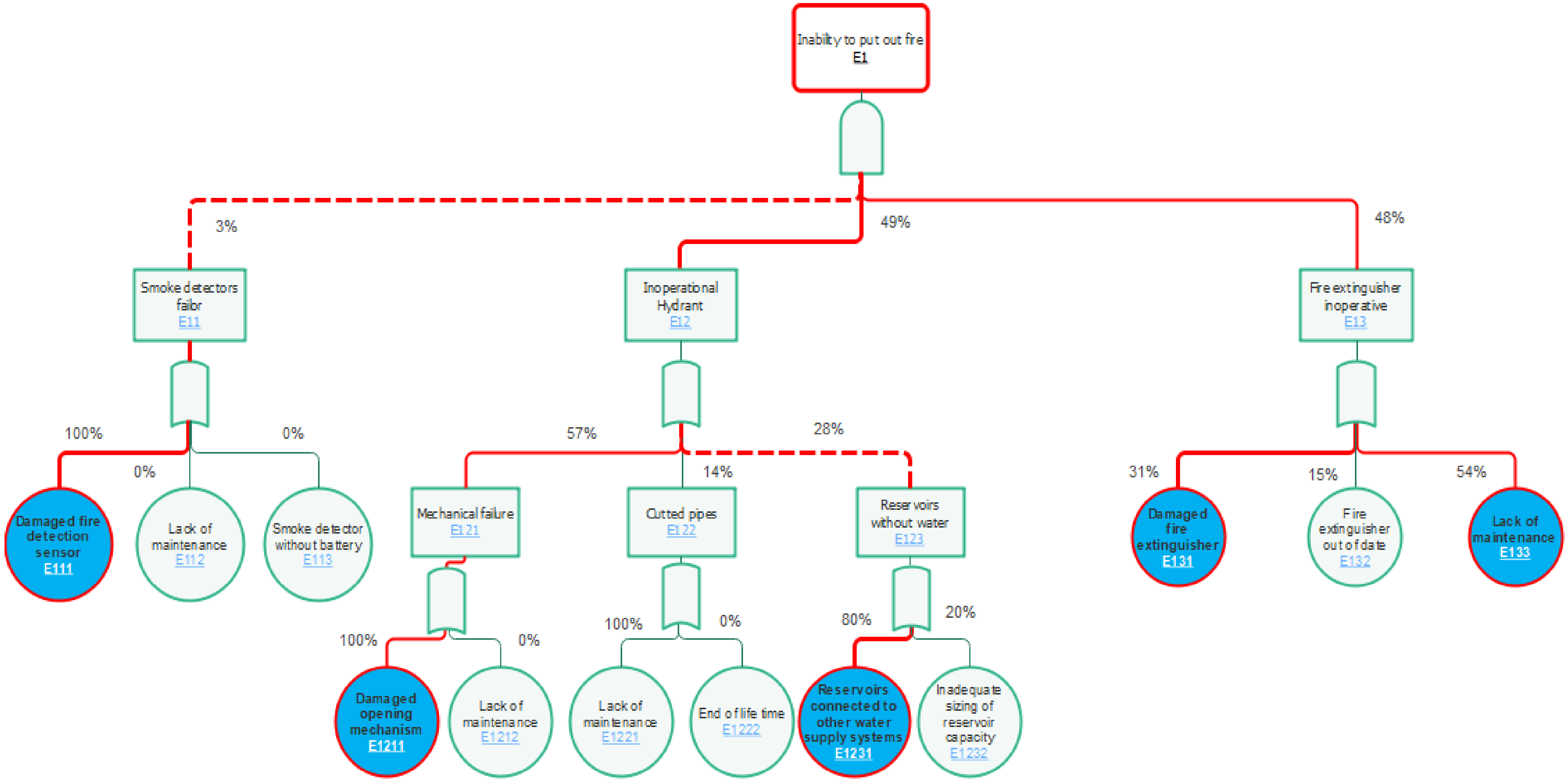


Figure 18: Inability to put out fire Critical Paths (Source: By Author)

According to the provisions above, there are three types of risk families that compete for the realization of the top event, as can be seen from the graph in the **Figure 19** below.

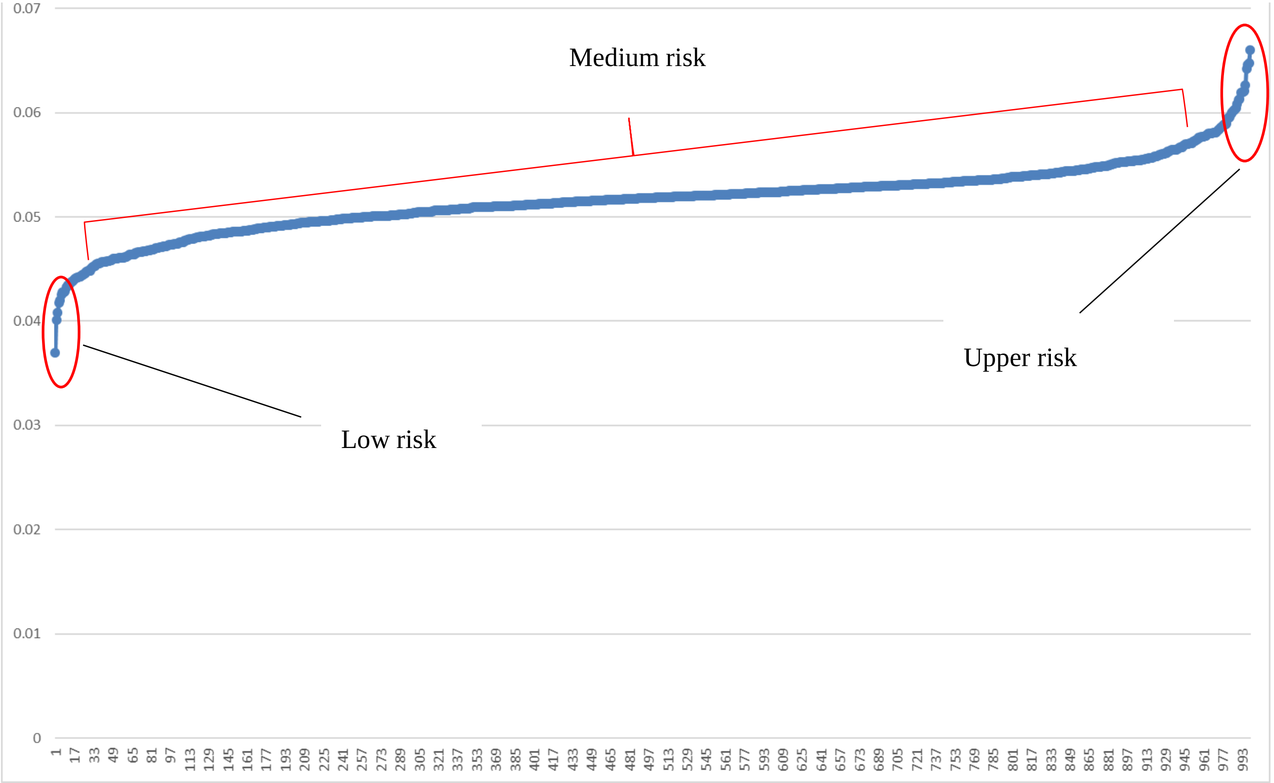


Figure 19: Family of risks that contribute to Inability to put out a fire (Source: By Author)

The following root causes correspond to the low risk family:

- E112, E113, E1212, E1222, E1232, E132

The following root causes correspond to medium risks family:

- E1232, E131, E133

The following root causes correspond to upper risks family:

- E111, E1211, E1231

According to the importance shown in the analysis of the fault tree above, an action plan was defined for the causes with the greatest influence on the top event, as can be seen in **Table 13**.

Table 13: Actions to be taken to reduce the feared event (Inability to put out fire) Probability

Ref.	**Root cause**	**Root cause factor**	**Action to be taken**
E111	Damaged fire detection sensor	Mechanical stress	Define a maintenance plan and ensure the monitoring of the implementation process
E1211	Damaged opening mechanism	Mechanical stress	Define a maintenance plan and ensure the monitoring of the implementation process
E1231	Reservoirs connected to other water supply systems	Human error	Separate and create a dedicated system to power critical devices
E131	Damaged fire extinguisher	Mechanical stress	Define a maintenance plan and ensure the monitoring of the implementation process
E133	Lack of maintenance	Human error	Define a maintenance plan and ensure the monitoring of the implementation process

(Source: By Author)

5.6.3. FTA for Non-reduction of occupational risks

The below FTA is for Non-reduction of occupational risks, the FTA contains 3 levels and has 3 antecedents whose interaction can potentially leads to the top event. The causes that precede the top event are described below and they are all related to human factor:

- Low safety culture;
- Non-involvement of Top management;
- Non-involvement of Employees;

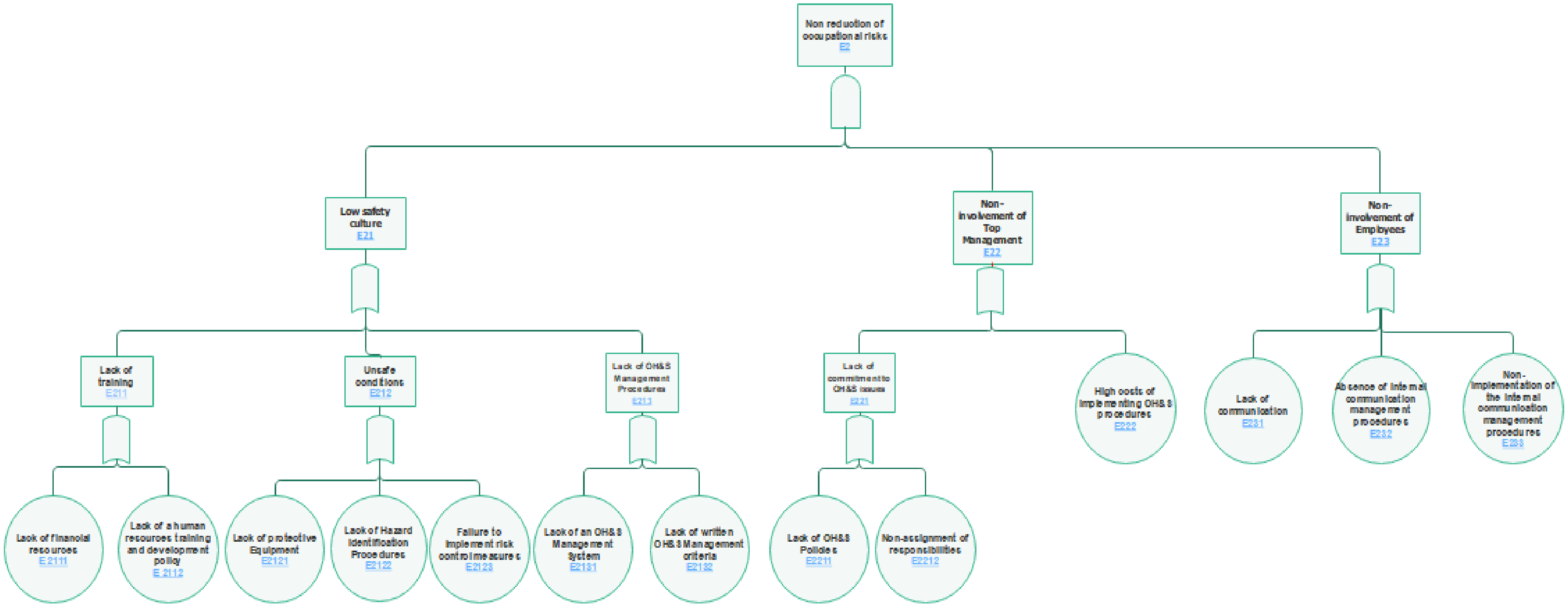


Figure 20: FTA of Non reduction of occupational Risks (Source: By Author)

5.6.3.1. Mathematical description of the events

As in the two previous cases, the definition of the parameters for calculating the probabilities were based on the author's criteria. The **Table 22** (see appendix V-C) define test questions used for calculating the probabilities of Non reduction of occupational Risks, and thirteen root causes have been defined.

The Figure 21 and 22 below show the results of the homogeneity test, based on below Histogram is possible to see that the sample is homogenous. Based in the Histogram (**Figure 21**) is possible to see that the probability of occurrence of the top event is very high (is between 98% and 99%), almost certain, which also do not correspond to reality.

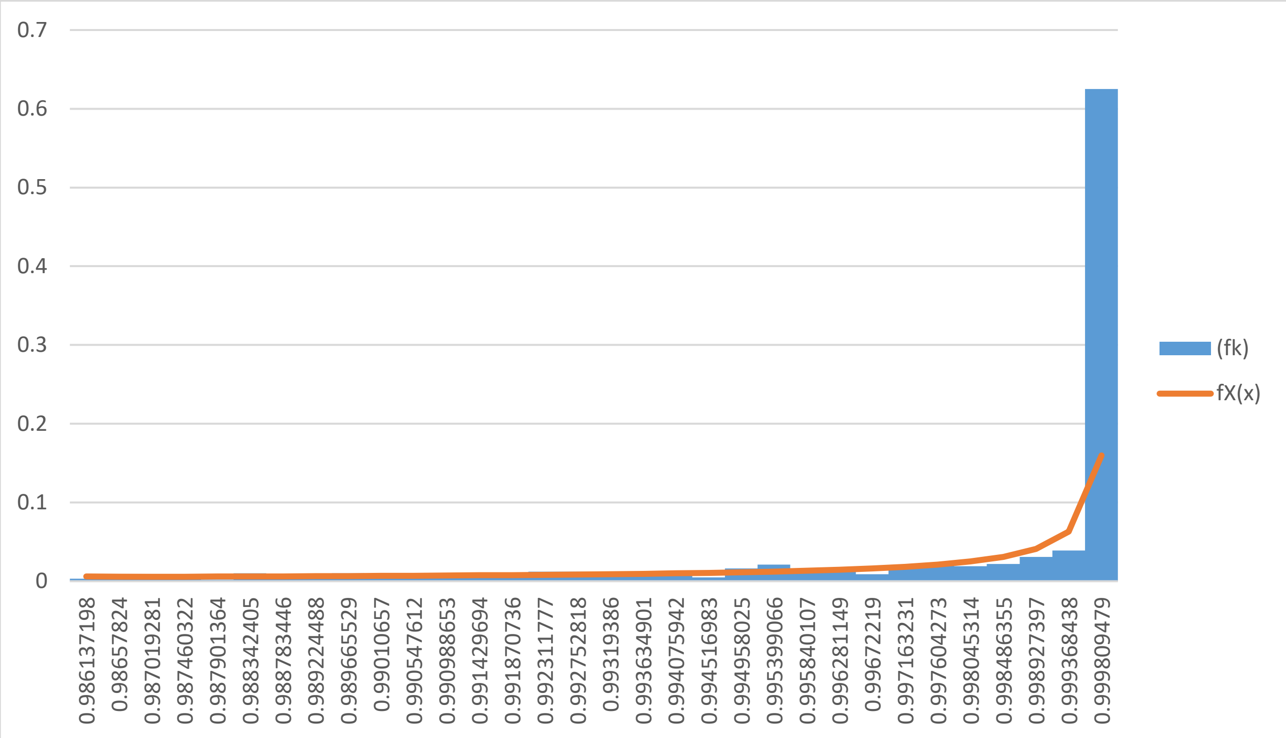


Figure 21: Histogram-Homogeneity study (Source: By Author)

The homogeneity test also shows that the data under analysis obey one law of probability, and, that is the GAMMA law. The data also show a good relationship with each other of about 98%.

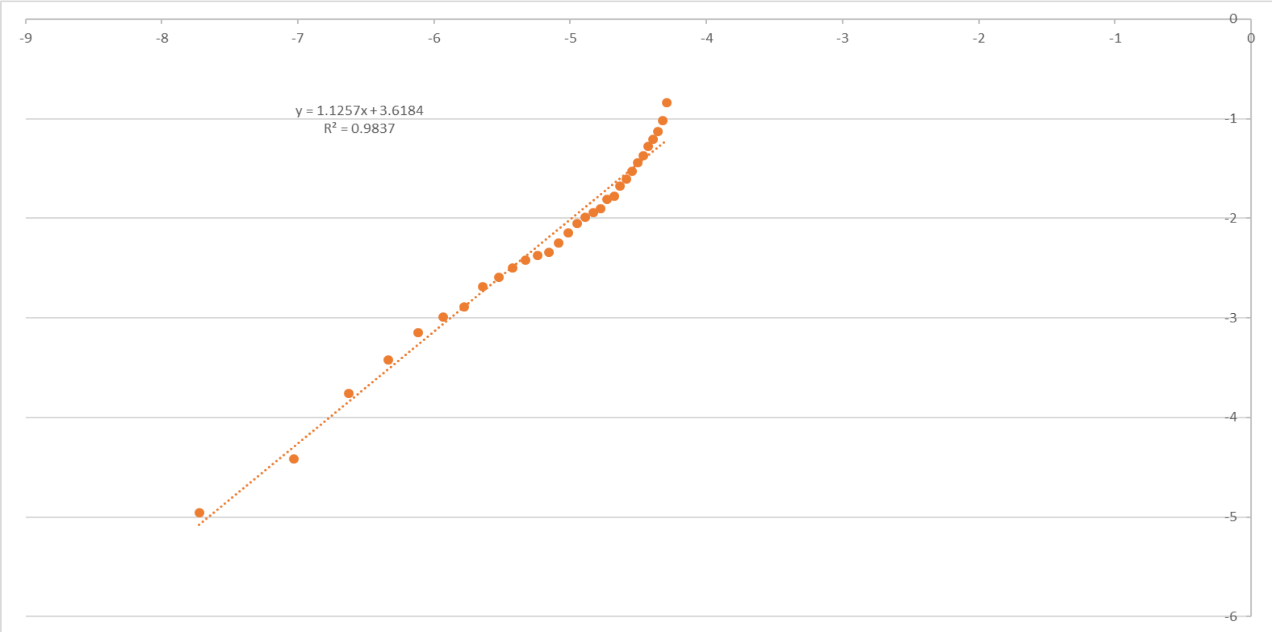


Figure 22: Correlation graphic- Non reduction of Occupational Risks (Source: By Author)

The FTA shows that the immediate causes that contribute to Non reduction of Occupational Risks has almost same weight as can be seen Low safety culture (34%), Non-involvement of Top management (33%), Non-involvement of Employees (33%), which means that in order to reduce the risk of the Top event, it is necessary to consider/manage the root causes of the three proximate causes presented previously.

Most of the identified causes are related to human factors. Which leads us to the need to define and monitor the implementation of policies and procedures in the organization, as well as provide the necessary financial resources for this purpose.

Among the most likely causes, the lack of a training and development policy for human resources configures the one that has 100% influence on the lack of training and consequently on the low safety culture, as can be seen from the existence and implementation of a clear training policy can be greatly reduced the potential for Non-reduction of Occupational Risks.

Another aspect to consider, the lack of communication despite having a reduced impact among the root causes (37%) of the critical path, plays a fundamental role not only for the good performance of the OH&S management processes but also for the good performance of the organization itself, that is, increase the production potential and productivity.

Therefore, in order to reduce the risk of Non reduction of Occupational Risks, it is necessary to correctly manage or treat the following root causes:

- E 2112- Lack of a human resources training and development policy
- E2122- Lack of Hazard Identification Procedures
- E2211- Lack of OH&S Policies
- E231- Lack of communication
- E232- Absence of internal communication management procedures

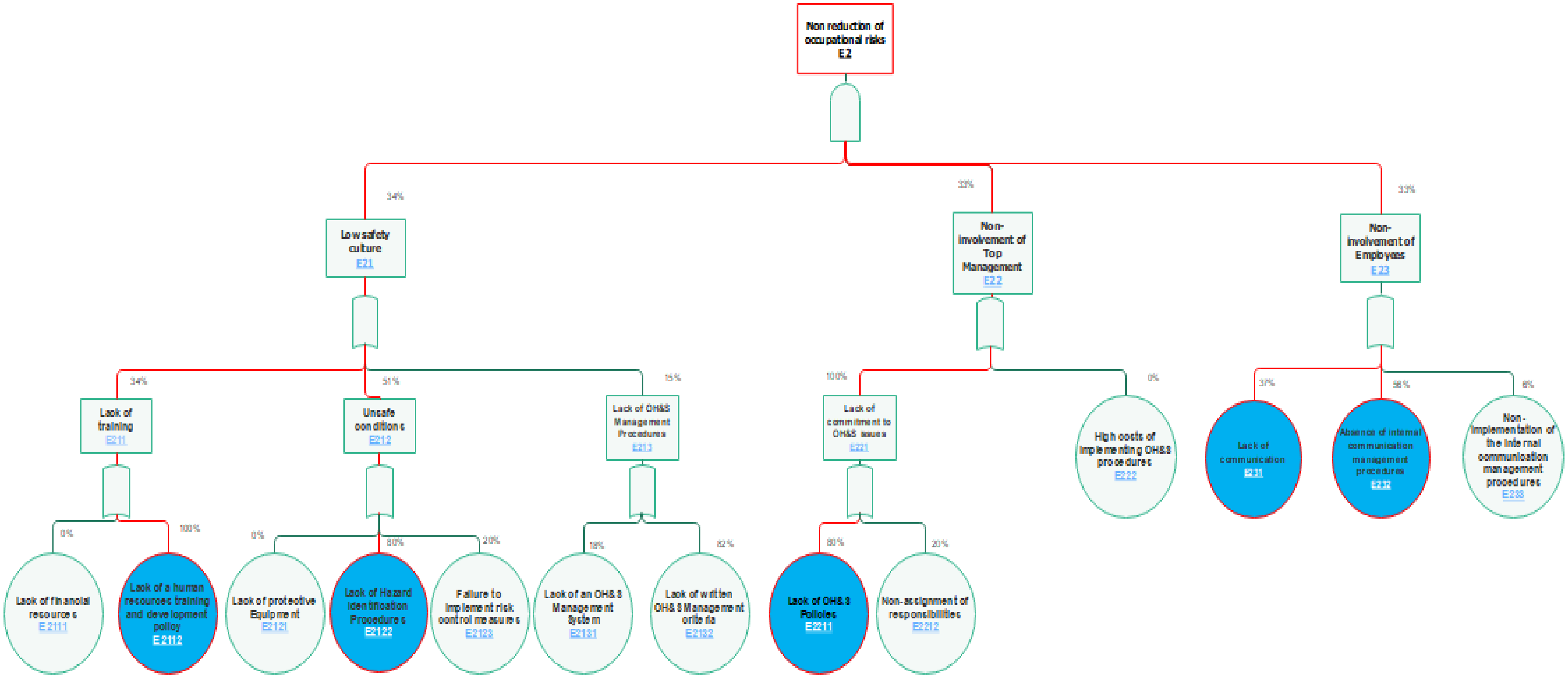


Figure 23: Non reduction of Occupational Risks Critical Paths

Based on the above data it can be said that there are two relevant types of risk families that compete for the realization of the top event. Medium and upper risk, as can be seen from the graph in the **Figure 24** below.

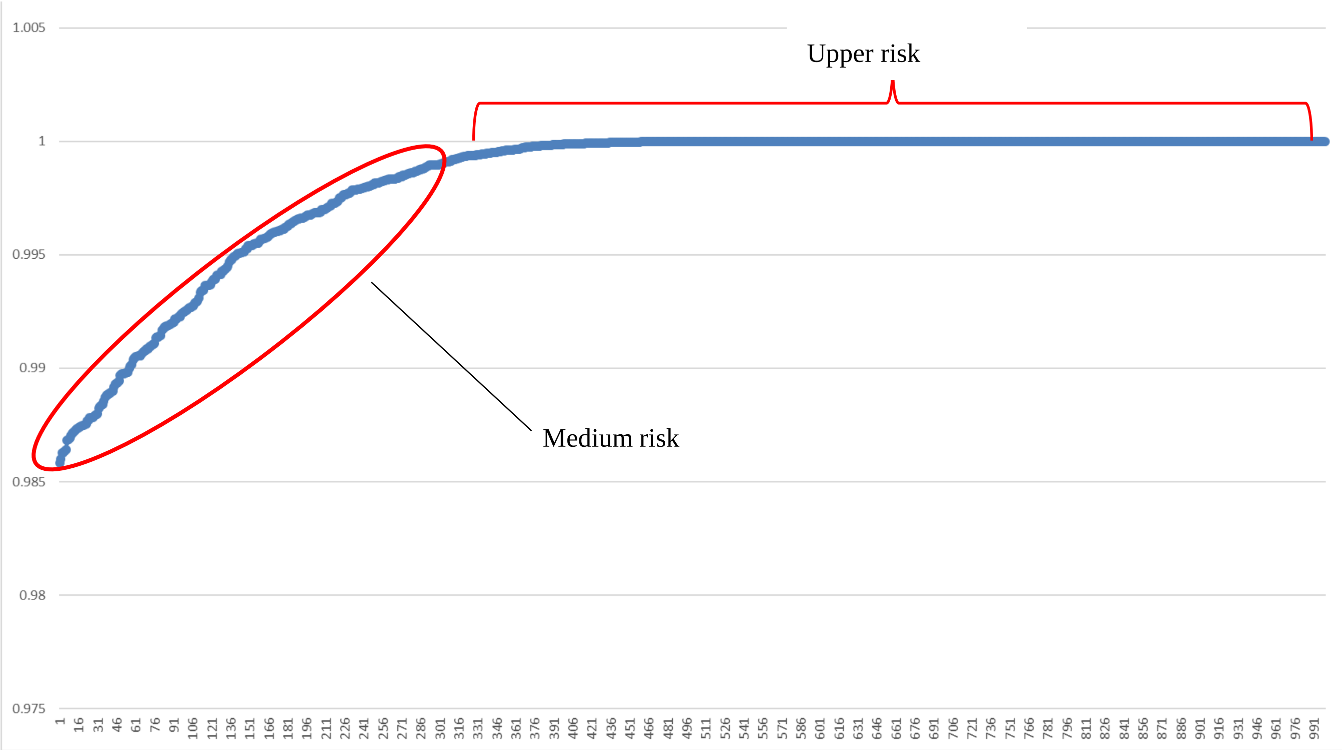


Figure 24: Family of risks that contribute to Non reduction of Occupational Risks (Source: By Author)

The following root causes correspond to medium risks family:

- E231, E232,

The following root causes correspond to upper risks family:

- E2112, E2122, E2211

According to the importance shown in the analysis of the fault tree above, an action plan is needed for the causes with the greatest influence on the top event, as can be seen in **Table 14**.

Table 14: Actions to be taken to reduce the feared event (Non reduction of Occupational Risks) Probability

Ref.	Root cause	Root cause factor	Action to be taken
E 2112	Lack of a human resources training and development policy	Human error	Define a training and development policy and the needed resources for the implementation process
E2122	Lack of Hazard Identification Procedures	Human error	Define and implement a Hazard Identification Procedures and ensure the monitoring of the implementation process
E2211	Lack of OH&S Policies	Human error	Develop and implement OH&S polices, ensure the review in a regular basis, and the monitoring of the implementation process
E231	Lack of communication	Human error	Define and implement the communication matrix and ensure the monitoring of the implementation process
E232	Absence of internal communication management procedures	Human error	Define the internal and external communication procedure and communicate it at all levels

(Source: By Author)

5.7. Risk analysis using Systemic Cindynogenic Deficits-SCD

In this section, we intend to make a global analysis and predict the risks in the OH&SMS design and implementation process, with the aim of obtaining a basis for optimizing the treatment of these risks in the design and implementation of OH&SMS in practice. Being a project to be developed, the present risk analysis using SCD intend to survey fatal issues for the OH&SMS design and implementation phases.

5.7.1. Risk analysis using Systemic Cindynogenic Deficits for System design

The System design process as can be seen in **Table 15** bellow has aspects that should not be neglected, such as engagement plan of Interested Parts (IP), good communication and feedback practice between management and workers, attribution of responsibilities in the design of the management system process, PDCA approach.

Table 15: SCD for System design

Subject/Topic/Activity	Development phase- System design	
SCD	Description	Cultural
SCD 1	**Culture of infallibility-Conviction of absence of danger**	_Overvaluation of internal systems development/design capabilities
SCD 2	**Culture of simplism- Aversion for complexity**	_Lack of a legal framework and clear, harmonised guidance (standards) in terms of design (scenarios/hypotheses Action Plan)
SCD 3	**Culture of non-communication**	_lack of or Communication and coordination difficulties; _Organisational fragmentation and administrative formalism
SCD 4	**Level of Culture- Non attention to the outside word**	_Lack of engagement plan of Interested Parts (IP) _Poor culture of evolve interested parts _Lack of Training
SCD	Description	Organisation
SCD 5	**Subordination of risk management functions to production –Prodution dominate Risk management**	_Cognitive and learning deficiencies (memory, history, data and statistics, lessons learned in system design).
SCD 6	**Dilution of responsibilities. Non-explanation of risk management tasks. Failure to assign tasks to designated officials.**	_ Lack of attribution of responsibilities in the design of the management system (Process managers)
SCD	Description	Management
SCD 7	**Lack of a feedback system-No post-accident information storage and processing**	_Weak cooperation between different actors (management team and workers) _Lack of feedback between management and workers

SCD 8	**Absence of a method cynical in the organization- No risk management methodology**	_Lack of risk-based thinking _Lack of Gap analysis before an implementation plan development
SCD 9	**Lack of a training program for cindynics adapted to each category of personal.**	_lack of specialized staff in analysing deficiencies in the development and implementation phases
SCD 10	**Lack of crisis planning**	_Lack of PDCA approach, especially for non-routine operations

5.7.2. Risk analysis using systemic cindynogenic deficits for OH&SMS Implementation

In the process of implementing the System, as can be seen in **Table 16** below, among other aspects, the following should be considered as important, the need to have an engagement plan for Stakeholders (IP), Staff training and compliance with adopted safety procedures, Internal Audits execution, risk-based approach, team specialized in the analysis of deficiencies, correct management of non-conformities.

Table 16: SCD for OH&SMS Implementation

Subject/Topic/Activity	OH&SMS Implementation	
SCD	**Description**	**Cultural**
SCD 1	**Culture of infallibility-Conviction of absence of danger**	_Lack of monitoring and implementation of internal procedures
SCD 2	**Culture of simplism- Aversion for complexity**	_Lack of written procedures
SCD 3	**Culture of non-communication**	_Lack of engagement plan of Interested Parts (IP) _Poor culture of evolve IP _Lack of Training
SCD 4	**Level of Culture- Non attention to the outside word**	_Lack of compliance with safety procedures _Noncompliance with the training practices
SCD	**Description**	**Organisation**
SCD 5	**Subordination of risk management functions to production –Production dominate Risk management**	_ Lack of full compliance with risk management procedures - use of shortcuts _Lack of competences to manage the implementation process _ Lack of goals or criteria to follow
SCD 6	**Dilution of responsibilities.** **Non-explanation of risk management tasks. Failure to assign tasks to designated officials.**	_Nonexistence of a Job description _Lack of competence
SCD	**Description**	**Management**
SCD 7	**Lack of a feedback system-No post-accident information storage and processing**	_weak cooperation between different monitoring actors _Lack of Internal Audits
SCD 8	**Absence of a method cynical in the organization- No risk management methodology**	_Lack of risk-based thinking
SCD 9	**Lack of a training program for cindynics adapted to each category of personal.**	_lack of specialized staff in analysing deficiencies
SCD 10	**Lack of crisis planning**	_Lack of preparation to manage written procedures, working instruction; _Lack of written procedures for managing non-conformities

5.8. Action Plan for the implementation of OH&SMS

The preparation of the Action Plan for the implementation of OH&SMS requirements was fundamentally based on data from the Gap Analysis questionnaire. The level of implementation of the ISO 45001:2018 requirements based on the gap analysis questionnaire is about 50%, see the graphic in appendix IV. Can be seen also, that the lowest performance level (about 4%) is related to the requirements of the clauses on Performance Evaluation and Improvement, which is most likely associated with human factors.

The **Table 17** below indicates the actions to be taken to meet the requirements of the ISO 45001:2018 standard, the results contained therein were based on the initial gap analysis.

The premises for the design of the plan follow the PDCA approach. The action plan consists of six phases whose actions can be summarized in initial diagnosis, training, development and implementation, audit and improvement, certification.

Below are indicated the actions to be taken to meet the requirements of the ISO 45001:2018 standard, the results contained therein were based on the initial gap analysis.

Table 17: Action Plan for the implementation of OH&SMS

Revision Nº 00	**PROJECT ACTION PLAN FOR THE IMPLEMENTATION OF THE OCCUPATIONAL HEALTH AND SAFETY MANAGEMENT SYSTEM ISO 45001:2018** Prepared by: Sarmento Filipe | Data: 16/08/2021 — Approved by: Meldine Houana -BCX | Data:												
	Label: ○ <25% feito | ◔ 25% done | ◑ 50% done | ◕ 75% done | ● 100% done | C- Create/Perform | R- Revision | E-Existing | NM - Not Mandatory | M - Mandatory Process | Proc - Procedure |												
PDCA Phases	**Phases**	**Objective**	**Standard requirement**	**Description**	**Type**	**Proc.**	**Doc.**	**Deliverable**	**Action required**	**Responsible**	**Start day**	**And day**	**Coments**
P	**Phase 1**	Diagnose the organization	**Audit**										
			4.1	Diagnostic audit (GAP analysis)	NM		Doc.	Gap analysis report	C				
				Development of the Implementation Action Plan	NM		Doc.	Action Plan approved	C				
D	**Phase 2**	Train workers and define processes	**Training**										
			7.2	Training-introduction to OH&SMS	M			workers trained	C				
	Phase 3		**4**	**Organization context**									

			4.1.	SWOT Analysis	M			SWOT Analysis	R				
			4.2.	Determine Interested Parties	M			Interested Parties Matrix	C				
			4.3.	Scope of the Management System	M			Scope of the Management System	R				
			4.4.	OH&SMS Processes	M			OH&SMS Processes	R/C				
			5	**Lidership and Employee participation**									
			5.1.	leadership and commitment	M			OH&S policy	R				
			5.2.	OH&S policy									
			5.3.	Definition of Roles, Responsibilities and Authorities	M		Doc.	Job Description Manual Review	R				
			5.4.	Employee Consultation and Participation	M	Proc.01		Safety meetings Program definition	C				
			6	**Planning**									
		Develop and implement the OH&SMS (elaborate procedures, forms, matrices, policy and Manuals)	6.1.	Actions to address risks and opportunities	M		Doc.	Hazards Identification and Risks Assessment Matrix development	C				
			6.1.2.1	Hazard identification	M	Proc.02		Procedure for Risk Identification and Assessment (Enterprise Risk Management Framework)	E				
			6.1.2.1	OH&S risk assessment and other risks to OH&SMS									
			6.1.3	Determination of legal and other requirements	M		Doc.	Legal requirements matrix Template	C				
			6.2.	OH&S objectives and planning to achieve them	M		Doc.	OH&S Objectives Matrix Template and Action Plan	C				
			7	**Support**									
			7.1	Resources			Doc.	Planning Matrix Template	C				
			7.2.	Skills		Proc. 03		Training management Procedure	E				
			7.3.	Awareness	M		Doc.	Learning and Development Plan	C				
							Doc.	Learning and Development Policy.	E				
			7.4.	Communication	M		Doc.	Health and safety communication plan	E				
					NM	Proc. 04		Service Desk Procedure	E				
			7.5.	Documented Information	NM	Proc. 05		Document Management Procedure	C				
			8	**Operationalization**									

			8.1.2	Eliminate hazards and reduce OH&S risks	M	Proc. 02		Enterprise Risk Management Framework	E				
			8.1.3.	Changes management	M	Proc. 06		Changes Management Matrix Template	E/C				
			8.1.4.3	Subcontracting	P	Proc. 07		Contractors Management Procedure	C				
			8.2.	Emergency preparedness and response	M		Doc.	Health And Safety Emergency Preparedness Plan	E				
					M		Doc.	Emergency Simulation Performance Control Form	C				
					M		Doc.	Emergency Plant	C				
			9	**Performance evaluation**									
			9.1	Monitoring, measurement, analysis and evaluation	NM		Doc.	OH&S Indicator Matrix: lagging & leading indicators	C				
							Doc.	Accident Investigation Form	E/C				
			9.2.	Internal Audit	M		Doc.	Internal Audit Program	C				
			9.3.	Management Review	M		Doc.	Management Review Minute Template	C				
			10	**Improvement**									
			10.2.	Incident, Non-Compliance and Corrective Action	M	Proc. 08		*Incident, Non-Conformance Reporting and Corrective Action Procedure*	E/R				
							Doc.	*Incident, Non Conformance Report*	E/R				
			10.3.	Continuous improvement	M			Continuous improvement					
				Advised									
				OH&SMS Manual	NM		Doc.	OH&SMS Manual	C				
				Induction Program	M		Doc.	Induction Program Template	C				
				Monitoring the implementation of the OH&SMS	NM			Sessions dedicated to areas/departments	C				
		Training of internal auditors			M			Internal auditors trained	C				
C	**Phase 4**	Internal audit execution			M			Internal audit report					
A	**Phase 5**	Changes implementation	**10.3**	Continuous improvement	M			Required Changes Implemented					
	Phase 6	Follow-up audit for certification			NM			Certification					

5.8.1. Action Plan time scale

Once the action plan was defined, it was necessary to establish a schedule that would allow better management of the Management System implementation process, the **Figure 25**, shows the executive plan from the gap assessment phase to implementing the necessary improvements at the end of the audit.

According to the schedule, at least 71 working days would be needed for the implementation of the Management System, it is also possible to note that there are six critical activities that condition the effective time of execution of the project that together form the critical path. they are the following:

- Gap assessment implementation;
- Development of the action plan;
- Training execution-introduction to OH&SMS ISO 45001:2018;
- Implementation of procedures and collection of records;
- Internal Audit execution;
- Changes implementation.

The above activities are part of the group of activities that cannot be postponed, on the one hand, they are activities that must take the expected execution time, that is, the project manager must guarantee the availability of sufficient resources for their execution in the time foreseen in the plan under risk of delay in the project implementation process.

		Predecessors	Name	Duration	Start	Finish
1			**OH&S Manangerment System Implamentation**	**71 days?**	**3/1/23 8:00 AM**	**6/7/23 5:00 PM**
2			**0. Gap assessment**	**8 days**	**3/1/23 8:00 AM**	**3/10/23 5:00 PM**
3			0.1. Gap Assessment Implamentation	5 days	3/1/23 8:00 AM	3/7/23 5:00 PM
4		3	0.2. Development of the Action Plan	3 days	3/8/23 8:00 AM	3/10/23 5:00 PM
5			**1. System Design and Development**	**39 days?**	**3/13/23 8:00 AM**	**5/4/23 5:00 PM**
6		4;3	1.1. Training execution - Introdution to OH&SMS (ISO 45001:2018)	5 days	3/13/23 8:00 AM	3/17/23 5:00 PM
7		6	1.2. SWOT Analysis Development	1 day	3/20/23 8:00 AM	3/20/23 5:00 PM
8		7	1.3. Interested parties Matrix Development	2 days	3/21/23 8:00 AM	3/22/23 5:00 PM
9		7;8	1.4. Management System Scope definition	1 day	3/23/23 8:00 AM	3/23/23 5:00 PM
10		9	1.5. OH&S policy Revew	3 days	3/24/23 8:00 AM	3/28/23 5:00 PM
11		9	1.6. Job Description Manual Review	2 days	3/24/23 8:00 AM	3/27/23 5:00 PM
12		11;10	1.7. Safety Meetings Program Definition	2 days	3/29/23 8:00 AM	3/30/23 5:00 PM
13		11	1.8. Hazards Identification and Risks Assessment Matrix Development	3 days	3/28/23 8:00 AM	3/30/23 5:00 PM
14		11;13;12	1.9 Development of the legal requirements matrixTamplate	1 day	3/31/23 8:00 AM	3/31/23 5:00 PM
15		14SS	1.10. OH&S Objectives Matrix Tamplete and Action Plan Development	2 days	3/31/23 8:00 AM	4/3/23 5:00 PM
16		15	1.11. Planning Matrix Tamplete Development	1 day	4/4/23 8:00 AM	4/4/23 5:00 PM
17		15	1.12. Learning and Development Plan Denvelopment	3 days	4/4/23 8:00 AM	4/6/23 5:00 PM
18		17;16	1.13. Document Management Procedure Development	1 day?	4/7/23 8:00 AM	4/7/23 5:00 PM
19		18	1.14. Changes Management Matrix Tamplete Development	2 days	4/10/23 8:00 AM	4/11/23 5:00 PM
20		18	1.15. Contractors Management Procedure	2 days	4/10/23 8:00 AM	4/11/23 5:00 PM
21		20;19	1.16. Emergency Simulation Performance Control Form	2 days	4/12/23 8:00 AM	4/13/23 5:00 PM
22		20	1.17. Emergency Plant Design	10 days	4/12/23 8:00 AM	4/25/23 5:00 PM
23		22;21	1.18. OH&S Indicator Matrix Development	3 days	4/26/23 8:00 AM	4/28/23 5:00 PM
24		22	1.19. Internal Audit Program Development	2 days	4/26/23 8:00 AM	4/27/23 5:00 PM
25		24	1.20. Management Review Minute Template	2 days	4/28/23 8:00 AM	5/1/23 5:00 PM
26		25	1.21. Induction Program Template	3 days	5/2/23 8:00 AM	5/4/23 5:00 PM
27			**2. Implementation of Procedures and Models**	**45 days**	**3/20/23 8:00 AM**	**5/19/23 5:00 PM**
28		6	2.1. Implementation of procedures and collection of records	45 days	3/20/23 8:00 AM	5/19/23 5:00 PM
29		28SS	2.2. Sessions dedicated to areas/departments	20 days	3/20/23 8:00 AM	4/14/23 5:00 PM
30			**3. Internal auditors training and Audit Execution**	**63 days?**	**3/13/23 8:00 AM**	**6/7/23 5:00 PM**
31		4	3.1. Audit Training	4 days	3/13/23 8:00 AM	3/16/23 5:00 PM
32		31;24;29;23;26;28	3.2. Internal audit Execution	3 days?	5/22/23 8:00 AM	5/24/23 5:00 PM
33			**4. Continuous improvement**	**10 days**	**5/25/23 8:00 AM**	**6/7/23 5:00 PM**
34		32	4.1. Changes implementation	10 days	5/25/23 8:00 AM	6/7/23 5:00 PM

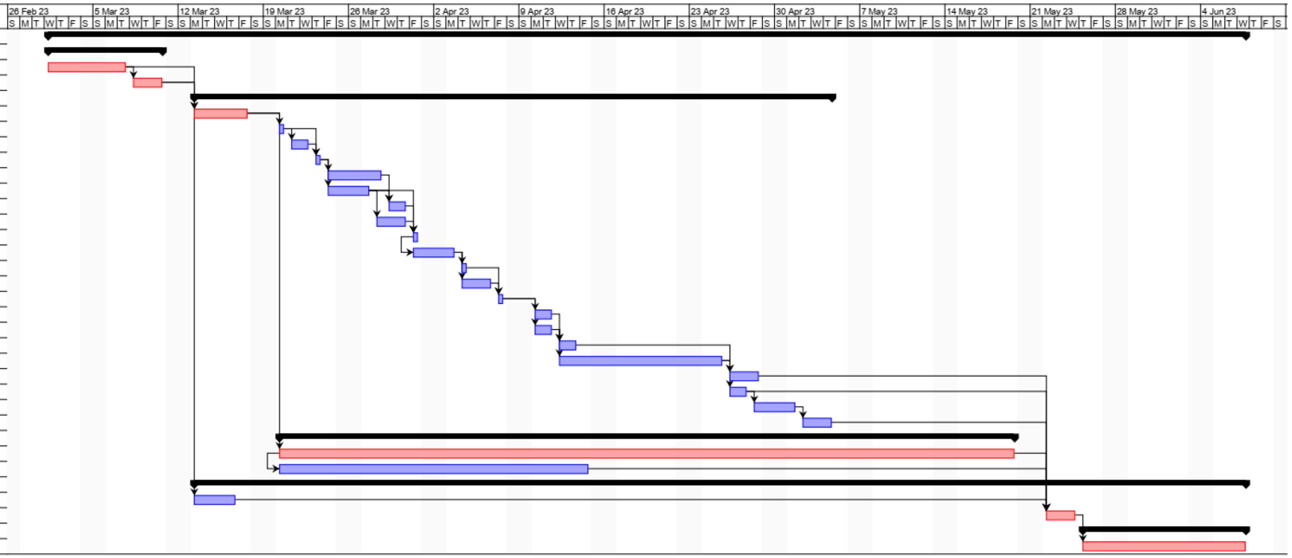


Figure 25: Action Plan time scale for the implementation of OH&SMS (Source: By Author)

CHAREPTER 6: Conclusions and recommendations

This chapter presents the conclusions resulting from the realization of this research taking into account the objectives outlined at the beginning of the research. Are also presented limitations and possible recommendations for future studies.

6. Conclusions

According to the objectives of this report, which was evaluate the effectiveness of the quality management system in improving OH&S conditions in the work environment at study area and develop an action plan for the development and implementation of the ISO 45001:2018 standard for safety and occupational health management.

This research project presents a perspective on how to develop and implement an effective occupational health and safety management system for the reduction of occupational risks based on the criteria of ISO 45001:2018.

- The existing opportunity related to the Increasing Multi nationals investment (coal oil gas), as expected demand from local services provider behind competence, safety integrity insurance that is, secure operations and workers safety. So, the implementation and maintenance of an operational OH&SMS can improve processes and information management, protect employees and assets, improve planning and communication, reduce occupational risks, increase the safety culture, manage resources.
- For the process of implementing ISO 45001:2018, it is possible to take advantage of the fact that the organization already has an ISO system in place (ISO 9001:2015), so that some elements can be used to complement the ISO 45001 implementation process. Since the ISO standards have the same structure, the so-called annex SL.
- Based on the gap analysis questionnaire, the level of implementation of the ISO 45001:2018 requirements is 50%.
- The results of the FMECA and FTA application, shows that the feared events without looking at the specificities, are related to OH&S issues. Each of these occurrences can be dealt with through the implementation of OH&S management procedures and/or safe work procedures, that is, it is necessary to set up policies and a team to manage the health and safety conditions and aspects.
- In the OH&SMS design/development has aspects that should not be neglected, such as engagement plan of Interested Parts (IP), good communication and feedback practice between

management and workers, attribution of responsibilities in the design of the management system process, PDCA approach.

- In the OH&SMS Implementation process among other aspects, should be considered as important, the need to have an engagement plan for Stakeholders, Staff training and compliance with adopted safety procedures, Internal Audits execution, risk-based approach, team specialized in the analysis of deficiencies, and correct management of non-conformities.
- The lack of an initial gap analysis that integrates these three visions, namely functional, structural and behavioral during the process of development and implementation of Management Systems can lead to failure in the process. These analyses allow gathering a certain type of knowledge about the system, such as what are the different functions of the system, the intended performance level for the system, what are the components and subsystems (or even the resources and their interaction) to support these processes, how the system can be adapted and controlled to prevent damage in an emergency, etc.
- Based on the proposed action plan would be needed at least 71 working days for the implementation of the OH&S Management System following the ISO 45001 :2018 requirements.

6.1. Recommendations for future studies

For future work it is recommended as a complement to the studies carried out in this research project:

- Carrying out an exhaustive assessment of the health and safety conditions related to the ergonomic component.
- Define other input data for the probabilistic analysis of the FTAs in order to establish a baseline for comparing the results obtained in this study

CHAREPTER 7: Bibliographic References

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Appendices

I. Gap analysis Questioner

Clauses	Requirement	Gap analysis Question(s)	DCRDS	DCRCS	Comments
ISO 45001:2018					
4. Context of organization	4.1 Understanding the organization and its context	Are external and internal issues that affect or may affect the ability to achieve the intended results of the OH&SMS identified?			
		Is there a plan to determine how the identified issues will be addressed?			
	4.2 Understanding the needs and expectation of workers and other interested parties	Have relevant stakeholders for the OH&SMS been identified?			
		Have legal requirements and other associated requirements relevant to the OH&SMS been identified?			
		How stakeholder needs and expectations are addressed taking into account legal requirements?			
	4.3 Determining the scope of the OH&S management System	Has the scope of the OH&SMS been determined?			
		Have the main external, internal and legal requirements and products and services impacting the scope of the OH&SMS been identified?			
		The scope of the OH&SMS is available as documented information?			
	4.4 OH&S management System	The necessary processes and their interactions were determined?			
		Does the organization maintain documented information that is sufficient for the process?			
	5.1 Leadership and commitment	Is the commitment and leadership of senior management in relation to the OH&SMS evident?			
		Is the health and safety policy and its objectives for the OH&SMS established?			

5. Leadership and worker participation					
		Is the integration of the OH&SMS requirements into the processes ensured?			
		Does it promote continuous improvement of the OH&SMS?			
		Does it communicate to the company the importance of contributing to effectiveness and of meeting the requirements of the OH&SMS, legal and regulatory requirements applicable?			
		What are the OH&SMS indicators and how are they monitored?			
		What are the initiatives and activities promoted by top management that demonstrate commitment to the continuous improvement of the OH&SMS?			
		Top Management promotes in the organization the culture of health and safety that supports the intended outcomes of the OH&MS?			
		How does top management ensure that workers do not suffer reprisals for reporting incidents, hazards, risks and opportunities?			
		How does Senior Management support the establishment and functioning of OH&S committees?			
	5.2 OH&S policy	Is there an established, implemented and understood OH&S policy that is appropriate to the organization's context?			
		Is the OH&S policy available to stakeholders?			
		Which document shows that the OH&S policy is maintained?			
	5.3 Organizational roles, responsibilities and authorities	How are responsibilities and authorities assigned, communicated and understood in the organization?			
	5.4 Consultation and participation of workers	How is consultation and participation of employees ensured?			
		What actions are used to identify risks and opportunities?			

6. Planning	6.1 Actions to address risks and opportunities	How is it ensured that the OH&SMS can achieve the intended results?			
		How are risks and opportunities controlled in order to achieve continuous improvement?			
	6.2 OH&S objectives and planning to achieve them	What is the system adopted to verify that the OH&S objectives are monitored, communicated and updated?			
		Are the OH&S objectives consistent with the OH&S policy? How are they measurable?			
		Are programs established to achieve OH&S objectives?			
		Does the organization maintain documented information on OH&S objectives?			
7. Support	7.1 Resources	How does the organization determine and provide the necessary resources for the establishment, implementation, maintenance and continuous improvement of the OH&SMS?			
	7.2 Competence	Is there an established competency matrix?			
		Is there a defined and established training program for your employees?			
		How is the effectiveness of training evaluated?			
		Does the organization maintain documented information as evidence of competence?			
	7.3 Awareness	Are employees aware of the OH&S policy, OH&S objectives, contribution to OH&S effectiveness and the implications of not complying with OH&S requirements?			
	7.4 Communication	How does the organization determine internal and external communications relevant to the OH&SMS?			
	7.5 Documented information	Does the documentation that ensures the implementation of the standard, determined by the organization as necessary, focus on the implementation of the OH&SMS?			

		Do the documents and records guarantee traceability and do they have a defined format and means of storage?			
		How is the control of OH&SMS documents performed?			
	8.1 Operational planning and control	How does the organization plan, implement and control its processes?			
		Is influence/control exercised over outsourced processes?			
		Are change management performed to mitigate any adverse effects?			
8. Operation	8.2 Emergency preparedness and response	The organization does not establish, implement and maintain the processes necessary to prepare for and respond to potential emergency situations, including the provision of first aid?			
		The organization does not provide training, conduct periodic tests and planned response capability exercises?			
		The organization does not assess performance, reviews the planned response, including after testing and, in particular, after the occurrence of emergency situations?			
		The organization communicates relevant information to workers, contractors, visitors, emergency response services, government authorities and, where appropriate, the local community?			
		The organization takes into account address the needs and capabilities of all relevant stakeholders and ensure their involvement, as appropriate, in the development of the planned response?			
9. Performance evaluation		Are there established indicators necessary to ensure validation of results?			

	9.1 Monitoring, measurement, Analysis and performance evaluation	What criteria are used to assess the performance and effectiveness of the OH&SMS?			
		How does the organization monitor customer perceptions if their needs and expectations have been met?			
		Is there a calibration program for critical instruments?			
	9.2 Internal audit	Is there a defined schedule for carrying out internal audits?			
		Are the results of this audit disclosed to relevant management?			
		Do internal audits have previously defined criteria and scopes?			
		Are internal auditors selected to ensure the impartiality of the process?			
		Does the organization perform appropriate correction and corrective actions without undue delay?			
		Does the organization retain documented information as evidence of the performance of the audit and its results?			
	9.3 Management review	Are periodic reviews carried out by top management?			
		Have all the items provided for in the standard been addressed?			
		Does the organization retain documented information as evidence of results?			
10. Improvement	10.2 Incident, nonconformity and corrective action	Are criteria defined for opening a non-compliance report?			
		Are identified non-conformities adequately addressed?			
		Are effectiveness checks made consistent with the non-compliance addressed?			
		Does the organization retain documented information as evidence?			

	10.3 Continual improvement	How does the organization continually improve the adequacy, sufficiency and effectiveness of the OH&SMS?			
NA	Complementary questions	Are OH&S changes carried out in a planned manner?			
		Does the organization consider the purpose of the change, its potential consequences, the integrity of the OH&SMS, the availability of resources, and the allocation or relocation of responsibilities and authorities?			
	∑ Total, Level of compliance				

***Note**: DCRDS - Degree of Compliance with the Requirements-**Desirable Situation**; DCRCS - Degree of Compliance with Requirements- **Current Situation**;

II. Nonconformities and potential hazards evaluation criteria

Severity

Index	Descriptor	Definition
1	Negligible	Minor abrasions, bruises, cuts, first aid type injury, constitui uma oportunidade de melhoria
2	Minor	Disabling but not permanent disability, constitutes an observation
3	Moderate	Non-fatal injury, permanent disability, constitutes a minor non-conformity
4	Major	Approximately one single fatality major property damage if hazard is realized
5	Catastrophic	Fatal, stoppage of processes or serious damage not fully reversible, with high costs for treatment, constitutes a major non-conformity

Probability

Index	Descriptor	Definition
1	Almost impossible	Is practically impossible and has never occurred
2	Rare	Has not been known to occur after many after
3	Likely	Might be occur at sometimes in future
4	Highly probable	Has a good chance of occurring and it is not unusual
5	Certen	The most likely result of the hazard/ event being realized

Criteria for prioritizing actions

Risk	
13-25	Critical risk, immediate action required
5-12	Moderate risk, measures should be implemented to reduce the risk
1-4	Very low risk, risk reduction not usually carried out

III. FMECA Scales Definition for the calculation of criticality

Criticality = Severity X Frequency X Control

Severity

Criterion	Associated Value
Death of man/considerable material damage	10
Serious injury/very significant material damage	8
Slightly injured/significant material damage	6
Minor material damage Lost time less than 2h	4
Minor material damage Without time lost	2

Adapted from Queiroz, P. R. (1999)

Control

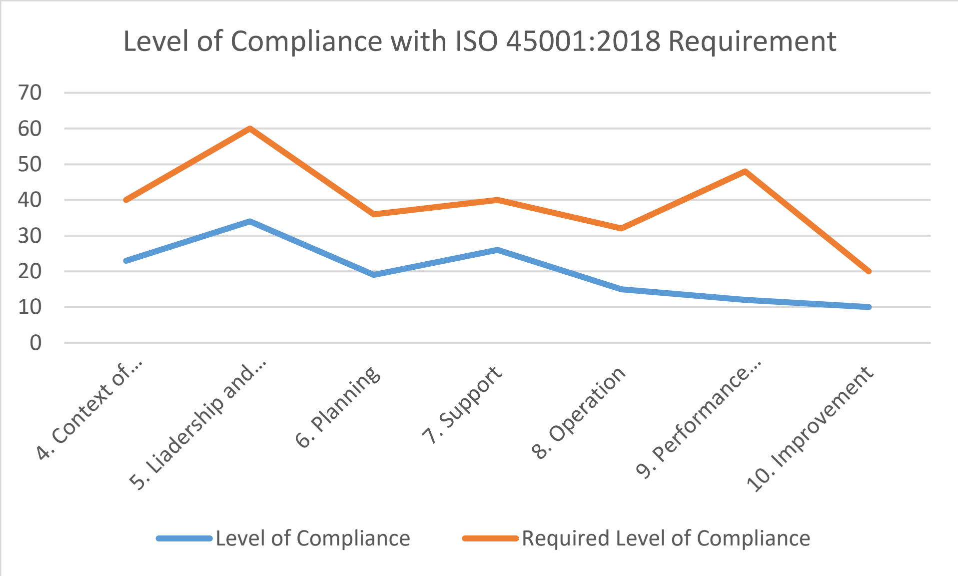
Criterion	Associated Value
No action is possible	10
No known control	8
Check not guaranteed	6
Average control (control detects the fault, but there may be occasional cases of non-detection)	4
Good control (control certainly detects the failure)	2

Adapted from Queiroz, P. R. (1999)

Criterion	Associated Value
Occurrence or failure once in Less than a week	10
Occurrence or failure once in Less than one month	8
Occurrence or failure once in Less than one year	6
Occurrence or failure once in Less than five years	4
Occurrence or failure once in More than five years	2

Source :Adapted from Queiroz, P. R. (1999)

IV. Level of Compliance with ISO 45001:2018 requirements based on Gap Analysis questionnaire



Requirements	Level of Compliance	Required Level of Compliance	Current Level of compliance (%)
4. Context of Organization	23	40	8%
5. Leadership and Workers Participation	34	60	12%
6. Planning	19	36	7%
7. Support	26	40	9%
8. Operation	15	32	5%
9. Performance Evaluation	12	48	4%
10. Improvement	10	20	4%
Total	**139**	**276**	**50%**

V. FTA Probabilistic Calculation
V-A: Probabilistic Calculation Of FTA Relating to Non-operational OH&SMS

Table 18: Criteria for calculating the probability of Non-operational OH&SMS

Ref.	Root cause	Root cause factor	Probability law	Test Question
E012	Low commitment from Top management	Human error	Beta 1	The probability of the commitment of top management be less than 5% when the average is 15%
E0111	Poor gap assessment	Human error	Beta 1	The probability of poor gap assessment be less than 5%
E0112	Lack of qualification of the consultant or the system manager	Human factor	Beta 1	The probability of the consultant have less than 3 years of experience
E0211	Poor communication	Human error	Beta 1	The probability of poor communication be less than 2% if the average is 4%
E0212	Lack of written procedures	Human error	Beta 1	The probability of lack of written procedures be less than 5%
E0213	Inadequate procedures	Human error	Beta 1	The probability of inadequate procedure be less than 5%
E022	Lack of liquidity	Economic Factors	Lognormal	The probability of implementation and maintenance be less than 900 000 MZN when the average is 2 000 000 MZN
E0231	Lack of maintenance	Mechanical stress	Gamma	The probability of the last maintenance be more than 3 months ago
E0232	Ineffective supervision	Human error	Beta 1	The probability of Ineffective supervision be less than 2% when the average is 10%
E031	Lack of training and awareness	Human error	Beta 1	The probability of doing more than 2 trainings and awareness when the average number is 5
E032	Failure to engage in the system planning and implementation process	Human error	Beta 1	The probability to engage the workers in the planning and implementation process more than 10% when the average is 2%
E033	Cognitive and learning deficiencies (memory, history, data and statistics, lessons learned)	Human error	Beta 1	The probability of Cognitive and learning deficiencies be less than 5% if the average is 10%
E0411	Non-treatment of non-conformities	Human error	Beta 1	The average probability of treat all non-conformity is 5%
E0412	Inadequate handling of non-conformities	Human error	Beta 1	What is the probability of inadequate handling of non-conformities be more than 5%
E042	Audit process failure	Human error	Beta 1	What is the probability of the audit process failure more than 5%

(Source: By Author)

For the purposes of analysing the probabilities of Non-operational OH&SMS, a sample whose identity card is shown on the side will be used. As can be seen the defined epsilon is between 0.001 and 0.003.

According to the data in **Table 19Error! Reference source not found.** below, the risk of the top event happens is to low, as can be seen just about 11%, in 103 occurrence that happen the risk is between 0.046230224 and 0.046743881 level.

Identity card

min	0.039078113
max	0.055310109
eps min	0.001
eps max	0.003
min*	0.039039035
max*	0.055476039
nb classes	32
pas	0.000513656
ideal freq	0.03125
medium	0.04722697
standard deviation	0.00242381
vx	0.05132259
vx*	0.296022163
my	0.498140369
p	5.228946967
q	5.267987811

Table 19: Statistical analysis of the probability of occurrence of the top event (Non-operational OH&SMS)

k	BINF	BSUP	x middle	(nk)	(fk)	[redacted]	Cumulative freq. (Fk)	u	y	fX(x)	FX(Binf)	FX(Bsup)	pk	ek
1	0.039039035	0.039552691	0.039295863	2	0.002	[redacted]	0.002	-7.57395601	-6.21360726	6.1286E-07	0	2.09876E-06	2.09876E-06	1.901893745
2	0.039552691	0.040066347	0.039809519	1	0.001	[redacted]	0.003	-6.88080883	-5.80764111	5.56268E-05	2.09876E-06	7.00812E-05	6.79824E-05	0.01277767
3	0.040066347	0.040580004	0.040323176	1	0.001	[redacted]	0.004	-6.47534372	-5.51945758	0.000418485	7.00812E-05	0.000518414	0.000448332	0.00067882
4	0.040580004	0.04109366	0.040836832	1	0.001	[redacted]	0.005	-6.18766165	-5.29581214	0.001498735	0.000518414	0.002065179	0.001546765	0.000193276
5	0.04109366	0.041607317	0.041350488	4	0.004	[redacted]	0.009	-5.96451809	-4.70601373	0.003724648	0.002065179	0.005851978	0.003786799	1.20034E-05
6	0.041607317	0.042120973	0.041864145	8	0.008	[redacted]	0.017	-5.78219654	-4.06598111	0.007429855	0.005851978	0.013350944	0.007498966	3.34759E-05
7	0.042120973	0.042634629	0.042377801	6	0.006	[redacted]	0.023	-5.62804586	-3.76064931	0.012778903	0.013350944	0.026197285	0.01284634	0.003648695
8	0.042634629	0.043148286	0.042891458	11	0.011	[redacted]	0.034	-5.49451446	-3.36414889	0.019731557	0.026197285	0.045985918	0.019788633	0.003903255
9	0.043148286	0.043661942	0.043405114	32	0.032	[redacted]	0.066	-5.37673143	-2.68415536	0.028041035	0.045985918	0.074066064	0.028080146	0.000547193
10	0.043661942	0.044175599	0.04391877	31	0.031	[redacted]	0.097	-5.27137091	-2.28246168	0.037279454	0.074066064	0.111360969	0.037294905	0.0010625
11	0.044175599	0.044689255	0.044432427	36	0.036	[redacted]	0.133	-5.17606073	-1.94689652	0.046883094	0.111360969	0.158232579	0.04687161	0.00252161
12	0.044689255	0.045202911	0.044946083	55	0.055	[redacted]	0.188	-5.08904936	-1.56899228	0.056210076	0.158232579	0.214403615	0.056171036	2.44134E-05
13	0.045202911	0.045716568	0.04545974	59	0.059	[redacted]	0.247	-5.00900665	-1.25987301	0.064603498	0.214403615	0.278942504	0.064538889	0.000475361
14	0.045716568	0.046230224	0.045973396	77	0.077	[redacted]	0.324	-4.93489868	-0.93761089	0.071453716	0.278942504	0.350310377	0.071367873	0.00044447
15	0.046230224	0.046743881	0.046487052	103	0.103	[redacted]	0.427	-4.86590581	-0.58542425	0.076254363	0.350310377	0.426463898	0.076153521	0.009464217
16	0.046743881	0.047257537	0.047000709	93	0.093	[redacted]	0.52	-4.80136728	-0.30928825	0.0786477	0.426463898	0.505003304	0.078539406	0.00266247
17	0.047257537	0.047771193	0.047514365	103	0.103	[redacted]	0.623	-4.74074266	-0.02479477	0.078455967	0.505003304	0.583351708	0.078348404	0.007756395
18	0.047771193	0.04828485	0.048028022	84	0.084	[redacted]	0.707	-4.68358425	0.205046927	0.075696575	0.583351708	0.658949553	0.075597845	0.000933839
19	0.04828485	0.048798506	0.048541678	69	0.069	[redacted]	0.776	-4.62951703	0.40286789	0.070580146	0.658949553	0.72944711	0.070497557	3.18121E-05
20	0.048798506	0.049312163	0.049055334	53	0.053	[redacted]	0.829	-4.57822373	0.568769039	0.063491603	0.72944711	0.792878129	0.06343102	0.001715346
21	0.049312163	0.049825819	0.049568991	35	0.035	[redacted]	0.864	-4.52943357	0.690694372	0.054955699	0.792878129	0.847799126	0.054920997	0.007225763
22	0.049825819	0.050339475	0.050082647	34	0.034	[redacted]	0.898	-4.48291355	0.825395079	0.0455895	0.847799126	0.893381294	0.045582168	0.002942962
23	0.050339475	0.050853132	0.050596304	28	0.028	[redacted]	0.926	-4.43846179	0.956929741	0.036045442	0.893381294	0.92944567	0.036064377	0.00180328
24	0.050853132	0.051366788	0.05110996	22	0.022	[redacted]	0.948	-4.39590218	1.084010046	0.026949561	0.92944567	0.956436768	0.026991098	0.000922936
25	0.051366788	0.051880445	0.051623616	14	0.014	[redacted]	0.962	-4.35508018	1.184841702	0.018840407	0.956436768	0.97533537	0.018898602	0.00126974
26	0.051880445	0.052394101	0.052137273	11	0.011	[redacted]	0.973	-4.31585947	1.284239048	0.012114846	0.97533537	0.987517415	0.012182045	0.000114696
27	0.052394101	0.052907757	0.052650929	4	0.004	[redacted]	0.977	-4.27811914	1.327674573	0.006987471	0.987517415	0.994572576	0.007055161	0.001323004
28	0.052907757	0.053421414	0.053164585	10	0.01	[redacted]	0.987	-4.2417515	1.468520665	0.003470519	0.994572576	0.998103041	0.003530465	0.011855346
29	0.053421414	0.05393507	0.053678242	4	0.004	[redacted]	0.991	-4.20666018	1.549800577	0.001380916	0.998103041	0.99952957	0.001426529	0.004642565
30	0.05393507	0.054448726	0.054191898	3	0.003	[redacted]	0.994	-4.17275862	1.632372065	0.000380043	0.99952957	0.999937462	0.000407892	0.016472556
31	0.054448726	0.054962383	0.054705555	2	0.002	[redacted]	0.996	-4.1399688	1.708642484	4.9455E-05	0.999937462	0.999998179	6.07171E-05	0.061940059
32	0.054962383	0.055476039	0.055219211	4	0.004	[redacted]	1	[redacted]	[redacted]	5.21331E-07	0.999998179	1	1.82121E-06	8.77739247
						[redacted]								
				1000	1	[redacted]							eg	159.3997265
						[redacted]							Limit	36.74121675
						[redacted]							Acceptable ?	NO

V-B: Probabilistic Calculation of FTA Relating to Inability to Put out Fire

Table 20: Criteria for calculating the probability of Inability to put out fire

Ref.	Root cause	Root cause factor	Probability law	Test Question
E111	Damaged fire detection sensor	Mechanical stress	Beta 1	What is the probability of the Sensor be damaged be less than 5%
E112	Lack of maintenance	Human error	Beta 1	What is the probability of lack of maintenance be less than 5% if the average is 10%
E113	Smoke detector without battery	Mechanical stress	Gamma	The probability of the smoke detector be without battery be 10 days if the average is more than 30 days
E1211	Damaged opening mechanism	Mechanical stress	Gamma	The probability of the open mechanism be damaged in 20 years when the expected time is 5 years
E1212	Lack of maintenance	Human error	Beta 1	The probability of the last maintenance be more than 2 months ago if the average is 1
E1221	Lack of maintenance	Human error	Beta 1	The probability of the last maintenance be more than 6 months ago
E1222	End of life time	Life time	WEIBULL	The probability of the pipe End of life time be more than 50 years
E1231	Reservoirs connected to other water supply systems	Human error	Beta 1	The probability of the Reservoirs be connected to other water supply systems is 95%
E1232	Inadequate sizing of reservoir capacity	Human error	Beta 1	The probability of Inadequate sizing of reservoir capacity is Less than 5%
E131	Damaged fire extinguisher	Mechanical stress	Gamma	The probability of the fire extinguisher be damaged in less than 5 years of use
E132	Fire extinguisher out of date	Human error	Beta 1	The probability of the fire extinguisher be out of date is 10%
E133	Lack of maintenance	Human error	Beta 1	The probability of the last maintenance be more than 12 months ago

(Source: By Author)

For the purposes of analysing the probabilities of Inability to put out fire, a sample whose identity card is shown on the side will be used. As can be seen the defined epsilon is between 0.001 and 0.002.

According to the data in **Table 21** below, the risk of the top event happens is to low, as can be seen just about 14%, in 136 occurrence that happen the risk is between 0.055002502 and 0.052805472 level.

Identity Card

min	0.03919417
max	0.064720587
eps min	0.001
eps max	0.002
min*	0.039154976
max*	0.064850028
nb classes	32
pas	0.00080297
ideal freq	0.03125
medium	0.051873354
standard deviation	0.003237864
vx	0.062418632
vx*	0.254581511
my	0.494973809
p	7.297227813
q	7.445426596

Table 21: Statistical analysis of the probability of occurrence of the top event (Inability to put out fire)

k	BINF	BSUP	x middle	(nk)	(fk)	[redacted]	Cumulative freq. (Fk)	u	y	fX(x)	FX(Binf)	FX(Bsup)	pk	ek
1	0.039154976	0.039957947	0.039556461	1	0.001	[redacted]	0.001	-7.12719275	-6.90725507	2.46198E-09	0	2.45439E-08	2.45439E-08	40.74126293
2	0.039957947	0.040760917	0.040359432	2	0.002	[redacted]	0.003	-6.43404557	-5.80764111	2.02079E-06	2.45439E-08	3.21128E-06	3.18673E-06	1.251207485
3	0.040760917	0.041563887	0.041162402	1	0.001	[redacted]	0.004	-6.02858046	-5.51945758	4.06665E-05	3.21128E-06	5.12369E-05	4.80256E-05	0.018870255
4	0.041563887	0.042366858	0.041965373	2	0.002	[redacted]	0.006	-5.74089839	-5.11298828	0.000270959	5.12369E-05	0.00034435	0.000293113	0.009939724
5	0.042366858	0.043169828	0.042768343	4	0.004	[redacted]	0.01	-5.51775484	-4.60014923	0.001047681	0.00034435	0.001437383	0.001093033	0.007731195
6	0.043169828	0.043972798	0.043571313	5	0.005	[redacted]	0.015	-5.33543328	-4.19215778	0.002919759	0.001437383	0.004429578	0.002992194	0.001347267
7	0.043972798	0.044775769	0.044374284	8	0.008	[redacted]	0.023	-5.1812826	-3.76064931	0.006524388	0.004429578	0.011049991	0.006620413	0.000287484
8	0.044775769	0.045578739	0.045177254	9	0.009	[redacted]	0.032	-5.04775121	-3.42580185	0.012414118	0.011049991	0.023572368	0.012522377	0.000990797
9	0.045578739	0.04638171	0.045980224	17	0.017	[redacted]	0.049	-4.92996817	-2.99091954	0.020872174	0.023572368	0.044547661	0.020975293	0.000753408
10	0.04638171	0.04718468	0.046783195	25	0.025	[redacted]	0.074	-4.82460766	-2.56549593	0.031770874	0.044547661	0.076396634	0.031848973	0.00147284
11	0.04718468	0.04798765	0.047586165	26	0.026	[redacted]	0.1	-4.72929748	-2.25036733	0.044512671	0.076396634	0.120944213	0.044547579	0.007722366
12	0.04798765	0.048790621	0.048389135	39	0.039	[redacted]	0.139	-4.6422861	-1.89938405	0.058070675	0.120944213	0.178994068	0.058049855	0.006251471
13	0.048790621	0.049593591	0.049192106	57	0.057	[redacted]	0.196	-4.56224339	-1.52254483	0.0711219	0.178994068	0.250035316	0.071041247	0.002775242
14	0.049593591	0.050396561	0.049995076	82	0.082	[redacted]	0.278	-4.48813542	-1.12168603	0.082246858	0.250035316	0.332147173	0.082111858	1.52379E-07
15	0.050396561	0.051199532	0.050798047	96	0.096	[redacted]	0.374	-4.41914255	-0.75842217	0.090156511	0.332147173	0.422128732	0.089981558	0.000402545
16	0.051199532	0.052002502	0.051601017	136	0.136	[redacted]	0.51	-4.35460403	-0.33778325	0.093903328	0.422128732	0.515838137	0.093709405	0.019085538
17	0.052002502	0.052805472	0.052403987	139	0.139	[redacted]	0.649	-4.29397941	0.045899376	0.09303729	0.515838137	0.608686584	0.092848447	0.022940242
18	0.052805472	0.053608443	0.053206958	105	0.105	[redacted]	0.754	-4.23682099	0.338201985	0.087678618	0.608686584	0.696204509	0.087517925	0.003492118
19	0.053608443	0.054411413	0.054009928	75	0.075	[redacted]	0.829	-4.18275377	0.568769039	0.078494657	0.696204509	0.774584883	0.078380374	0.000145788
20	0.054411413	0.055214384	0.054812898	61	0.061	[redacted]	0.89	-4.13146048	0.791758684	0.066585937	0.774584883	0.841113466	0.066528583	0.00045943
21	0.055214384	0.056017354	0.055615869	38	0.038	[redacted]	0.928	-4.08267031	0.96739789	0.053302881	0.841113466	0.894417213	0.053303748	0.004393775
22	0.056017354	0.056820324	0.056418839	19	0.019	[redacted]	0.947	-4.0361503	1.077546408	0.040027356	0.894417213	0.934495963	0.04007875	0.011086017
23	0.056820324	0.057623295	0.057221809	12	0.012	[redacted]	0.959	-3.99169854	1.16133141	0.027959848	0.934495963	0.962542968	0.028047005	0.009181243
24	0.057623295	0.058426265	0.05802478	13	0.013	[redacted]	0.972	-3.94913892	1.274119225	0.017952124	0.962542968	0.980599427	0.018056459	0.001415991
25	0.058426265	0.059229235	0.05882775	8	0.008	[redacted]	0.98	-3.90831693	1.364054633	0.010416604	0.980599427	0.991119039	0.010519612	0.000603486
26	0.059229235	0.060032206	0.059630721	3	0.003	[redacted]	0.983	-3.86909621	1.404758332	0.00532801	0.991119039	0.996534029	0.00541499	0.001077043
27	0.060032206	0.060835176	0.060433691	3	0.003	[redacted]	0.986	-3.83135589	1.451308851	0.002312835	0.996534029	0.998909571	0.002375542	0.000164151
28	0.060835176	0.061638146	0.061236661	4	0.004	[redacted]	0.99	-3.79498824	1.527179626	0.000801174	0.998909571	0.999748247	0.000838676	0.01191637
29	0.061638146	0.062441117	0.062039632	3	0.003	[redacted]	0.993	-3.75989692	1.601777674	0.000198577	0.999748247	0.999964242	0.000215995	0.035883597
30	0.062441117	0.063244087	0.062842602	2	0.002	[redacted]	0.995	-3.72599537	1.667389292	2.82088E-05	0.999964242	0.999997898	3.36555E-05	0.114885014
31	0.063244087	0.064047058	0.063645572	2	0.002	[redacted]	0.997	-3.69320555	1.759433054	1.29314E-06	0.999997898	0.999999986	2.08799E-06	1.911720953
32	0.064047058	0.064850028	0.064448543	3	0.003	[redacted]	1	[redacted]	[redacted]	1.33237E-09	0.999999986	1	1.44461E-08	622.9978277
						[redacted]								
				1000	1	[redacted]							eg	3458.202989
													Limit	36.74121675
													Acceptable ?	NO

(Source: By Author)

V-C: Probabilistic Calculation Of FTA Relating To Non Reduction Of Occupational Risks

Table 22: Criteria for calculating the probability of Non reduction of occupational Risks

Ref.	Root cause	Root cause factor	Probability law	Question
E 2111	Lack of financial resources	Economic Factors	Lognormal	The probability of implementation of a training program be less than 100 000 MZN when the average is 200 000 MZN
E 2112	Lack of a human resources training and development policy	Human error	Beta 1	What is the probability of lack of a human resources training and development policy be less than 5% if the average is 25%
E2121	Lack of protective Equipment	Human error	Beta 1	The probability of the lack of protective Equipment be in less than 1 working day during a month
E2122	Lack of Hazard Identification Procedures	Human error	Beta 1	The probability of lack of Hazard Identification Procedures be more than 10% if the average is less than 5%
E2123	Failure to implement risk control measures	Human error	Beta 1	What is the probability to Failure to implement risk control measures be less than 5%
E2131	Lack of an OH&S Management System	Human error	Beta 1	What is the probability of lack of an OH&S Management System be less than 95%
E2132	Lack of written OH&S Management criteria	Human error	Beta 1	What is the probability of lack of written OH&S Management criteria be less than 5%
E2211	Lack of OH&S Policies	Human error	Beta 1	The probability of lack of OH&S Policies be less than 5% if the average is 10%
E2212	Non-assignment of responsibilities	Human error	Beta 1	The probability of non-assignment of responsibilities be less than 5%
E222	High costs of implementing OH&S procedures	Economic Factors	Lognormal	The probability of the implementation of OH&S procedures be less than 50 000 MZN when the average is 200 000 MZN
E231	Lack of communication	Human error	Beta 1	What is the probability of lack of communication be less than 5%
E232	Absence of internal communication management procedures	Human error	Beta 1	What is the probability of absence of internal communication management procedures be less than 5% if the average is 25%
E233	Non-implementation of the internal communication management procedures	Human error	Beta 1	What is the probability of non-implementation of the internal communication management procedures be less than 10%

(Source: By Author)

For the purposes of analysing the probabilities of Non reduction of occupational Risks, a sample whose identity card is shown on the side will be used. As can be seen the defined epsilon is between 0.00015 and 0.00003.

According to the data in **Table 23** below, the risk of the top event happens is low, as can be seen just about 65%, in 653 occurrences that happen the risk is between 0.985922129 and 1.00003 level.

Identity Card

min	0.986070039
max	1
eps min	0.00015
eps max	0.00003
min*	0.985922129
max*	1.00003
nb classes	32
pas	0.000440871
ideal freq	0.03125
medium	0.998194697
standard deviation	0.003413275
vx	0.003419448
vx*	0.27812231
my	0.869909261
p	0.811892201
q	0.121414567

Table 23: Statistical analysis of the probability of occurrence of the top event (Non reduction of Occupational Risks)

k	BINF	BSUP	x middle	(nk)	(fk)	[redacted]	Cumulative freq. (Fk)	u	y	fX(x)	FX(Binf)	FX(Bsup)	pk	ek
1	0.985922129	0.986363	0.986142564	5	0.005	[redacted]	0.005	-7.72675829	-5.29581214	0.008083178	0	0.008726923	0.008726923	0.001591621
2	0.986363	0.986803871	0.986583435	6	0.006	[redacted]	0.011	-7.03361111	-4.50433463	0.006763033	0.008726923	0.015517504	0.006790581	9.2042E-05
3	0.986803871	0.987244742	0.987024306	8	0.008	[redacted]	0.019	-6.62814601	-3.95374022	0.006326013	0.015517504	0.021852384	0.00633488	0.000437676
4	0.987244742	0.987685613	0.987465177	5	0.005	[redacted]	0.024	-6.34046393	-3.71757969	0.006120698	0.021852384	0.027977438	0.006125054	0.000206651
5	0.987685613	0.988126484	0.987906048	7	0.007	[redacted]	0.031	-6.11732038	-3.45806406	0.006024192	0.027977438	0.034004288	0.00602685	0.000157134
6	0.988126484	0.988567355	0.988346919	4	0.004	[redacted]	0.035	-5.93499883	-3.33464652	0.005992924	0.034004288	0.039999082	0.005994794	0.000663777
7	0.988567355	0.989008226	0.98878779	10	0.01	[redacted]	0.045	-5.78084815	-3.07815915	0.006007155	0.039999082	0.046007699	0.006008617	0.002651381
8	0.989008226	0.989449097	0.989228661	10	0.01	[redacted]	0.055	-5.64731675	-2.87227026	0.006056796	0.046007699	0.05206574	0.00605804	0.002565029
9	0.989449097	0.989889968	0.989669532	9	0.009	[redacted]	0.064	-5.52953372	-2.71598456	0.006136471	0.05206574	0.058203343	0.006137604	0.001334936
10	0.989889968	0.990330839	0.990110403	6	0.006	[redacted]	0.07	-5.4241732	-2.62319412	0.006243449	0.058203343	0.064447884	0.00624454	9.57634E-06
11	0.990330839	0.990771709	0.990551274	2	0.002	[redacted]	0.072	-5.32886302	-2.59396003	0.006376688	0.064447884	0.070825671	0.006377787	0.003004964
12	0.990771709	0.99121258	0.990992145	3	0.003	[redacted]	0.075	-5.24185164	-2.55153963	0.006536368	0.070825671	0.077363188	0.006537517	0.001914186
13	0.99121258	0.991653451	0.991433016	8	0.008	[redacted]	0.083	-5.16180894	-2.44590358	0.006723679	0.077363188	0.084088104	0.006724916	0.000241763
14	0.991653451	0.992094322	0.991873887	10	0.01	[redacted]	0.093	-5.08770096	-2.32674635	0.006940754	0.084088104	0.091030225	0.006942122	0.00134694
15	0.992094322	0.992535193	0.992314758	6	0.006	[redacted]	0.099	-5.01870809	-2.26096321	0.00719072	0.091030225	0.098222489	0.007192264	0.000197642
16	0.992535193	0.992976064	0.992755629	11	0.011	[redacted]	0.11	-4.95416957	-2.14957378	0.00747783	0.098222489	0.105702096	0.007479606	0.001656928
17	0.992976064	0.993416935	0.9931965	7	0.007	[redacted]	0.117	-4.89354495	-2.08401134	0.007807708	0.105702096	0.113511887	0.007809791	8.39666E-05
18	0.993416935	0.993857806	0.993637371	7	0.007	[redacted]	0.124	-4.83638654	-2.0220093	0.008187734	0.113511887	0.121702105	0.008190218	0.000172965
19	0.993857806	0.994298677	0.994078242	11	0.011	[redacted]	0.135	-4.78231932	-1.93084381	0.008627604	0.121702105	0.130332726	0.008630621	0.000650469
20	0.994298677	0.994739548	0.994519113	8	0.008	[redacted]	0.143	-4.73102602	-1.86874402	0.009140189	0.130332726	0.139476649	0.009143922	0.000143107
21	0.994739548	0.995180419	0.994959984	7	0.007	[redacted]	0.15	-4.68223586	-1.81696079	0.009742829	0.139476649	0.149224196	0.009747547	0.000774453
22	0.995180419	0.99562129	0.995400855	17	0.017	[redacted]	0.167	-4.63571584	-1.69979139	0.010459376	0.149224196	0.159689677	0.010465481	0.004080075
23	0.99562129	0.996062161	0.995841726	10	0.01	[redacted]	0.177	-4.59126408	-1.63578662	0.011323485	0.159689677	0.171021281	0.011331604	0.00015648
24	0.996062161	0.996503032	0.996282597	10	0.01	[redacted]	0.187	-4.54870446	-1.57491973	0.012384184	0.171021281	0.18341663	0.012395349	0.000462891
25	0.996503032	0.996943903	0.996723468	12	0.012	[redacted]	0.199	-4.50788247	-1.50555399	0.01371579	0.18341663	0.197148413	0.013731784	0.000218404
26	0.996943903	0.997384774	0.997164339	18	0.018	[redacted]	0.217	-4.46866176	-1.40803873	0.015436715	0.197148413	0.212609273	0.01546086	0.000417004
27	0.997384774	0.997825645	0.99760521	11	0.011	[redacted]	0.228	-4.43092143	-1.35181283	0.017748202	0.212609273	0.230396563	0.01778729	0.0025899
28	0.997825645	0.998266516	0.998046081	18	0.018	[redacted]	0.246	-4.39455378	-1.26456212	0.021023121	0.230396563	0.251489482	0.021092918	0.000453524
29	0.998266516	0.998707387	0.998486952	29	0.029	[redacted]	0.275	-4.35946246	-1.13449766	0.026041858	0.251489482	0.277675892	0.02618641	0.000302305
30	0.998707387	0.999148258	0.998927823	28	0.028	[redacted]	0.303	-4.32556091	-1.01896079	0.034772876	0.277675892	0.312833911	0.035158019	0.001457341
31	0.999148258	0.999589129	0.999368694	44	0.044	[redacted]	0.347	-4.29277109	-0.85289783	0.054129037	0.312833911	0.368711729	0.055877818	0.00252484
32	0.999589129	1.00003	0.999809565	653	0.653	[redacted]	1	[redacted]	[redacted]	0.141249384	0.368711729	1	0.631288271	0.000746726
						[redacted]								
				1000	1	[redacted]							eg	30.96835042
						[redacted]							Limit	36.74121675
						[redacted]							Acceptable ?	OK

(Source: By Author)