UNIVERSIDADE EDUARDO MONDLANE

FACULTY OF ENGINEERING

MASTER’S IN HEALTH, SAFETY AND ENVIRONMENT ENGINEERING

MASTER'S THESIS

OCCUPATIONAL HEALTH AND SAFETY RISK ASSESSMENT IN INDUSTRIAL KITCHENS: THE CASE STUDY OF CATERING INTERNATIONAL & SERVICES – NACALA

BY

Mauricio Ernesto Guiliche

Maputo

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Mauricio Ernesto Guiliche

Supervised by:

Prof. Doutor João Chidamoio, Engº

Maputo, 2022

RECOMMENDATION OF THE BOARD OF EXAMINERS

The undersigned certify that they have read and recommend to the Faculty of Engineering a thesis entitled "**OCCUPATIONAL HEALTH AND SAFETY RISK ASSESSMENT IN INDUSTRIAL KITCHENS: THE CASE STUDY OF CATERING INTERNATIONAL & SERVICES – NACALA** " submitted by **MAURICIO ERNESTO GUILICHE**, in partial fulfillment of the requirements for the degree of Master Program in **HEALTH, SAFETY AND ENVIRONMENT ENGINEERING.**

Prof. Doutor João Chidamoio, Engº

Supervisor

Doutor Marcelino Januário Rodrigues, Arq.^{to}

Course Coodinator

DECLARATION

I hereby certify that this material, which I now submit in part fulfilment of the requirements for the award of Master’s in Health, Safety and Environment Engineering is entirely my own work and has not been taken from the work of others save to the extent suck work has been cited and acknowledged within the text of my work.

(Maurício Ernesto Guiliche)

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ABSTRACT

The present study focuses on occupational health and safety in the catering industry and the study makes an assessment of potential risks to health and safety in industrial kitchens through a case study of the kitchen of the company Catering International & Services (CIS) located in the Port of Nacala. The aim of this study is to Contribute in reducing health and safety risks at work in industrial kitchens. The study is very relevant to the sector of services as is mainly focus on health and safety hazards in the kitchen and all results and conclusions can help to improve the health and safety management practices not only at CIS Nacala but also in an organization with similar operation and kitchen system design include hotels, take way, restaurant and even for domestic kitchen. The methodology for the present study consisted of the bibliographic review, data collection at CIS Nacala, function Analysis, preliminary hazard Analysis, failure mode and effect analysis (FMEA), fault tree and event tree analysis and ending with the compilation of the final report. There are many things that can go wrong at CIS Nacala kitchen system, among of then we can highlight those hazards related to the use of electricity by being responsive of two critical risk, namely electrical shock and fire. The electric oven, when analysed as an ignition source, demonstrates the existence of failure modes of some components that can contribute to the start of a fire in the kitchen. The thermal fuse component has one failure mode (The fuse fails to open when expected) and it assumes that it is caused by defective thermal fuse, the failure mode can make the Oven Overheat with possible fire risk. No current failure mode can be caused by defective cord, defective plug or defective heating coil and can lead to potential fire due to heat accumulation. Through the fault trees analysis, it was possible to identify the different basic events that can be associated to result in a fire in the kitchen, considering the oven as the source of ignition. The quantitative analysis of the fault tree points to 1.8×10^{-2} of probability of occurrence in one year of a fire in the kitchen, with the critical path as combination of the occurrence of grease, oxygen, thermal fuse fails and power switch failure, the critical path contributes with 53.33% to the occurrence of the unwanted event. Actions such as regular oven cleaning to remove grease, avoiding placing combustible material near the oven, and preventive maintenance can reduce the likelihood of a fire in the kitchen.

Key words: CIS Nacala; Kitchen; Fault tree analysis; FMEA.

RESUMO

O presente estudo centra-se na saúde e segurança do trabalho na indústria da restauração e o estudo faz uma avaliação dos potenciais riscos para a saúde e segurança em cozinhas industriais através de um estudo de caso da cozinha da empresa Catering International & Services (CIS) localizada no Porto de Nacala. O objetivo deste estudo é contribuir na redução dos riscos de saúde e segurança no trabalho em cozinhas industriais. O estudo é muito relevante para o sector dos serviços pois foca-se principalmente nos riscos de saúde e segurança na cozinha e o mesmo pode ajudar a melhorar as práticas de gestão de saúde e segurança não só na CIS Nacala mas também em organizações com sistema de cozinha semelhante como hotéis, take way, restaurante e até mesmo para cozinha doméstica. A metodologia para o presente estudo consistiu na revisão bibliográfica, recolha de dados no CIS Nacala, análise de funções, análise preliminar de perigos, análise de modo de falha e efeito (FMEA), análise de árvore de falhas e árvore de eventos e finalizando com a compilação do relatório final. Existem vários perigos identificados na cozinha da CIS Nacala, entre elas podemos destacar os perigos relacionados ao uso de eletricidade por responder a dois riscos críticos, nomeadamente, choque elétrico e incêndio. O forno elétrico, quando analisado como fonte de ignição, demonstra a existência de modos de falha de alguns componentes que podem contribuir para o início de um incêndio na cozinha. O componente fusível térmico tem um modo de falha (o fusível não abre quando esperado) e assume-se que é causado por fusível térmico defeituoso, o modo de falha pode causar superaquecimento do forno com possível risco de incêndio. O modo de falha de ausência de corrente pode ser causado por cabo defeituoso, tomada defeituoso ou resistência defeituosa e pode levar a um possível incêndio devido ao acúmulo de calor. Através da análise das árvores de falhas, foi possível identificar os diferentes eventos básicos que podem estar associados para provocar um incêndio na cozinha, considerando o forno como fonte de ignição. A análise quantitativa da árvore de falhas aponta para $1{,}8 \times 10^{-2}$ de probabilidade de ocorrência em um ano de incêndio na cozinha, com o caminho crítico como combinação da ocorrência de gordura, oxigênio, falha de fusível térmico e falha do interruptor de alimentação. Ações como a limpeza regular do forno para retirar a gordura, evitar a colocação de material combustível próximo ao forno e a manutenção preventiva podem reduzir a probabilidade de incêndio na cozinha.

Palavras-Chave: CIS Nacala; Cozinha; Análise de árvore de falhas; FMEA.

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CHAPTER I: INTRODUCTION

1.1.Context

Occupational safety and health (OSH) is a cross-disciplinary area and it is concerned with guarding the safety, health and welfare of people who are engaged in work or employment. Health is associated to the physical conditions of both mind and body, of all people at the workplace including the workers, contractors and visitors, and their protection from harm in the form of injury or disease. Safety is related to the physical condition at the worksite and applies to a state where the risk of harm and damage has been removed or reduced to a tolerable level.

Worldwide there is increasing emphasis on the health and safety of workers in every sector of employment including the construction industry, agriculture, the manufacturing industry, office based employment as well as the service industry. The catering industry falls within the service sector. While the risk to health and safety of a worker on a construction site is apparently far greater than working in the catering industry, there are a vast amount of hazards and risks involved in working in a catering premises which can lead to injury and even fatality (Howard & Galbraith, 2004).

The cost associated with accidents because of unhealthy and unsafe measures in an organization extends beyond the affected worker to include the growth of the organization. Therefore, every stakeholder in an organization should collaborate to avoid such organisational hazards from occurring. In restaurants and most kitchens, workers are prone to different forms of risks. Therefore, failure to establish adequate health and safety procedures by employers to protect employees from these risks result to untimely deaths of staff. In fact, safety and health in the organization have to be everybody's concern. On the contrary, this is not the case in most tourism and hospitality establishment, especially, the traditional eating places. There is no burden on stakeholders in making health and safety issues effective (Adanse & Yamga, 2017).

The present study focuses on occupational health and safety in the catering industry and the study makes an assessment of potential risks to health and safety in industrial kitchens through a case study of the kitchen of the company Catering International & Services (CIS) located in the Port of Nacala.

1.2.Problem statement

Maguire’s study (as cited in Kivlehan, 2005) states with regard to kitchens in the food service sector, that as service time approached the importance of food quality ascended while health and safety issues were relegated, thus highlighting a potential contradiction between quality management and risk management.

Safety, health and welfare of all those working in this industry from chefs to kitchen porters to waiting staff needs to be considered carefully and given the same attention as that given to food safety issues. It has been estimated that 70% of accidents in the catering industry could be prevented by improved safety management practice (HSE, 1997b cited in Kivlehan, 2005). As way to improve the safety management practice in catering industry particularly in the Kitchen system, regular risk assessment is need to find answers to the flowing questions:

- What can go wrong in terms of safety and health in the kitchen?
- Which dangers or hazards are critical?
- What measures are need to prevent the occurrence of those hazards in kitchen system?
- What measures are need to mitigate the consequences of those hazards in case they take place in kitchen system?

CIS Nacala has provided services to the mining and construction sector and their core activities are in the Nacala port coal terminal where they manage a kitchen and restaurant with seating for six hundred people. The CIS’s Kitchen system is considered as industrial kitchen. thus, was selected in this study for qualitative and quantitative risks assessment to find possible answers to the above questions.

1.3.Motivation

The author's interest, in terms of awareness and compliance with safety, health and well-being at work in the Catering industry, stems from the completion of a professional internship at CIS Nacala behind the Master's Program in Health, Safety and Environment Engineering. When carrying out bibliographic research on health and safety management in the catering sector, it was found that many companies in the sector have given more importance to food safety compared to occupational safety and health, what makes the activity dangerous for workers due the lack of knowledge of the risks associated with their activities. At this context, the author considered it opportune to reconcile the knowledge of the qualitative and quantitative risk assessment technique acquired in the master's degree with skills acquired in the professional internship about the catering activities to make a contribution to the knowledge of occupational health and safety risks taking the kitchen of CIS Nacala as a case study.

There are several techniques for risk assessment, and a tool is selected according to the process, purpose of the assessment and the degree of detail required. Depending on the circumstances, the assessment can be qualitative, semi-quantitative or quantitative. Risk assessments seek to calculate (or classify) the risk related to the undesired event, triggered when exposed to hazardous conditions, without forgetting that the controls applied to minimize the risk of this undesired event must be taken into account (Barros, 2013). for the academic site, the study is relevant for researchers who want to know more about the integrated applicability of qualitative and quantitative risk assessment tools, specifically; preliminary hazard analysis, Failure mode and effect analysis, fault tree, event tree and reliability in a real cases scenario of Health and safety risk assessment, as many studies use these techniques in an isolated way.

Furthermore, the results of Occupational safety and health risk assessment in the kitchen will help to improve the health and safety management practices not only at CIS Nacala but also in an organization with similar operation and kitchen system design include hotels, take way, restaurant and even domestic kitchen.

1.4.Objectives

1.4.1. General

The aim of this study is to contribute in reducing health and safety risks at work in industrial kitchens.

1.4.2. Specifics

- To describe the subsystems and components of the kitchen system;
- To Identify hazards and possible consequences related to the kitchen system;
- To Make a qualitative and quantitative estimative of risks in the kitchen system;
- To Propose preventive and mitigation measures of the identified risks.

1.5.Governance of health and safety at CIS Mozambique

Catering International & Services (CIS) provides catering, accommodation management, facility management and support services to different clients in remote areas and politically sensitive countries. Worldwide, the Company serves engineering, mining, Oil & Gas companies (Onshore & Offshore) and Defence & International Organizations.

Its subsidiary CIS NACALA was created in 2013 with its registered office in Nacala (Mozambique). The company has provided services to the mining and construction sector, the core activities are in the Nacala port coal terminal where they manage a kitchen and restaurant with seating for six hundred people.

As a provider of integrated services, CIS has developed a full range of services and turnkey solutions designed to assure the well-being and safety of the residents in remote sites so that their customers can concentrate on their own core businesses.

Health and safety of people are a fundamental pillar of CIS in Mozambique. The goal for zero incidents permanently remains a top priority. Therefore, no service or activity should be undertaken to the detriment of the health and safety of anyone. CIS in Mozambique is committed to providing all its employees with safe and healthy working conditions. In return, CIS employees have the mission - and the duty - to:

- Participate in the improvement of safety at work and act proactively to prevent any accident or material damage;
- Continually identify, assess and manage risks to perform all services safely;
- Promote a culture of proactive intervention and promote any awareness-raising initiative or improvement of safety;
- Strictly apply emergency response procedures;
- Stop any task or activity that may create an unacceptable risk to the health and safety of any person.

In terms of quality, health, safety and environment (QHSE) governance, there are the following positions (table 1) established in CIS Mozambique:

Table 1:Positions established at CIS Mozambique for QHSE Governance. Source: provided by the company

POSITION	DESCRIPTION
1- QHSE Director	a single QHSE person with functional authority in the CIS group
2- Country QHSE Responsible	a single QHSE person with functional authority in an entire country
3- Site QHSE Responsible	a single QHSE person with hierarchical authority in a site
4- QHSE Supervisor	a QHSE technician with authority and hierarchy over a QHSE team
5- QHSE Technician	a person with tertiary studies in QHSE that provide technical knowledge to apply the method
6-QHSE commissionaire	A person whose mission is to ensure the application of the method
7- QHSE Assistant	a person who provides administrative and logistical support

QHSE representative number 1 is the person designated to ensure the implementation and compliance of the CIS management system in Mozambique. QHSE Representative number 2 is the person who backs up QHSE Representative number1 when needed.

Typically, QHSE representative number 1 is assigned to QHSE manager and number 2 to another person in the QHSE. If there is no QHSE responsible, number 1 must be the highest level in the organization and number 2 must be a designated person, who can assume the active duties of the role of number 1 (for example: number 1 being the person in charge of the parents/country Manager and number 2 being a QHSE coordinator)

- **Maturity of the QHSE system at CIS Mozambique**

A new tool begins to be used to measure the level of maturity of QHSE and Sustainable Development (SD) in each CIS Organization. QHSE -SD is the acronym for the management system that integrates the areas of Quality, Occupational Health and Safety, Environment, and Social Responsibility in use in the company. The result of this integration is the transformation of the work environment, making it more productive, safe and healthy. This tool – in the form of a simple form – has 4 maturity levels to know (table 2):

Table 2:Maturity level of the QHSE and SD system. Source: provided by the company

Level	DESCRIPTION
1	Basic organization without formal approach, but meeting minimum industry requirements
2	Reactive organization that goes beyond minimum industry requirements
3	Stable formal organization, certifiable if necessary
4	Efficient organization characterized by operational excellence, in addition to certification

The application of the CIS Principles of Excellence Management allows all those responsible for each CIS Organization to improve towards excellence, moving up the QHSE maturity ladder, level by level, with an increase in information, trust and accountability.

As part of this effort, The CIS Mozambique company is committed to a quality process which is ISO 9001 certified since May, 2020. CIS in Mozambique is committed to providing safe and quality catering services to their customers and residents. As well as acknowledging its responsibility for food safety, ensuring that the provision of all food and beverage is safe and fit for human consumption. Functioning on the principles of Hazard Analysis and Critical Control Point (HACCP) and ISO 22000 management system standard requirements, CIS in Mozambique operates a comprehensive risk based quality food safety management system.

CIS Mozambique has established occupational health, safety and environment (OHSE) system regulatory Performance Indicators consisting of total recordable injury rate and lost time injury rate. Data is required by regulatory bodies and needs to be submitted by the OHSE department. They are not obtained by the OHSE department, but by other departments such as Human Resources, Operations, Finance, etc. Its representatives must be responsible for providing these values to the QHSE Representative within the allotted time, and must also ensure their accuracy and reliability.

In this context, the maturity of the CIS Mozambique QHSE system can be classified at level 2 (Reactive organization that goes beyond the minimum requirements of the industry) with a tendency towards level 3 (Stable formal organization, certifiable if necessary).

Due to the fact that the organization is not licensed under ISO 45001, it can lead to believe of the existence of a deficiency in the organization characterized by Production dominates risk management (S.C.D 5) for more details about systemic deficits cindynogens (DSC) see Planchette

(2021). This is because ISO 9001 and ISO 22000 certifications are part of the production process for the catering sector. This kind of deficient is very familiar in the services industry where usually the importance of food quality is prioritized against the health and safety issues.

CHAPTER II: LITERATURE REVIEW

2.1. Legal and regulatory framework

According to Nhantumbo et al. (2017), After the independence of Mozambique, the Constitution of the Republic was approved, which in article 85 establishes the right to remuneration and job security. On the basis of this article, other laws were enacted that regulate aspects related to conditions of Hygiene and Safety at Work, among which the following stand out:

- In light of no. 2 of art. 85 of the Constitution of the Republic, Law no. 23/2007, of 1st of August, which approves the Labor Law and repeals Law no. 8/98, of 20th of July. This law contains a total of 273 articles and results from the dynamics of the social, economic and political situation, which requires the conformation of the legal framework that disciplines the work, employment and social security. In these terms, article 54, paragraph 5, establishes, to each employee, the right to enjoy adequate measures of protection, Security and Hygiene at Work, capable of guaranteeing their physical, moral and mental integrity;
- Employers are responsible for creating and developing appropriate means. to protect the physical and mental integrity of employees and continuous improvement working conditions. Employers are also required to take all of the adequate precautions to ensure that all jobs and means of access and exit to work are safe and free from risks to the safety and health of the workers. (art. 59 and 216 of Law no. 23/2007, of August 1, 2007);
- Likewise, the Labor Law requires employers to provide equipment for protection and adequate work clothing in order to prevent the risk of accidents or harmful effects on the health of workers, and instructs them on compliance of the occupational health and safety standards. (art. 216; points 2 and 5);
- Decree No. 62/2013, of December 4, of the Council of Ministers, approves the regulation establishing the Legal Regime for Work Accidents and Occupational Diseases and revokes Legislative Diploma No. 1706, of October 19, 1957. It is a decree with 74 articles;

On the other hand, and as a way to make a contribution to the knowledge of interested parties on the Health and Safety at Work legislation, the Government of Mozambique enacted and published some legal diplomas defining general and specific rules that regulate the legal regime applicable in industrial establishments and other branches of activities, with the following objectives:

- Develop awareness of safety at work;
- Allow the learning of prevention techniques and risk overcoming;
- Allow the internalization of safety rules and on the legal obligation of fulfil them;

Thus, it is presented as the main applicable Health and Safety at Work legislation in Mozambique and with the value of universal relevance as follows:

The Legislative Diploma No. 48/73, of 5 July, which approves the General Regulation of OHS in industrial establishments. This legal diploma constitutes the framework of applicable rules in all sectors of industry, with the aim of preventing professional risks in the industrial branch of the country. It has 162 articles, which are summarized in terms of the content of the its standards, in the following:

- Delimits its scope of application in all industrial establishments (Articles 1 and 2);
- Duty of employers and workers to comply with HST standards (Articles 3 and 4);
- Forecast of professional risk prevention measures in the design of industrial building designs, building surfaces, lighting, ventilation, temperature, humidity, noise, radiation, electricity, storage and fire extinguishers. (article 5 to 45);
- Forecast of risk prevention measures in the use of machines, in activities repair and maintenance of metal projection machines. (article 45 to 68);
- Forecast of risk prevention measures in the use of devices and means of lifting, transport and storage, in manoeuvring, handling loads, conservation, stacking of materials, in piping and plumbing, railways and detachment, electrical equipment, among other operations likely to expose different risks to workers;
- Prediction of prevention rules in activities related to the installation of cubes, tanks and reservoirs, ovens, greenhouses, installations, refrigerators, boilers steam, pressure appliances, electrical installations, gas welding and cutting and electric, hand and portable power tools (articles 98 to 107);
- Definition of prevention measures to be observed in conservation activities and repair of buildings, machines, installations and equipment. (article 108 to 111);
- Provision of mandatory risk prevention rules in activities with dangerous and bothersome substances, dangerous mixtures of gases and vapors explosives, corrosive substances at

high temperature, maintenance and transport of corrosive substances, toxic substances, asphyxiants, corrosive liquids (article 112 to 140);

- Provision of applicable standards to ensure health in industrial activities such as water supply, cleaning of workplaces, evacuation of residues, against rodents and insects, ergonomic conditions, sanitary facilities, changing rooms and dining rooms (Articles 141 to 148);
- Forecast of risk prevention measures through the availability of personal protective equipment to protect the head, eyes, ears, hands and arms, feet and legs, airway and seat belt (article 149 to 158);
- Prediction of standards on signs in the workplace, aiming at signaling machines, equipment, delimit areas and warn personnel of the danger they are in; The mandatory creation of the HST commission, its functions and mandatory existence of first-aid boxes and medical posts (Article 159 to 162), Labor Law No. 23/2007, of 1 August (Chapter VI);

Law No. 19/2014, of 27 August (Assembly of the Republic) - Law for the Protection of Person, Worker and Job Candidate Living with HIV/AIDS. The Law contains 73 articles and establishes the rights and duties of people living with HIV/AIDS and ensures the promotion of necessary measures for prevention, protection and treatment.

Decree No. 45/2009, of 14 August, approves the General Regulation of Labor Inspection and contains 48 articles, of which article 2 emphasizes the role of the General Inspectorate as being to control compliance with the rules relating to the conditions of work, the prevention of occupational risks, mandatory social security, placement, employment, hiring foreign labor and other laws. Article 12 of the present decree empowers inspection personnel, which includes visits to any location of work without prior notice.

It should be noted, however, that there is a public institution in Mozambique in the Ministry of Industry and Commerce (MIC), which has carried out activities of standardization, metrology, certification and quality management, which is the National Institute of Standardization and Quality (INNOQ). This institution has made efforts to create several Mozambican Standards (NM) for various areas, including Safety and Health at Work. This body has implemented the practical approach of NM OSHAS 18001 which currently has the designation of ISO 45001.

Other entities and/or institutions intervene in the field of HST, such as MITESS, MISAU and Labor Inspection. This last body is governed by the General Inspection Regulation of Labor (IGT), approved by Decree No. 45/2009, of 14 August, having as mission ensure the control of compliance with the rules relating to working conditions.

2.1.1. International conventions and protocols

The unfair and deplorable conditions of the working and living circumstances of workers caused that in June 1919 and during the Industrial Revolution it was created in Versailles, by the Peace Conference, the International Labor Organization (ILO). The Treaty of Versailles, which in its XIII part created the ILO, is an international document prepared by the nations that were victorious in World War I (1914-1918), with the aim of promoting peace, social justice and enunciating the improving labor relations based on principles that would govern international labor law **(**Nhantumbo et al., 2017**).**

Mozambique has been adhering to a series of international legal instruments that relate to the need to be proactive in protecting and conserving health, safety and the environment. According to number 2 of article 18 of the constitution of Mozambique, the rules of international law have the same value as national law and, once ratified by the parliament and the government, they become constitutional normative acts. Under the terms of number 1 of article 18 of the constitution, international treaties and agreements duly approved and ratified are approved in the Mozambican legal system.

With regard to health and safety and the environment, some protocols ratified by Mozambique are:

- Mozambique has rectified the Labour Inspection Convention, 1947 (No. 81);

Labour Inspection has been recognized by the ILO as a fundamental element of labour protection since its inception. Standard setting in this area culminated in the adoption of the Labour Inspection Convention, 1947 (No. 81).

- Convention No. 17: On compensation for an accident at work, adopted by the ILO Conference in 1925;

- Convention No. 18: On compensation for occupational diseases adopted by the ILO Conference in 1935;
- No. 87: Convention on Freedom of Association and Protection of the Right to Organize, 1948 - guarantees all workers and employers the right, without prior authorization, to form organizations of their choice and to join them and establish a set of guarantees for the free functioning of these organizations without interference from public authorities;
- No. 98: Convention on the Right to Organize and Collective Bargaining, 1949 - which provides for protection against acts of anti-union discrimination and protection of workers' and employers' organizations against acts of interference by one another, as well as measures to promote collective bargaining;
- No. 138: Convention on Minimum Age for Employment, 1973 – aims at the abolition of child labor, stipulating that the minimum age for admission to employment cannot be lower than the age for completing compulsory education;
- No. 182: Convention on Worst Forms of Child Labor, 1999 - calls for immediate and effective measures to ensure the prohibition and elimination of the worst forms of child labor, including slavery and similar practices, forced recruitment of children with a view to their use in armed conflicts, the use of children for the purposes of prostitution, the production of pornographic material and any illegal activity, as well as work that is likely to harm the health, safety or morality of children;
- Mozambique has signed the Rio Declaration on Environment and Development;
- Mozambique ratified Estocolmo convection about persistent organic pollutant in 2005;

2.2. Hazards in the Catering Industry

There are many risks in the catering industry that need to be controlled in order for these businesses to be compliant with the legislation. Hazards need to be identified, assessed, minimised and controlled so as to pose as little risk as possible to the safety, health and welfare of the industries workforce. This section will highlight the different risks, their adverse effects on health and safety, and some of the measures that can be employed to maintain a high level of health and safety among the workforce, this content was found in the work done by Kivlehan (2005) and Heads of Workplace Safety Authorities (2009)**.**

2.2.1. Chemicals, cleaning agents and disinfectants

Disinfectants are biocidal chemicals used to control food contamination by microorganisms. Disinfectants are classified as hazardous substances. Although disinfectants used in the food and drink industries are especially selected so that potential residues left on surfaces etc do not taint the food or are harmful to the consumer, many affect the skin, eyes or respiratory system and can be harmful if ingested in sufficient quantity. A risk assessment of chemicals should identify the purpose of the disinfectants and eliminate their use where appropriate, e.g. where cleaning alone is adequate or heat can be used. This risk assessment must be written and updated as required. The assessment of disinfectants, which are required, should include:

- A list of chemicals to be used; Ensure chemical containers have a label to identify the chemical and the safety information about the chemical (eg flammable, toxic if swallowed and avoid contact with skin):
- Provide air monitoring or health surveillance requirements ; Store chemicals in approved containers; do not use old drink or food containers;
- Do a risk assessment for all hazardous substances to determine how to use the chemicals safely;
- Make the MSDS and risk assessments available to people who use the chemicals at all times so they can refer to them;
- Train staff to use chemicals safely and to administer first aid;
- Post emergency numbers, including poison information numbers, beside the telephone;

2.2.2. Electrical Safety

Electricity at normal mains voltage (240v) can cause fatal shock, bums and fire. Wet conditions increase the risk of electric shock so particular care is needed in catering and food preparation premises (HMSO 1990 in Kate Kivlehan**,** 2005). Electrical safety can easily be compromised with the abundance of steam, grease and water spillages. Many unnecessary electrocution accidents are recorded each year. Equipment wear and tear, missing panels, ad hoc connections and defective wiring amplify this hazard (Boella, 2001 cited in Kivlehan**,** 2005). the common tips to prevent injury and death from electrical equipment in the catering industries are following:

- Remove faulty electrical equipment immediately from service and attach a warning label to it;
- Install safety switches to guard against electric shock;
- Always hire a licensed electrical contractor to install or repair electrical equipment. It's dangerous, illegal and could be fatal to attempt this work yourself;
- Provide enough power points for each work area. Only use power boards fitted with overload protection. The use of extension leads or double adaptors is not recommended;
- Be aware of the locations of all safety switches and what equipment they cover.
- Only use electrical appliances designed for use in the workplace environment (eg splash-proof or waterproof);
- Turn off power to electrical equipment not designed for the workplace environment if the area becomes wet;
- Ensure electrical equipment is regularly inspected, tested and maintained by competent people;
- Report faulty electrical equipment (eg when cords are frayed or bare wires are exposed, smoke is coming out of the equipment or the equipment cuts out for no obvious reason);
- Store extension cords and electrical leads away from water, chemicals, hot surfaces and walkways;
- Use childproof plastic plug covers;
- Ensure workers wear appropriate footwear and are trained in working safely with electrical equipment (eg correct ways to use electrical equipment, function of controls and guards);

2.2.3. Gas Safety

Gas, including liquefied petroleum gas (LPG), is widely used in the catering industry as a source of direct heat for ovens, boiling tops, grillers etc and also for heating water in steam boilers, water sets etc. The main hazards associated with gas are:

- Fire and possibly explosion when accumulations of unburned gas are ignited;
- Carbon monoxide poisoning from gas, which is not burned properly. Carbon monoxide is odourless and tasteless and therefore hard to detect. It can be given off by

installations, which are faulty or inadequately maintained. It is highly poisonous and inhaling it can quickly lead to death;

the common tips to prevent injury and death from gas in the catering industries are following:

- Put gas equipment in a well-lit and draught-free area and install a gas shutoff valve so the supply can be stopped if necessary
- Inspect and maintain gas equipment and the fuel supply system regularly. The switch for the gas supply should be accessible and clearly labelled.
- Store flammable materials, clothes and paper appropriately and away from sources of heat.
- Ventilation, whether natural or mechanical, should be provided to ensure an adequate supply of fresh air, otherwise the gas will not bum completely and poisonous carbon monoxide will be produced
- Clean exhaust fans and hoods regularly to prevent build-up of residue.

2.2.4. Slips, Trips and Falls

Slips, trips and falls are the highest cause of injury in kitchens. More than a quarter of these result in major injuries, such as a broken arm or requiring hospital treatment. Carrying loads or pushing/ pulling trolleys increases the risks of slips and should be avoided or reduced. Accidents can also be avoided by:

- Slip resistant flooring in kitchens;
- Floors being kept clean, dry and free from obstruction;
- Using only recommended cleaning materials on floors, as the wrong chemicals may damage the slip-resistant properties or cause the flooring to lift;
- Cleaning up spilled water, grease immediately;
- Proper storage to keep floors clear;
- Notices to warn staff of wet floor areas;
- Ensuring that suitable footwear is worn by catering staff;
- Minimise the need to carry full pots or pans;
- Provide adequate lighting;

2.2.5. Manual Handling, Strains & Sprains

Catering involves a lot of stretching and carrying, and repetitive manual work, such as chopping large amounts of food. lifting, manual handling, Muscleoskeletal Disorders (M SD's) and Work Related Upper Limb Disorders (WRULDs, commonly known as Repetitive Strain Injury or RSI) are a frequent cause of injury in catering. Lifting, carrying accidents account for more than one fifth of all recorded accidents in catering. This figure is likely to be much higher, because lifting and manual-handling injuries can occur over a long period of time and may not be related to the workplace when looking at the causes. Back injuries and WRULDs are often difficult to treat and can lead to disability, but they can be prevented. Manual Handling tasks include pushing, pulling and carrying as well as lifting. Heavy or unsafe loads, poor working environment, badly planned work methods, inadequate training can all lead to manual handling injuries for catering staff. Common tasks in this line of work include:

- Lifting, pushing, pulling, folding or moving tables and chairs around Setting up equipment
- Moving stock to and from storage areas
- Filling and carrying large food containers, pots, pans etc
- Silver service i.e. manoeuvring between dinners trying to serve them whilst holding large, heavy and often very hot trays of food.

In assessing manual handling risks employers should consider:

- Whether floors are uneven or slippery and include steps;
- If smaller pots, pans, trays etc could be used;
- How and when goods are delivered and Whether storage arrangements can be improved;
- The layout of a kitchen, e.g. can it be altered to avoid/ reduce carrying loads Type and size of equipment, materials and supplies used and the labelling of any loads likely to be handled;
- Overalls, uniforms and other work clothing supplied i.e. can staff move easily when wearing them and is footwear suitable?
- The type of training provided. Training in proper lifting techniques is important, but must not be a substitute for employers reducing risks in the first place;

2.2.6. Temperature

High temperatures and humidity are not unusual in kitchens because of the cooking process and the need for food to be served hot, but high temperatures can sometimes have an adverse effect on catering workers.

Working in high temperatures can result in loss of concentration, irritability, muscle cramps and fainting. Some women are more at risk, when working in high temperatures, e.g. women working through the menopause and those who are pregnant. Working in high temperatures can aggravate common menopausal symptoms such a hot flushes and sweating. Pregnant women tolerate heat less well and are more likely to succumb to heat stress or fainting. While this risk is reduced after birth, it is not known how quickly it happens. Breastfeeding may also be affected by heat dehydration (Boella, M.J., 2001 in Kate Kivlehan, 2005).

Working in cold temperatures can cause discomfort, loss of concentration, irritability and tiredness. Cold conditions and also lead to fatigue since the body uses energy to keep warm. There is an increased risk of accidents due to numb fingers and obstruction by protective clothing. Extreme cold for long periods can lead to more severe conditions such as hypothermia.

There are a number of steps that can be taken to provide a comfortable temperature for workers in kitchens. For example, ventilation systems should be checked and regularly maintained to ensure staff comfort. Other systems such as periodic breaks and rest facilities in cooler conditions should be given to the type of materials used for overalls and other clothing issued to catering staff as some synthetic material can increase the problem. Where exposure to cold in unavoidable steps must be taken to protect kitchen staff including:

- Systems of work that minimise the length of time of exposure to cold working conditions, e.g. job rotation which gives workers the opportunity to go to heated areas;
- Providing suitable heated rest facilities and allowing workers ready access to them
- Providing suitable protective clothing and equipment;
- Provide rest breaks for workers in a cool area, and ensure they have access to cool drinking water;
- Train workers about the risks of heat stress;

2.2.7. Burns and Scalds

Most scalds and bums are caused by spillage of hot foods from grills and fat fryers, pots and pans. Not surprisingly, most bums and scalds occur to the hands, arms and feet. This highlights the need for heatproof clothing for these parts of the body. These accidents can be avoided by ensuring that:

- Staff do not lift or carry heavy pans of hot food or water;
- Oil and fat is filtered, moved or discarded only when cool;
- Appliances are allowed to cool before being cleaned;
- Special oven clothes and gloves are used when opening ovens and handling pots, pans and utensils while cooking;
- Appropriate fire-fighting equipment is available, and staff are properly trained in its use;
- Maintenance of seals etc. on appliances will prevent hot steam escaping causing bums and scalds also**;**

2.2.8. Equipment /Machinery Safety

The first time you enter a commercial kitchen the amount of specialist equipment is truly bewildering. Without intrinsic safety devices, adequate training and supervision, even the most experienced caterer could suffer serious injury from mistake. Work equipment in the catering industry covers machinery like food processors and slicers, appliances like ovens, hand tools including knives, and any other items such as shelving and footstools. There are a number of issues which can cause work equipment dangers within the workplace, including:

- Equipment suitability- often staff use equipment which is not correct for the purpose intended, e.g. use of chair to access shelving;
- Use of damaged equipment with broken guards;
- Use of equipment which is not properly locked down and secured or lacks proper control buttons to control danger;
- Non-use of safety measures such as push sticks, which prevent fingers coming in contact with blades, e.g. food processors;
- Consider re-designing the machines so they can’t be operated without guards;

Machine guarding prevents any part of a person or their clothing coming into contact with a moving part of a machine, which might cause harm. In principle, therefore, any moving part of any machine must be sufficiently guarded to prevent such contact, although consideration must be given to the normal use of the machine. Decisions on the need for, or suitability of, machinery guarding must consider whether contact can be made with any moving parts of that machine while it is in motion. If so, this part should be guarded. If the part is already guarded is the guarding adequate?

Catering machinery is fairly unique in that it must also comply with another comprehensive legal framework, food hygiene legislation. Guards will need to be removable for cleaning, and their properties must meet the requirements of Hygiene of Foodstuffs Regulations which states that all articles, fittings and equipment with which food comes into contact shall be kept clean and with the exception of non-returnable containers and packaging, be so constructed, be of such materials and be kept in such good order, repair and condition as to enable them to be kept thoroughly cleaned, and where necessary disinfected, sufficient for the purpose intended. Most catering equipment is not fitted with interlocking guards, and could still function when guarding has been removed. In this case, a safe system of work will be necessary (Boella, 2003 cited in Kivlehan, 2005).

2.2.9. Permits to Work

During service or repair work, a system should exist to ensure the machine cannot be accidentally started this is usually in the form of a permit to work system issued by the maintenance manager or manager in charge. This permit will contain written authority to carry out the work, and the machine must be rendered inoperative during this work, with notices to that effect also. On completion of works, the person carrying them out will report back to the manager, to allow checks to be made before the machine is put back into use (Boella, 2000 cited in Kivlehan, 2005).

2.2.10. Safe use of Knives

Caterers use a range of different knives for a variety of tasks, for example cutting, slicing and dicing. Knife accidents are common in the catering industry. They usually involve cuts to the non-knife hand and fingers. The food being cut is held in the non-knife hand and the knife is pushed down through the food. The work is often done at high speed and there is always a danger of cuts to the non-knife hand. Cleavers are commonly used or chopping. The risk is the same as for knives but the injury can be much more serious, even amputation of fingers. Certain precautions need to be taken by catering staff in order to prevent injuries, including:

- Knives must not be used without proper training;
- Select the correct knife for the task. Kitchen knives are generally designed for a particular job. Use only good quality kitchen knives;
- Knives should be kept in good condition. They should be kept sharp and have handles that can be properly held. The handles should be kept clean;
- When using a knife, use a firm grip, try to use even pressure for cutting, cut downward and avoid cutting towards the body. Never try to catch a falling knife;
- There should be enough room for there to be no danger of a person using a knife colliding with another staff member;
- When carrying knives hold the knifepoint downwards;

2.2.11. Fire Safety

It is the responsibility of management, to ensure the conditions set out for fire safety is met, and the precautions against fire are kept at a high standard. It is the staff's responsibility to know what to do if a fire breaks out. Know where all fire exits and emergency routes are and to report fire hazards to management. Written instructions as well as verbal instructions from management need to be given to all members of staff as regards steps to be taken in the event o f a fire including fire drills. These cover the precautions that should be taken to prevent fires starting.

At least once every six months there should be a fire drill. Fire drills give staff a chance to practice what you have to do when the alarms are raised in the event of an actual fire i.e.:

- Know the escape routes
- Know where the fire alarms are
- Know the location of fire equipment

Regular instructions should be given on how to use fire extinguishers and other firefighting equipment. This should be a training requirement for all staff. Fires burning in ordinary combustible materials like wood, cloth, paper, rubbish, etc, which, are not close to live electrical equipment, can be put out by water. A fire in ordinary combustible materials can also be put out by being deprived of air - smothering it with a fire blanket or sand, or beating it out with a shovel. But do NOT use a water extinguisher on fires involving gases, electrical hazards or burning liquids such as oil, fat or paint. Fire involving electrical hazards (TV sets, computers, room heaters etc) can be tackled using CO_2 gas extinguisher, a powder extinguisher, or a Halon (BCF) extinguisher.

Never use water on an electrical fire. You may electrocute yourself. Foam or water extinguishers are not suitable for fires involving electrical hazards. Use a foam extinguisher, or a powder extinguisher for fires involving burning liquids, oils, fat or paints.

A fire blanket will also smother the flames, depriving the fire of air. Your hotel may have a Halon (BCF) extinguishers or a CO_2 gas extinguisher. Both are suitable for such fires. Never use water on an oil or fat fire. It will spread the flames. If the fire involves gases, the gas must be turned off before extinguishing, or explosive risk is caused.

2.3. Examples of Accident and Injury in the Catering Industry

The following cases highlight just some of the things that can go wrong when health and safety is not properly managed in the catering environment. All case describes here were found in Kivlehan (2005).

2.3.1. Electrocution Case

In the U.K. the ex-health and safety manager of a fast food chain was found guilty of health and safety breaches, which lead to the death of a young kitchen assistant. He was found guilty for failing to take reasonable care of the health and safety of himself and other persons between August 1997 and January 1999 at various outlets of “Fatty Arbuckles”. The young worker in question, aged 17 died while “deck scrubbing” the floor of the restaurant’s kitchen after the premises had closed. The process involves a lot of water lying on the floor. The worker was standing on the water when he came into contact with an incorrectly wired 1960’s plate warmer, which electrocuted him proving fatal. The Environmental Health Officer leading the investigation stated that the likelihood of electrocution would have been significantly reduced had risk assessments been carried out and “appropriate yet obvious control measures been implemented”. The accused’s defence barrister stated that the company had been in breach of health and safety legislation for several years before the accused had been employed, and that the duty to arrange risk assessments rested with the employer, not the employee. However, the Environmental Health Officer said that the accused had been responsible for both food safety and health and safety, he had prioritised food safety over health and safety, following high-profile health scares, and had not examined the company’s existing position on health and safety compliance. He should have advised the company’s directors of breaches, she said. The judge in the case accepted that the accused had not directly or remotely caused the death of the young man, but the lack of risk assessments over a prolonged period did make events more likely. He said “the young man’s death was the catalyst for an enquiry which lead to the prosecution... that prosecution does not set out to prove causation in relation to the death, albeit it does suggest that the young man’s safety was put at risk, along with other employee’s safety”.

2.3.2. Fall from Height

McDonald’s Restaurants Ltd and co-defendant Jones Lang LaSalle were fined a combined total of £75,000 at Birmingham Crown Court after an investigation by Birmingham city council into the circumstances surrounding the serious spinal injuries suffered by an employee of the well-known fast-food firm, who fell from a roof area at Birmingham’s Paradise Forum shopping centre. The injuries sustained by the employee were so serious that her lower rib had to be removed and grafted on to her spine, while part of her spine was put into a titanium cage held together by metal pins.

McDonald admitted that on the 1st of July 2002, it had allowed an employee to access a roof area, which housed ventilation equipment serving its premises in the Paradise Forum. The area had no protection to prevent falls from the edge of the roof. While conducting a survey of the ventilation equipment and the roof area the employee had stepped onto an adjacent suspended false ceiling, thinking it was a load-bearing part of the roof. There were no signs identifying the fragile nature of this ceiling and she fell more than 11 ft to through the ceiling to the ground below.

McDonalds had conducted a health and safety audit of this premises 5 times between November 2001 and June 2002 and only the final audit in June 2002 highlighted the lack of edge protection. However, the company continued to allow employees to access the roof area. The court heard that

McDonalds relied on its generic risk assessment procedures to help identify hazards at this premises.

However, the generic risk assessments mainly applied to modular or “generic” premises where the edge protection is built into the roof structure. Paradise Forum was a shopping centre premises that had not been designed or built by McDonalds, so it did not fit into the generic profile. It should, therefore, have been subject to site-specific risk assessment, which should have identified the lack of edge protection and prompted McDonalds to act. Jones Lang LaSalle Ltd, who managed Paradise Forum, admitted it had known about the lack of edge protection since 1999 but had taken no steps to make the roof area safe. The investigating Environmental Health Officer also discovered that a similar accident had occurred in January 2001, when a security officer working on behalf of Jones Lang LaSalle Ltd had fallen through the same false ceiling. “Throughout the period of the investigation both defendants felt the other was responsible for the failings”, the EHO stated. “Both defendants had failed to comply with their statutory duties resulting in the employee suffering the consequences of their inaction. This investigation has highlighted that, although generic risk assessments are a valid means of identifying and controlling hazards, they are not suitable in all circumstances and are more effective for those premises that fit a generic profile”.

Summing up, the judge accepted that both defendants were “respected and reputable companies” and that the incident had not occurred through putting profit before safety. McDonalds also cited its previous good safety record. However, the judge remarked that the incident was entirely avoidable, as there were warnings well in advance.

2.4. Risk management

A risk is a random event that may possibly occur and if it did occur, would have a negative impact on the organization goals (Khan, 2014). Risk is often described in terms of risk sources, potential events, their consequences and their likelihoods. An event can have multiple causes and lead to multiple consequences. Consequences can have a number of discrete values, be continuous variables or be unknown. Consequences may not be discernible or measurable at first, but may accumulate over time. Sources of risk can include inherent variability, or uncertainties related to a range of factors including human behaviour and organizational structures or societal influences for which it can be difficult to predict any particular event that might occur.

ISO 31000 describes principles for managing risk and the foundations and organizational arrangements that enable risk to be managed. It specifies a process that enables risk to be recognized, understood and modified as necessary, according to criteria that are established as part of the process. Risk assessment techniques can be applied within this structured approach which involves establishing context, assessing risk and treating risk, along with ongoing monitoring, review, communication and consultation, recording and reporting. This process is illustrated in figure 1.

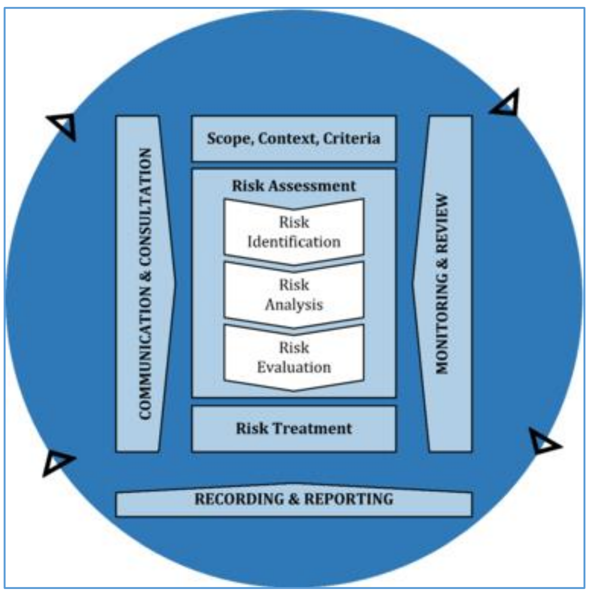

Figure 1:Risk management process: Source - ISO31010 (2019)

In the ISO 31000 process, risk assessment involves identifying risks, analysing them, and using the understanding gained from the analysis to evaluate risk by drawing conclusions about their comparative significance in relation to the objectives and performance thresholds of the organization. This process provides inputs into decisions about whether treatment is required, priorities for treatment and the actions intended to treat risk. In practice an iterative approach is applied. It follows that risk cannot always be tabulated easily as a set of events, their consequences and their likelihoods. Risk assessment techniques aim to help people understand uncertainty and the associated risk in this broad, complex and diverse context, for the purpose of supporting better-informed decisions and actions.

As the present study is basically a risk assessment we a going to describe the different type of risk assessment technique selected from ISO_31010_2019 and ISO_3110_2009 only for Preliminary hazard analysis as it not described in ISO_31010_2019.

2.4.1. Preliminary hazard analysis (PHA)

PHA is a simple, inductive method of analysis whose objective is to identify the hazards and hazardous situations and events that can cause harm for a given activity, facility or system. It is most commonly carried out early in the development of a project when there is little information on design details or operating procedures and can often be a precursor to further studies or to provide information for specification of the design of a system. It can also be useful when analysing existing systems for prioritizing hazards and risks for further analysis or where circumstances prevent a more extensive technique from being used.

Inputs include:

- information on the system to be assessed;
- such details of the design of the system as are available and relevant.

Outputs include:

- a list of hazards and risks;
- recommendations in the form of acceptance, recommended controls, design specification or requests for more detailed assessment.

Process

A list of hazards and generic hazardous situations and risks is formulated by considering characteristics such as:

- materials used or produced and their reactivity;
- equipment employed;
- operating environment;
- layout;
- interfaces among system components, etc.

Strengths and limitations

Strengths include:

- that it is able to be used when there is limited information;
- it allows risks to be considered very early in the system lifecycle.

Limitations include:

- a PHA provides only preliminary information; it is not comprehensive, neither does it provide detailed information on risks and how they can best be prevented.

2.4.2. Failure modes and effects analysis (FMEA) and failure modes, effects and criticality analysis (FMECA)

In FMEA, a team subdivides hardware, a system, a process or a procedure into elements. For each element the ways in which it might fail, and the failure causes and effects are considered. FMEA can be followed by a criticality analysis which defines the significance of each failure mode (FMECA). For each element the following is recorded:

- its function;
- the failure that might occur (failure mode);
- the mechanisms that could produce these modes of failure;
- the nature of the consequences if failure did occur;
- whether the failure is harmless or damaging;
- how and when the failure can be detected;
- the inherent provisions that exist to compensate for the failure.

For FMECA, the study team classifies each of the identified failure modes according to its criticality. Several different methods of criticality can be used. The most frequently used are a qualitative, semi-quantitative or quantitative consequence/likelihood matrix or a risk priority number (RPN). A quantitative measure of criticality can also be derived from actual failure rates and a quantitative measure of consequences where these are known. The RPN is an index method that takes the product of ratings for consequence of failure, likelihood of failure and ability to detect the problem (detection). A failure is given a higher priority if it is difficult to detect.

FMEA/FMECA can be applied during the design, manufacture or operation of a physical system to improve design, select between design alternatives or plan a maintenance program. It can also be applied to processes and procedures, such as in medical procedures and manufacturing processes. It can be performed at any level of breakdown of a system from block diagrams to detailed components of a system or steps of a process. FMEA can be used to provide information for analysis techniques such as fault tree analysis. It can provide a starting point for a root cause analysis.

Strengths and limitations

Some strengths of FMEA/FMECA are listed below:

- It can be applied widely to both human and technical modes of systems, hardware, software and procedures.
- It identifies failure modes, their causes and their effects on the system, and presents them in an easily readable format.
- It avoids the need for costly equipment modifications in service by identifying problems early in the design process.
- It provides input to maintenance and monitoring programs by highlighting key features to be monitored.

Some Limitations of FMEA are listed below:

- FMEA can only be used to identify single failure modes, not combinations of failure modes.
- Unless adequately controlled and focused, the studies can be time consuming and costly.
- FMEA can be difficult and tedious for complex multi-layered systems.

2.4.3. Fault tree analysis (FTA)

FTA is a technique for identifying and analysing factors that contribute to a specified undesired event (called the "top event"). The top event is analysed by first identifying its immediate and necessary causes. These could be hardware or software failures, human errors or any other pertinent events. The logical relationship between these causes is represented by a number of gates such as AND and OR gates. Each cause is then analysed step-wise in the same way until further analysis becomes unproductive. The result is represented pictorially in a tree diagram, which is the graphical representation of a Boolean equation.

FTA is used primarily at operational level and for short- to medium-term issues. It is used qualitatively to identify potential causes and pathways to the top event, or quantitatively to calculate the probability of the top event. For quantitative analysis strict logic has to be followed. This means that the events at inputs of an AND gate have to be both necessary and sufficient to cause the event above and the events at an OR gate represent all possible causes of the event above, any one of which might be the sole cause. Techniques based on binary decision diagrams or Boolean algebra are then used to account duplicate failure modes. FTA can be used during design, to select between different options, or during operation to identify how major failures can occur and the relative importance of different pathways to the top event.

Inputs for fault tree analysis are the following.

- An understanding of the system and the causes of failure or success is required, as well as a technical understanding of how the system behaves in different circumstances. Detailed diagrams are useful to aid the analysis;
- For quantitative analysis of a fault tree, data on failure rates, or the probability of being in a failed state, or the frequency of failures and where relevant repair/recovery rates, etc. are required for all base events;
- For complex situations, software and an understanding of probability theory and Boolean algebra are recommended so inputs to the software are made correctly;

The outputs from fault tree analysis are:

- a pictorial representation of how the top event can occur, which shows interacting pathways each of which involves the occurrence of two or more (base) events;
- a list of minimal cut sets (individual pathways to failure) with, provided data is available, the probability that each will occur;
- in the case of quantitative analysis, the probability of the top event and the relative importance of the base events;

Strengths and limitations

Strengths of FTA are listed below:

- It is a disciplined approach which is highly systematic, but at the same time sufficiently flexible to allow analysis of a variety of factors, including human interactions and physical phenomena;
- It is especially useful for analysing systems with many interfaces and interactions. It provides a pictorial representation leading to an easier understanding of the system behaviour and the factors included;
- Logic analysis of the fault trees and the determination of cut sets is useful in identifying simple failure pathways in a complex system where particular combinations of events and event sequences which lead to the top event could be overlooked;
- It can be adapted to simple or complex problems with the level of effort dependent on complexity;

Limitations of FTA are listed below:

- In some situations, it can be difficult to ascertain whether all important pathways to the top event are included; for example, including all ignition sources in an analysis of a fire. In these situations, it is not possible to calculate the probability of the top event;
- Time interdependencies are not addressed;
- FTA deals only with binary states (success/failure);
- While human error modes can be included in a fault tree, the nature and extent of such failures can be difficult to define;
- FTA analyses one top event. It does not analyse secondary or incidental failures.
- An FTA can get very large for large scale systems;

2.4.4. Event tree analysis (ETA)

ETA is a graphical technique that represents the mutually exclusive sequences of events that could arise following an initiating event according to whether the various systems designed to change the consequences function or not. The tree can be quantified to provide the probabilities of the different possible outcomes.

The tree starts with the initiating event then for each control lines are drawn to represent its success or failure. A probability of failure or success can be assigned to each control, by expert judgement, from data, or from individual fault tree analyses. The probabilities are conditional probabilities. For example, the probability of an item functioning is not the probability obtained from tests under normal conditions, but the probability of functioning under the conditions of the initiating event.

The frequency of the different outcomes is represented by the product of the individual conditional probabilities and the probability or frequency of the initiation event, given that the various events are independent.

ETA can be used qualitatively to help analyse potential scenarios and sequences of events following an initiating event, and to explore how outcomes are affected by various controls. It can be applied at any level of an organization and to any type of initiating event. Quantitative ETA can be used to consider the acceptability of the controls and the relative importance of different controls to the overall level of risk. Quantitative analysis requires that controls are either working or not (i.e. it cannot account for degraded controls) and that controls are independent. This is mostly the case for operational issues. ETA can be used to model initiating events which might bring loss or gain.

Strengths and limitations

Strengths of ETA are listed below:

- Potential scenarios following an initiating event are analysed and the influence of the success or failure of controls shown in a clear diagrammatic way that can, if required, be quantified;
- It identifies end events that might otherwise not be foreseen;

- It identifies potential single point failures, areas of system vulnerability and low payoff counter-measures, and hence can be used to improve control efficiency;
- The technique accounts for timing and for domino effects that are cumbersome to model in fault trees;

Limitations ETA are listed below:

- For a comprehensive analysis, all potential initiating events need to be identified. There is always a potential for missing some important initiating events or event sequences;
- Only success and failure states of a system are dealt with, and it is difficult to incorporate partially operating controls, delayed success or recovery events;

CHAPTER III: METHODOLOGY

The methodology for the present work followed the steps showed in figure 2, which consisted of the bibliographic review, data collection at CIS Nacala, Function analysis, Preliminary Hazard analysis, FMEA/FMECA, Fault tree and Event tree analysis and ending with the compilation of the final report.

From a scientific point of view, this research can be considered of an applied nature with exploratory objectives, since it intends to apply its results. In terms of approach, it is a combination of qualitative and quantitative methods (Miguel, 2010).

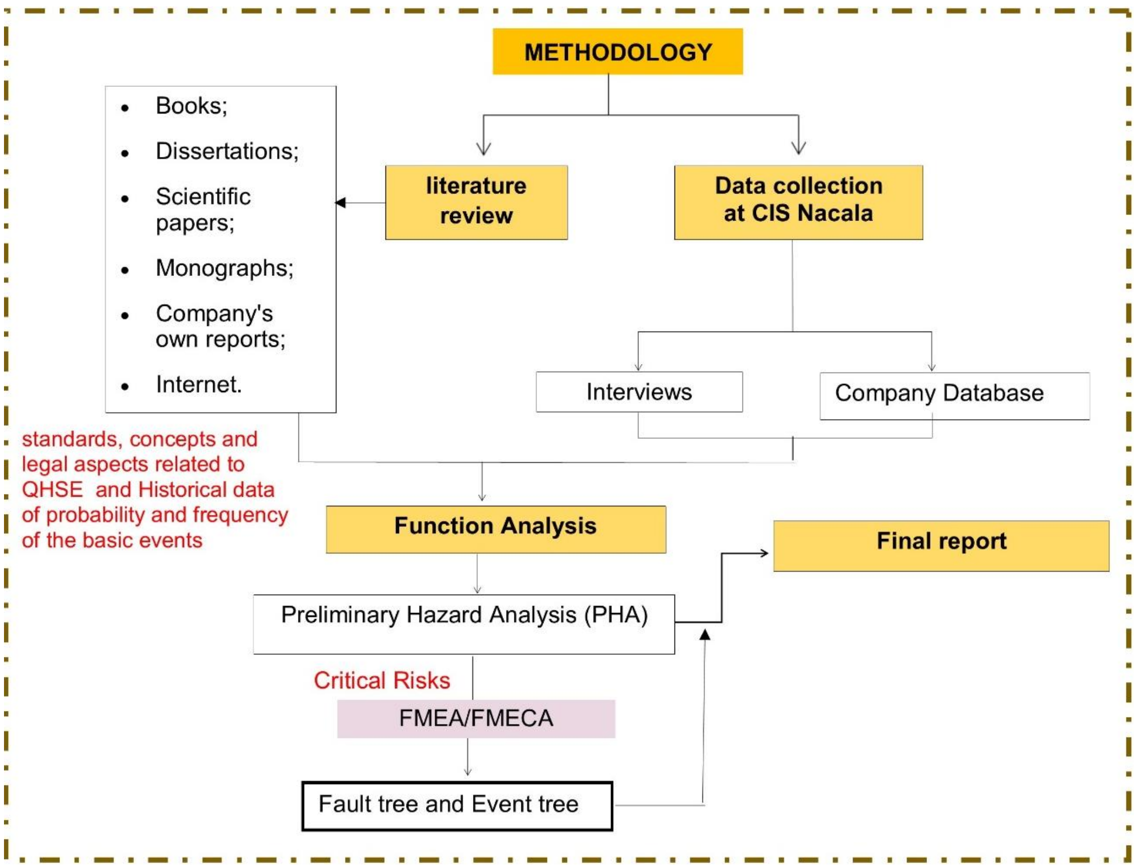

Figure 2:Flowchart of the methodology of the study. Source: Author

3.1. bibliographic review

In search of literary information, bibliographical and documental research was carried out, through books, dissertations, scientific papers, and reports from the company itself, on standards, concepts and legal aspects related to QHSE and Historical data of probability and frequency of the basic events, bibliographic review was part of the process in all step until the compilation of the final report.

3.2. Data collection at CIS Nacala

The present study was carried out as part of internship program at CIS, all relevant data's regards the kitchen system was made available by QSHE department and also the representative of the department made himself available for interview when was necessary. all provided information was relevant for system definition and function analysis.

3.3. Function Analysis

With the goal to understanding how the kitchen system works, system map was elaborate and all subsystem and components were identified and their function also defined. This approach was important step to conduct hazards identification and risk analysis.

3.4. Preliminary Hazard analysis (PHA)

Considered the kitchen as complex system preliminary Hazard analysis (PHA) was used to quickly identify and evaluate those risks present in the system. Furthermore, existing control and mitigation measures at CIS Nacala were also described and additional recommendations were give when necessary. The critical risks (fire in the kitchen) was selected for detailed analysis with FMEA, Fault tree and event tree.

3.5. FMEA/FMECA

The critical risks fire in the kitchen was considered associated with one component of the system (the electrical oven) as possible source of ignition. Block diagram of the electric oven was built to held understand how the system works and identify important parts of the system. Only after discretion of the system was possible to fill the spreadsheet of FMEA/FMECA. The index tables of Severity, Occurrence and Detection proposed by Soares (2015) in annex 3, 4 and 5 respectively were used to calculate The Priority Risk Number (PRN).

The Priority Risk Number (PRN) results from the product of the three indices referred to previously (S – Severity; O – Occurrence; D – Detection), according to equation 1:

$$\boldsymbol{PRN = S * O * D} \quad \textbf{(1)}$$

Where:

PRN - The Priority Risk Number

S - Severity

O - Occurrence

D - Detection

The PRN works as an indicator of the criticality of failures, that is, the higher the PRN, the greater the risks for the worker and the company, therefore, the greater the Most Urgent Risk Priority Number is to solve or minimize the failure.

3.6. Fault tree and Event tree

The data's for probabilistic analysis of fault tree were fund in the works from Sung-Ho Hong, 2008 whom did fault tree of fire from electric heater and iron with similar work principal compared to the electrical oven others supplemental data's of probability basics events Grease, food and miscellaneous materials may catch fire in the kitchen were found from Ling (1978). In the case of event tree the probability of effectiveness of each mitigation system for the case of fire in the kitchen were found in the work from New Zealand Fire Service Commission (2008).

In our fault tree (fire in kitchen) Boolean algebra was used to reduce equations and find the minimal cuts sets. Selected basic mathematical rules of Boolean algebra are given in (appendices G). Conventionally, the symbol **"+"** is used to represent the logical OR operator and the symbol "." is used to represent the logical AND operator.

The probability of occurrence of the events in one year were calculate according to equation 2.

$$p = 1 - e^{-\lambda t} \quad (2)$$

Where:

p – annual probability of occurrence

λ - Annual frequency

t – time period (i.e., 1 year)

Regarding the reliability analysis of fire detector, was used in this study the Weibull distribution model, as according to Kapur & Pecht (2014) the Weibull distribution is widely used for reliability analyses because a wide diversity of hazard rate curves can be modeled with it. The distribution can also be approximated to other distributions under special or limiting conditions. The Weibull distribution has been applied to life distributions for many engineered products, and has also been used for reliability testing, material strength, and warranty analysis.

3.7. Final report Compilation

The diagram, illustrations, graphic and tables were prepared using Microsoft office software (word, excel and publish). At this stage, the preparation of the final report consisted of the compilation of all information from the literature review, information from data processing and interpretation of results obtained.

CHAPTER IV: RESULTS AND DISCUSSION

4.1. CIS Nacala Kitchen system definition and functional analysis

System is a set of components, humans or machines or both, which has certain functions and acts and interacts, one in relation to another, to perform some task or tasks in a particular environment or environments. Figure 3 shows the map of the CIS Nacala kitchen system, the system consists of subsystems and components that work under certain environmental conditions.

The system as a whole was designed for the purpose of preparing meals (primary function), in this system we have raw material in the form of raw foods as input and we have meals and waste as output of the system. For the system to fulfil its function, it needs to operate under certain conditions in its environment, which are Enough space, Suitable lighting, Good ventilation, Unobstructed passage and Dry floor. The following is a description of the functions of each subsystem and system components:

- subsystem 1 Electrical supply - with the function of supplying the electrical energy necessary for the functioning of electrical equipment and other devices present in the kitchen.
- subsystem 2 Ventilation: with function to keep the environment cool and pleasant temperature
- subsystem 3 Exhaust – with the function of removing smoke and strong odors from the system.
- subsystem 4 Water supply – function of providing water in sufficient quantities for kitchen activities such as cleaning, preparing meals, etc.

In addition to these subsystems, there are also system components which are:

- Oven and stove - with the function of transforming electrical energy into thermal energy and producing the heat needed to cook food
- Knives and cutting utensils - with function to cut food in desired sizes
- Food Processing Machines – function includes mixing food, grinding, etc. for the context of occupational safety risk analysis, dishwashers were included in this group.
- Staff/operators – responsible for managing kitchen activities in a safe, healthy way and guaranteeing the quality of the final product.

- Chemical substances – with the function of facilitating the washing of kitchen materials.

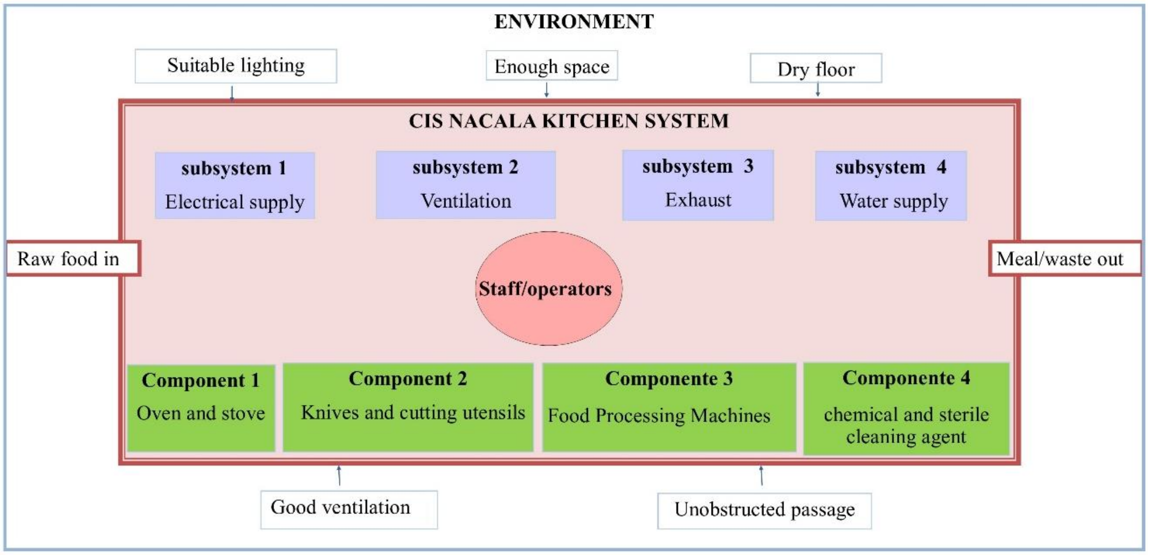

Figure 3:CIS Nacala kitchen system map. Source: Author

As we can see, this is a complex system with many activities involved, use of equipment and electricity, which can compromise safety at work. Work safety can be improved by carrying out a good analytical approach to determine potential hazards and occupational safety risks that might occur in a design or process of making a product.

Preliminary hazard analysis (PHA) can be chosen as the right method to identify hazards in a complex system and minimize the incidence of accidents in the workplace. According to Olaide et al. (2021) in PHA studies, it is not necessary to quantitatively estimate risk since the final objective is to have a broad-scope view of the system's hazards at the preliminary stage.

4.2. Preliminary Hazard analysis of the kitchen system

Preliminary hazard analysis was performed for All subsystem and components of our system (table 3). The analysis consisted of identifying the hazards (Feared event), causes, consequences, evaluation of intrinsic risk according to probability of occurrence and severity of consequences (annex 1 and 2), Existing controls at CIS Nacala and additional recommendation improvements or controls were given when necessary.

The risk matrix were used to classify the risks with focus in safety aspects, according to the classification, the risk of Electrocution / burn and Fire and explosion all related to the electrical subsystem were found to be critical, others subsystem and components were found to have risks that varying in high (Scald & Burn, Cut, Cut and Trap, and Inhalation, Swallowing or Skin Contact of Chemical and sterile cleaning agent) to moderate (Physical workload risks, Noise, Slip/ trip due wet floor; Exposure to smoke and hot steam and Exposure to high temperature). Among the critical risks, the risk of fire it's the only one which has catastrophic consequences, thus, was studied in details with quantitative methods.

Since CIS Nacala uses an electric Oven to cook food, it was selected to study possible failure modes and how it can contribute to fire initiation in the kitchen. Failure Mode and Effect Analysis (FMEA) were used to analyse the oven failures, by describing the effects that arise from these failures.

Table 3:Preliminary Hazard Analysis of the CIS Nacala Kitchen system. Source: Author

Subsystem/ Components	**Feared event**	**Probability**	**Consequence**	**Intrinsic risk**	**Existing controls at CIS Nacala**	**Recommended improvements or controls**
Electrical subsystem 1	Electrocution / burn	Possible (C)	Major (4)	**Critical**	Preventive maintenance control, identification of non-conform equipment	Install safety switches to guard against electric shock. All Electrical Equipment and appliances to be inspected by a competent person monthly. Provide enough power points for each work area. Only use power boards fitted with overload protection. The use of extension leads or double adaptors is not recommended. Only clean electrical equipment when the plug is removed from the power supply. Ensure workers wear appropriate footwear and are trained in working safely with electrical equipment (eg correct ways to use electrical equipment, function of controls and guards).
	Fire and explosion	Possible (C)	Catastrophic (5)	**Critical**		Unobstructed fire escape route Do not cover EXIT and escape direction signs Don't hang clothes above heating appliances Learn how to use firefighting equipment Perform regular fire drills No flammable substance near electrical works, especially electrical arc welding
Ventilation subsystem 2	Exposure to high temperature	Likely (B)	Minor (1)	**Moderate**	Water available for deshydratation risk, Limit time exposure extreme temperatures, installing a ventilator	Train workers about the risks of heat stress
Extraction subsystem 3	Exposure to smoke and hot steam	Likely (B)	Minor (1)	**Moderate**	Refer to SWART CARD arranged in the kitchen, use of PPE advocated in the SWART CARD, Safety trained permit, On job training , topic Toolbox	Extraction system to extract smoke and hot steam
Water supply subsystem 4	Slip/ trip due wet floor	Possible (C)	Medium (2)	**Moderate**	Signage implmented on dangerous place, Keep a good housekeeping of the premises, Clean all slippery surfaces, Slow down at intersections (blind spot, door beating), Dry the ground when wet and put a signage	Using only recommended cleaning materials on floors, as the wrong chemicals may damage the slip-resistant properties or cause the flooring to lift. Slip resistant flooring in kitchens. Ensuring that suitable footwear is worn by catering staff. Provide adequate lighting. Texting while working and walking
Oven and stove	Scald & Burn	Likely (B)	Serious (3)	**High**	Refer to SWART CARD arranged in the kitchen, use of PPE advocated in the SWART CARD, Safety trained permit, On job training , topic Toolbox	• Staff do not lift or carry heavy pans of hot food or water • Oil and fat is filtered, moved or discarded only when cool Oven trays that is still hot to be placed in cooling racks to prevent uninformed staff from being burnt.
Knives and cutting utensils	Cut	Likely (B)	Serious (3)	**High**	PPE (metalic and kevlar gloves), On job training , topic Toolbox, swart card	Select the correct knife for the task. Use only good quality kitchen knives. Only kitchen staff is allowed to do any preparation of cutting of food and dishes inside kitchen. When carrying knives hold the knifepoint downwards. Never try to catch a falling knife.

Food Processing Machines	Cut and Trap	Possible (C)	Serious (3)	High	PPE (metalic and kevlar gloves), On job training , topic Toolbox, swart card	Consider re-designing the machines so they can't be operated without guards; Equipment suitability- often staff use equipment which is not correct for the purpose intended
	Noise	Likely (B)	Minor (1)	Moderate		Isolate noisy process in order to reduce impact to employee and environment Isolate noisy machine or use quieter machine. Suitable repair and maintenance of machines and ventilation. Working in shift Suitable PPE
Chemical and sterile cleaning agent	Inhalation (Breathing) Swallowing (Eating) Skin Contact	possible (C)	Serious (3)	High	Use of adequate PPE, Compliance with HAZCOM program, MSDS available in the store and HSE office	Emergency Preparedness: Fire, Evacuation, First Aid, Leakage Handling Procedures. Select safer chemicals Post emergency numbers, including poison information numbers, beside the telephone.
receiving raw materials and meal distribution	ergonomic hazards (Physical workload risks)	Possible (C)	Medium (2)	Moderate	Respect for the rules "Gestes and postures", Alternating posts every 15 minutes, Carrying loads 25kg to 2, Mechanical assistance	Get help from others

4.3. Failure Mode and Effect Analysis of the Oven

The electric oven is a heating chamber which is meant for baking foods by means of conversion of electrical energy to heat or thermal energy. An electric baking oven is widely used in industries due to their durability, efficiency and availability. They are classified as a heating chamber, thermally insulated enclosure, or small furnace that is used for material processing, heat treatment of engineering materials, sterilization of equipment and extraction of moisture from engineering materials to improve their mechanical properties such as hardness and ductility (Abdulmumuni, 2020).

CIS Nacala use a semi –industrial oven in their kitchen. The FMEA analysis is focus on electrical subsystem (heating coil, Cord and plug) and nonelectrical component the thermal fuse and thermostat (figure 4). The electric oven's block diagram was simplified to show the basic function and components which are directly dependent on the kitchen electrical system where a critical fire risk was identified in the PHA. Although, we recognize that the oven has more complex design, we believe that the selected subsystem and components are enough to the purpose of the feared event of fire in the kitchen as the FMEA will focus mainly on safety issues related to the defined feared event, and secondary on mission success and repair cost.

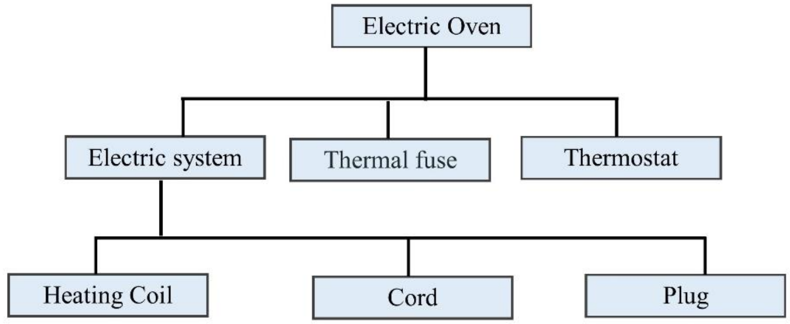

Figure 4:Block diagram of electric Oven. Source: Author

Some of the most important parts of an electric Oven are the electric system, which convert electrical energy into heat for cooking. The Electric oven feature two heating elements. One is located near the top of the oven for broiling or heating food from above. The other is located near the base of the oven and supplies heat for baking. Cooks can activate one or both heating elements, depending on cooking needs. The plug act as interface element to connect the system to a source of electricity which will be drive by the cord to the heating coil.

An electric oven's thermostat is a simple device that monitors the temperature inside the oven and disengages or engages the heating elements as necessary. The thermostat is connected to the control knobs and may also supply a digital read-out of the desired temperature or activate a light when the oven is heated to the desired level. Thermal fuse is a heat-sensitive safety feature that shuts down system when overheating is detected. In electrical wiring, the thermal fuse reacts to high temperature caused by too many amps on the electric circuit. When temperature exceeds the fuse amp rating, then the fuse trips and cuts power to electric circuit.

The table 4 shows the results of FMEA of the oven system, for criticality assessment the severity, occurrence and detectability were estimated using the annex 3, 4 and 5 respectively, for each component failure mode.

The electrical oven system has two identified failure mode (no current and current flows to ground by an alternative rout). No current failure mode can be cause by defective cord, defective plug or defective heating coil and potentials effects are cooking interruption (mission failure) and potential fire due the heat accumulation (safety failure), When current flows to ground by alternative rout may cause be faulty insulation that can lead to the electrical shock (safety failure), cooking interruption (mission failure) and in also possible fire initiation.

Table 4:FMEA/FMECA of electric oven. Source: Author

Item	Failure Mode	Failure Causes	Failure Effects	S	O	D	C	ACTION REQUIRED /REMARKS
Electrical System	no current	- Defective cord - Defective plug - Defective heating coil	Cooking interruption (mission failure) potential fire due the heat accumulation	10	4	2	80	- Use high-quality components. - Periodically inspect cord and plug.
	Current flows to ground by an alternate rout	Faulty insulation	Shock Cooking interruption	10	4	3	120	- Use a grounded plug. - Only plug into outlets controlled by ground-fault circuit interrupters - PPE
Thermostat	Open	Defective thermostat	no heat production; mission fails	4	4	3	48	Use a high-quality thermostat
	Closed	Defective thermostat	Continuous heating; food overheat (mission fails)	4	4	3	48	Use a high-quality thermostat
Thermal Fuse	The fuse fails to open when expected	Defective Thermal Fuse	fire risk due the Oven Overheat	10	4	4	160	Use a high-quality thermal fuse Periodically inspect the fuse.

Severity; O – Occurrence; D – Detection

The thermostat component has also two failure mode (remain in open position or closed position) and its assume that both are cause by defective thermostat. The failure mode can lead to cooking interruption in case of remain in open position and food overheat (mission fails) due Continuous heating in the case of remain in closed position.

The thermal fuse component has one failure mode (The fuse fails to open when expected) and its assume that is cause by defective thermal fuse. The failure mode can make the Oven Overheat with possible fire risk due the Overheat.

Those most critical failures modes are the fuse fails to open when expected and current flows to the ground by alternative rout with 160 and 120 respectively, following by no current in the electric subsystem (80) and thermostat remaining in open position or in closed position (48). Preventive and mitigation measures were recommended for each scenario.

As we can see that there are some failures mode in the oven system that can lead to initiation of fire in the kitchen its import to assess how many ways different events can be combined to generate a fire accident with catastrophic consequences. To do this analysis we will use Fault tree analysis method, because according to Ericson (2005) FMEA emphasizes on single failure in isolation and it is not geared toward multiple failures in combination although some hazards arise from other multiple hazards or events and not necessarily mechanical or electrical failure modes.

4.4. Fault tree analysis

Fault Tree Analysis (FTA) is a top-down probabilistic risk assessment technique. It is a deductive method that investigates the factors and conditions that contribute to adverse events in a system. The strength of the FTA is that it is a visual model that clearly depicts the cause and-effect relationship between the root cause events to provide both qualitative and quantitative results (Altabbakh, 2013). In this study both qualitative and quantitative approach were used to analysis de probability of fire in the CIS Nacala kitchen considering the electric oven as the Source of ignition.

In figure 5, we can see the fault tree of the top event fire in the kitchen with all defined intermediate and basic event connected by (and) and (or) gates. All that is necessary for occurrence of fire is combination of fuel, oxygen and ignition at same time and space. the oxygen is expected to be present in the kitchen trough the ventilation system and here considers as basic event, regarding the fuel we considered as basic events the miscellaneous combustible product present in kitchen (wood material, plastic material, cooking oil, etc.), grease, and food that have potential to catch fire from an ignition source.

In our case study the Oven is considered as the potential source of ignition with two immediate intermediate event (heat accumulation or oven overheat). Oven overheat is define caused by simultaneous occurrences of thermal fuse failure and power switch failure. The other branch (heat accumulation event) can caused by combination of bad contact and cord overheat. Furthermore, the cord over heat may cause by overload or half disconnection basic events, when the bad contact resulting by conjunction failure or contact failure basic events. All this Basic events can combine each other in different configurations to lead to the top event in form of minimum cut set.

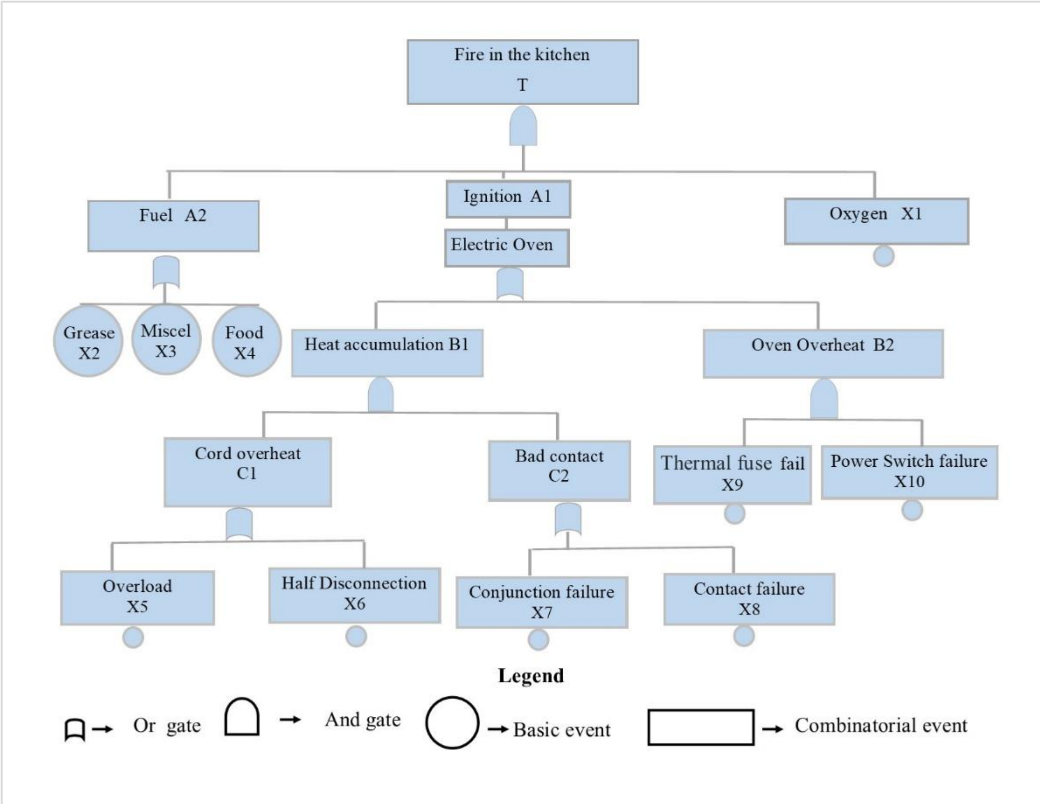

Figure 5:Fault tree diagram of fire in the kitchen. Source: Author

Minimal cut set analysis is a mathematical technique for manipulating the logic structure of a fault tree to identify all combinations of basic events that result in the occurrence of the top event. These basic event combinations, called cut sets, are then reduced to identify those "minimal" cut sets, which contain the minimum sets of events necessary and sufficient to cause of the top event (American Institute of Chemical Engineers, 2000).

In our fault tree (fire in kitchen) Boolean algebra was used to reduce equations composed of variables that can take only two values resulting in 14 minimal cut set (table 5 and 6). Selected basic mathematical rules of Boolean algebra are given in (annex 6). Conventionally, the symbol **"+"** is used to represent the logical OR operator and the symbol "." is used to represent the logical AND operator.

All 14 minimal cut sets of the top event always include one common basic event oxygen (X1), and one among the basic events of fuel branch. The definition of minimal cut set of the fault tree is important step for qualitative and quantitative analysis of a fault tree.

Table 5:Boolean expression of the fault tree fire in the kitchen. Source: Author

Step	Boolean expression for top event
1	T= A2.A1. X1
2	T= (X2 + X3 + X4) A1.X1
3	T= A1.X1.X2 + A1.X1.X3 + A1.X1.X4
4	T= X1.X2(B1 + B2) + X1X3(B1 + B2) + X1X4(B1 + B2)
5	T= X1.X2(C1.C2 + X9.X10) + X1.X3 (C1. C2 + X9.X10) + X1.X4(C1.C2 + X9.X10)
6	T= X1X2.C1.C2 + X1.X2X9.X10 + X1.X3.C1.C2 + X1.X3.X9.X10 + X1.X4.C1.C2 + X1.X4.X9.X10
7	T= X1.X2(X5 + X6)(X7 + X8) + X1.X2.X9.X10 + X1X3(X5 + X6)(X7+X8) + X1.X3.X9.X10 + X1.X4(X5 + X6)(X7 + X8) + X1.X4.X9.10
8	T= X1.X2 [X5(X7 + X8) + X6(X7 +X8)] + X1X2.X9.X10 + X1.X3[X5(X7+X8) + X6(X7 + X8)] + X1.X3.X9.X10 + X1.X4[X5(X7+X8) + X6(X7 + X8)] + X1.X4.X9.X10
9	T = X1.X2 (X5.X7 + X6.X7 + X6.X8) + X1.X2.X9.X10 + X1X3(X5.X7 + X5.X8 + X6.X7 + X6.X8) + X1.X3.X9.X10 + X1.X4(X5.X7 + X5.X8 + X6.X7 + X6.X8) + X1.X4.X9.X10
10	T= X1.X2.X5.X7 + X1.X2.X7 + X1.X2.X6.X8 + X1.X2.X9.X10 + X1.X3.X5.X7 + X1.X3.X5.X8 + X1.X3.X6.X7 +X1.X3.X6.X8 + X1.X3.X9.X10 + X1.X4.X5.X7 + X1.X4.X5.X8 + X1.X4.X6.X7 + X1.X4.X6.X8 + X1.X4.X9.X10

Table 6:Minimal cut set of the fault tree fire in the kitchen. Source: Author

Min. Cut Sets	Basic event
C1	X1.X2.X5.X7
C2	X1.X2.X6.X7
C3	X1.X2.X6.X8
C4	X1.X2.X9.X10
C5	X1.X3.X5.X7
C6	X1.X3.X5.X8
C7	X1.X3.X6.X7
C8	X1.X3.X6.X8
C9	X1.X3.X9.X10
C10	X1.X4.X5.X7
C11	X1.X4.X5.X8
C12	X1.X4.X6.X7
C13	X1.X4.X6.X8
C14	X1.X4.X9.X10

4.4.1. Qualitative analysis

the number of basic event in each minimal cut set give the order of a cut set and the significance or importance of each of them to the occurrence of top event, low order minimal cut set generally are most important. In our fault tree all minimal cut set have the same order (order 4), thus, we can qualitatively consider that all of them have the same importance to the top event fire in the kitchen. But if we look at singular basic event we can highlights as the most important (oxygen and the basic events of the fuel branch) because they are present in all 14 minimal cut set making them worth for reducing the probability of occurrence in our system.

In our system the oxygen is part of the ventilation subsystem and is crucial for the best environment conditions and correct function of the system what make it hard to prevent its occurrence, in the other hand the basic events miscellaneous combustible material, grease and food may can be reduce their occurrence be avoid the exposition to the ignition source. Electric ovens should be cleaned regularly for not only health safety but for fire protection as well. A dirty oven could have a build-up of combustible substances in it (Grease). the oven should also be placed away from other equipment to avoid heat transfer from one to the other. Any item used in oven should be cleaned along with it and should be made of noncombustible materials like metal.

The qualitative analysis of the fault tree had shown to not be enough to identify the critical path and determination of the probability of the top event, thus make it necessary the use of quantitative analysis approach of our fault tree.

4.4.2. Quantitative analysis

For the quantitative evaluation of fault tree of fire in the kitchen the probability of failures of basic events were collected and shown in Table 7, data were used to calculate the probability of each minimal cut set, the probability of top event and the importance of each minimal cut set to the occurrence of the top event (table 8). According to Ruijters & Stoelinga (2015) in reliability and risk calculations, basic events are typically rare (low probability events), so that the probability of their intersection in minimal cut sets is very small; therefore, the law of rare-event approximation is applied by summing the probability of all minimal cut set for the top event. The estimation of the failure probability of the top event by summing the individual probabilities of the cut sets resulted 2.06 x 10^{-6} /hr of probability of frequency and 1.8 x 10^{-2} of probability of occurrence in one year.

Table 7:Probability and frequency of the basic events of the fault tree. Source: Author

Basic Event	Probability	Failure frequency /10^{6} hr	Reference
Oxygen X1	1		
Grease X2	0.35		Teresa Ling, W. (1978)
Miscel X3	0.059		Teresa Ling, W. (1978)
Food X4	0.11		Teresa Ling, W. (1978)
Overload X5		2.3	Sung-Ho Hong, 2008
Half Disconnection X6		0.16	Sung-Ho Hong, 2008
Conjunction failure X7		0.3221	Sung-Ho Hong, 2008
Contact failure X8		0.0394	Sung-Ho Hong, 2008
Thermal Fuse fail X9		2.61	Sung-Ho Hong, 2008
Power Switch failure X10		1.2	Sung-Ho Hong, 2008

Table 8: Frequency and probability of the minimal cut set and the top event. Source: Author

Basic Event	Min. Cut Sets	Cut set expression	Frequency of cut set	Cut Set importance	P(Year)
Oxygen X1	C1	X1.X2.X5.X7	0.259	12.62	0.002269
Grease X2	C2	X1.X2.X6.X7	0.018	0.88	0.000158
Miscel X3	C3	X1.X2.X6.X8	0.002	0.11	0.000019
Food X4	C4	X1.X2.X9.X10	1.096	53.33	0.009557
Overload X5	C5	X1.X3.X5.X7	0.044	2.13	0.000383
Half Disconnection X6	C6	X1.X3.X5.X8	0.005	0.26	0.000047
Conjunction failure X7	C7	X1.X3.X6.X7	0.003	0.15	0.000027
Contact failure X8	C8	X1.X3.X6.X8	0.000	0.02	0.000003
Thermal Fuse fail X9	C9	X1.X3.X9.X10	0.185	8.99	0.001617
Power Switch failure 10	C10	X1.X4.X5.X7	0.081	3.96	0.000714
	C11	X1.X4.X5.X8	0.010	0.48	0.000087
	C12	X1.X4.X6.X7	0.006	0.28	0.000050
	C13	X1.X4.X6.X8	0.001	0.03	0.000006
	C14	X1.X4.X9.X10	0.345	16.76	0.003013
		Top event	2.06	100.00	0.017844

The figure 6 show the plot of minimal cute set and their importance in percentage to the top event, among the all 14 minimal cut set the most contributor is Cut set 4 (grease, oxygen, thermal fuse fails and power switch failure) with 53.33 % followed by minimal cut set 14 (oxygen, food, thermal fuse fails and power switch failure) with 16.76 % and minimal cut set 1 (oxygen, grease, overload and conjunction failure) with 12.63%. the rest of minimal cut set have contributions importance less them 10 % to the top event.

To reduce the probability of the top event the company need to do regular inspection and preventive maintenance to the oven with focus in thermal fuse, power switch and the cleaning of grease that may present in the system, because they forma a critical Path to occurrence of the top event in the failure tree. Furthermore, the operators must take 5 minutes to do a checklist of the oven to insure that the all function works properly and all components of the electric system are in good conditions before the use, never leave the oven untended when is in use and switch off the oven when work is completed.

To reduce the contribution of events Conjunction failure, contact failure, and half disconnection on the probability of the top event, the company must consider use a safety switches in the socket that supplier power to the oven. A safety switch is a device that quickly switches off the electricity supply if an electrical fault is detected, to minimize the risk of electricity-related fires, electric shock, injury and death.

Although, we know that the prevention measures are the best option of risk management, there are always chances of failure of the preventive measures and the feared event take place, in this context is desirable to have mitigation measures to reduction the negative impacts of the feared event.

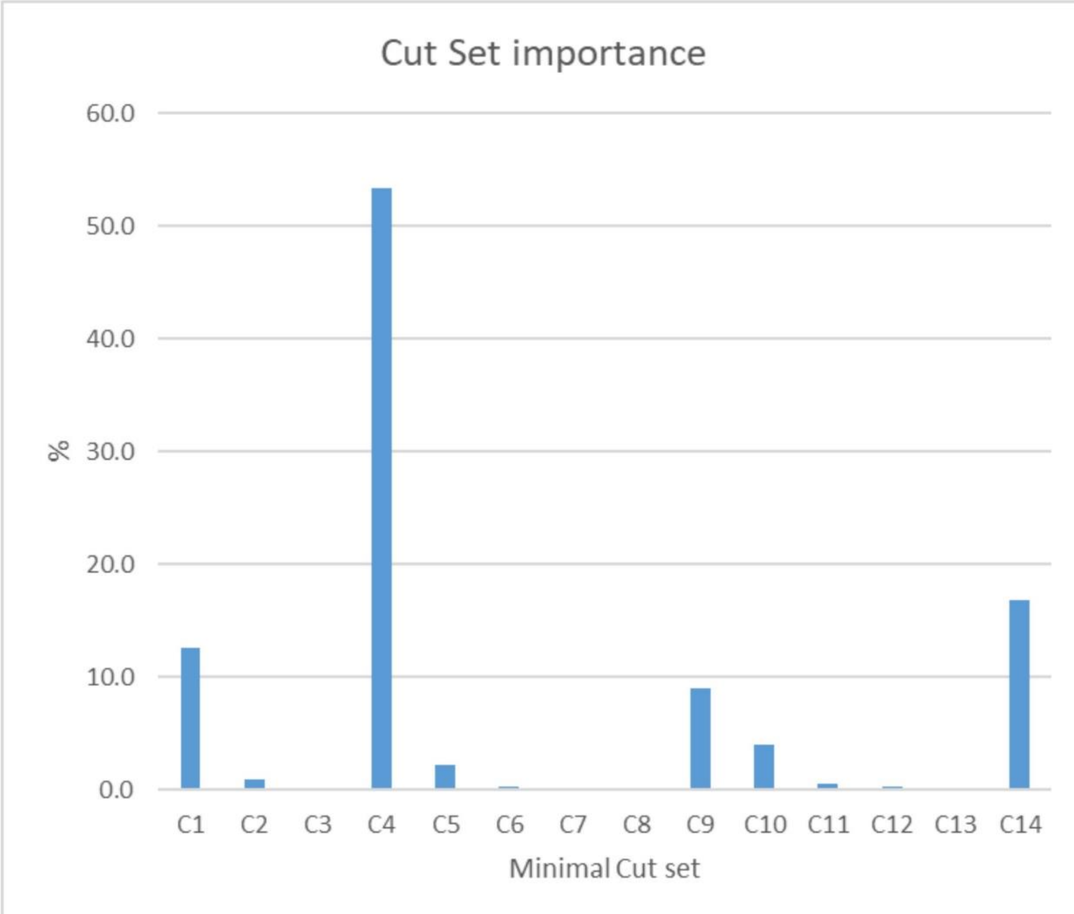

Figure 6: Importance in percentage of each minimal cut set to the occurrence of the top event. Source: Author

4.5. Mitigation measures to reduce the impact of fire in the kitchen

The event tree of the case of fire in kitchen is presented in figure 7, the system is composed of fire detection, fire alarm and fire sprinkler. we can see that when all systems fail or are not present in the kitchen the fire can lead to death or injury and extensive damage, differently when all system are in place and work properly the consequences of a fire can be reduced to limited damage.

At CIS Nacala Kitchen system fire detection and fire alarms are in place, although the fire sprinkler system is not present the company is using the fire extinguish instead. In the way the company is operating we can consider in our event tree that in case of fire the consequences can be extensive damage and the people may escape with probability of (0.0012). this scenario its seem logical because in situation of emergence may people will fail to use the fire extinguish. The company used to conduct training and simulation of case of emergence twice per year to keep the employees already to respond properly in all scenarios include fire drill, however the company should be considering the installation of fire sprinkler system to improve even more the safety system.

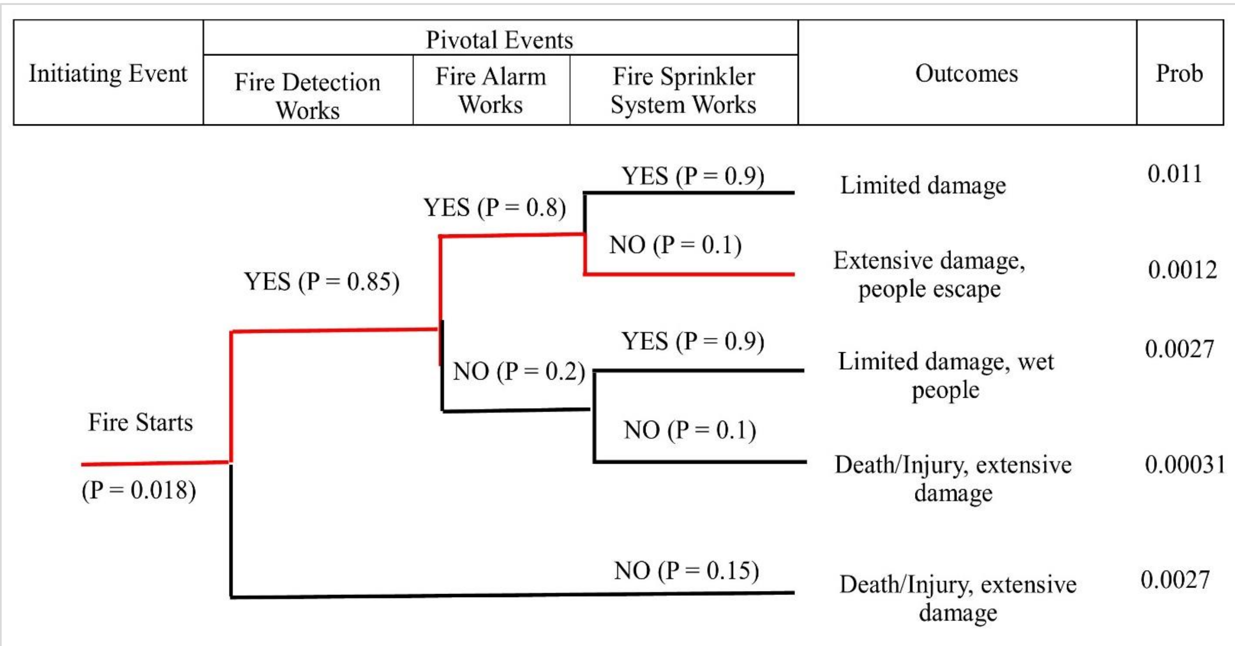

Figure 7:Event tree of mitigation measures of fire accidents in the kitchen. Source: Author

As we see in our event tree fire results in loss of life and money, thus, is necessary to have reliable and operational mitigation devices in place. In our system the first device to respond to the fire is the fire detector and considering the importance, its reliability becomes equally important. We studied its reliability to help the maintenance team to schedule the time for inspection and maintenance in safety and cost effective way. According to Prayoga et al. (2018) Risk based inspection (RBI) is the one of risk assessment methodology which optimized inspection plan on pressurized equipment based on their risk category.

To calculate de probability of failure of the fire detector (PoF) there are two parameters that must firstly be obtained for Weibull distribution, i.e. scale parameter (η) and shape parameter (β). In order to determine the value of η, Offshore and Onshore Reliability Data (OREDA) will be used in this work (annex 7). OREDA contains the failure frequency data for different process equipment that usually used in onshore and offshore oil and gas industry. For fire detector the mean failure rate for all failure mode is 4.1 per 10^6 hours that was converted to 0.036 per years using the equation 3.

$$\boldsymbol{FR = \frac{mean\ failure\ rate}{10^6}\ x\ 8760\ \mathrm{hours}} \qquad \textbf{(3)}$$

Where:

FR - mean failure rate in years

Mean Time Between Failures (**MTBF**) may be used to determine the value of η. The OREDA data follows an exponential distribution, which is a Weibull distribution with a shape factor of 1. So, assume that the shape factor is 1 and the MTBF value will be converted into a Weibull curve using a β value of 1. Therefore, the η parameter calculated using the gamma function (equation 4) is 27.84 years, as β =1, η = MTBF.

$$\eta = \frac{\mathrm{MTBF}}{\Gamma[1 + \frac{1}{\beta}]} \qquad \textbf{(4)}$$

Where:

MTBF – Mean time before failure

Γ- Gamma function

β – beta parameter

η - Scale parameter

The hazard rate (h) or failure rate for exponential distribution is constant through time see figure 8, what meaning that de fire detector has random failures (independent of age) according to the bathtub curve model, that can be cause by operational failure, dirt particles and maintenances failures. Although, we can see in figure 9 that the reliability is decrease exponentially with time (for reliability calculation the equation 5). So, is very important to choice the correct time for maintenance to reduce the probability of failure and keep the risk at acceptable level.

$$R(t) = e^{-\frac{t}{\eta}} \quad (5)$$

Where:

R - reliability

η - Scale parameter

t – time in years

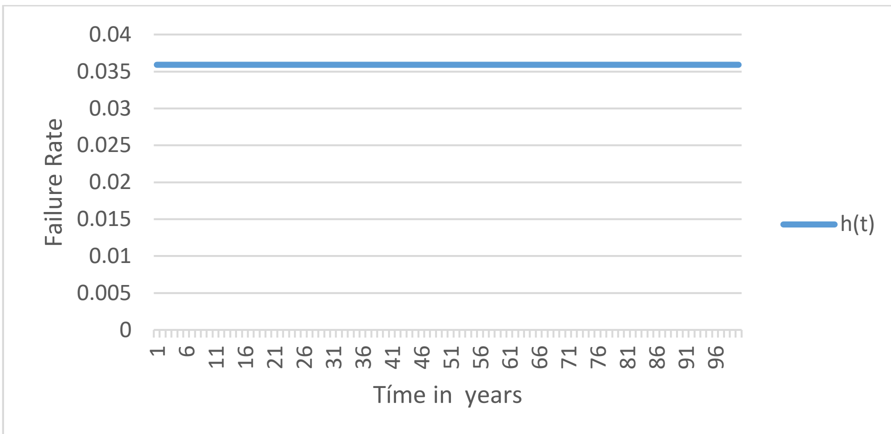

Figure 8: Constant hazard rate of fire detector time in years. Source: Author

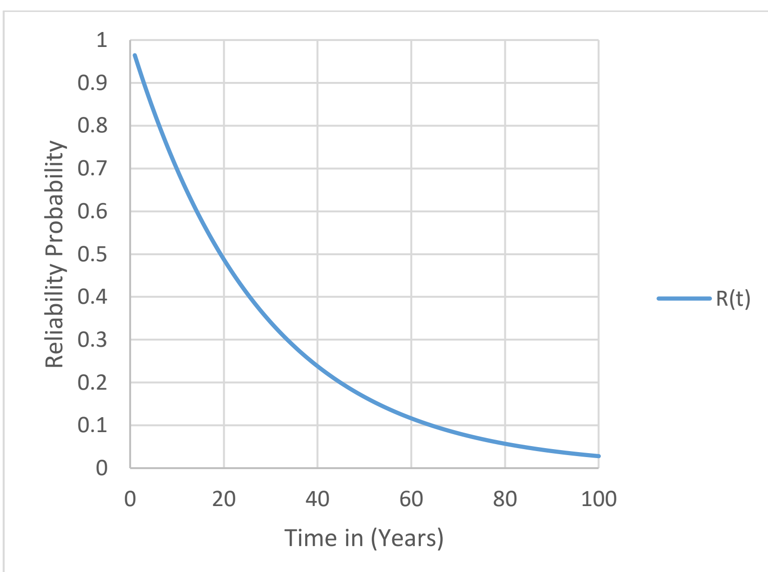

Figure 9: Exponential decrease of reliability of fire detector troughs time. Source: Author

The PoF for a fire detector at a certain time is give in equation 6:

$$\boldsymbol{F(t) = 1 - e^{-\left(\frac{t}{\eta}\right)^{\beta}}} \tag{6}$$

Figure 10 shows the exponential value of PoF and Reliability (R) using Weibull distribution. From the graph, it is shown that the PoF will increase every year exponentially. Consequently, the failure of fire detector will be grow faster year by year. Based on that statement, we can establish the acceptable PoF and find the exact time for first inspection and maintenance, for example if the company decide that would like to operate in PoF = 0.1 the inspection and maintenance must be done 3 years after the installation and the reliability will be between [0.85, 0.94] with 0.90 confidence limits on its reliability when number of failed devices is r = 13 in total of T= 369.67 years of aggregated time. Furthermore, the regular fire detector cleaning is necessary to avoid the failure cause by dirt particulars.

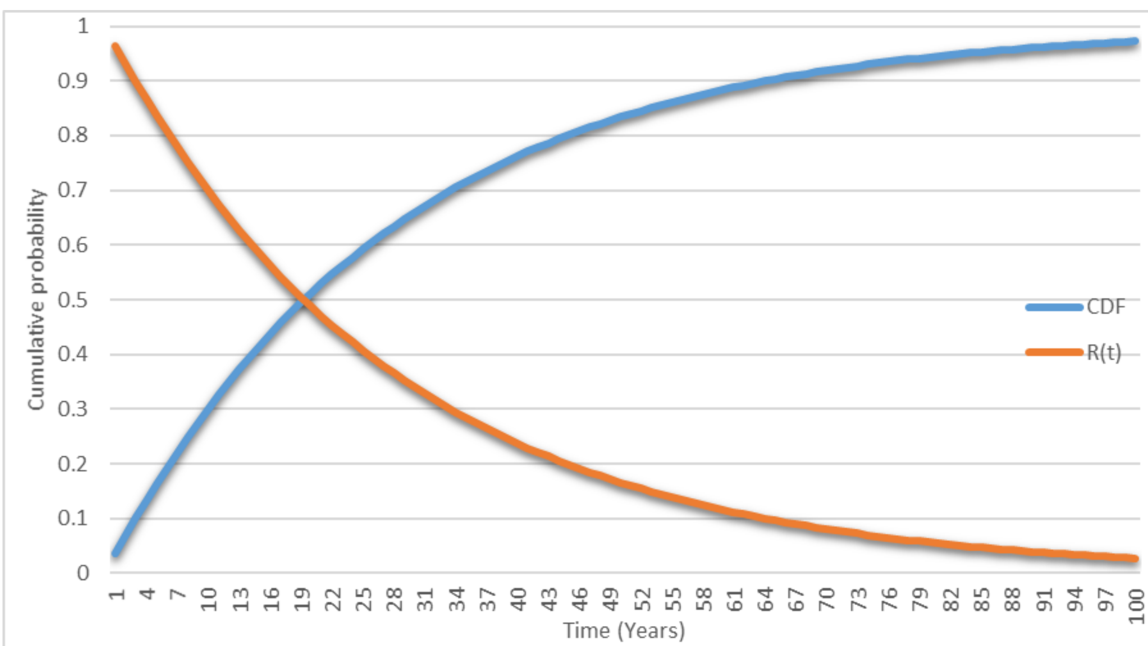

Figure 10:Plot of reliability and probability of failure of the fire detector time in years. Source: Author

CHAPTER V: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

CIS Nacala is committed to the safety, health and well-being of its employees and has established a safety policy that highlights the importance of safety above any other interest within the organization. Over the next few years, the company intends to raise the maturity level of the QSHE system from level 2 to excellence level 4. For this, the company has been carrying out a regular risk assessment in the organization and has also established performance indicators of the QSHE system.

There are many things that can go wrong at CIS Nacala kitchen system, among of then we can highlight those hazards related to the use of electricity by being responsive of two critical risk, namely electrical shock and fire. Others subsystem and components were found to have risks that varying in high (Scald & Burn, Cut, Cut and Trap, and Inhalation, Swallowing or Skin Contact of Chemical and sterile cleaning agent) and to moderate (Physical workload risks, Noise, Slip/ trip due wet floor; Exposure to smoke and hot steam and Exposure to high temperature).

The electric oven, when analyzed as an ignition source, demonstrates the existence of failure modes of some components that can contribute to the start of a fire in the kitchen. The thermal fuse component has one failure mode (The fuse fails to open when expected) and its assumes that it is cause by defective thermal fuse, the failure mode can make the Oven Overheat with possible fire risk due to the Overheat. No current failure mode can be caused by defective cord, defective plug or defective heating coil and can lead to potential fire due to heat accumulation.

Through the fault trees analysis, it was possible to identify the different basic events that can be associated to result in a fire in the kitchen, considering the oven as the source of ignition. The quantitative analysis of the fault tree points to 1.8×10^{-2} of probability of occurrence in one year of a fire in the kitchen, with the critical path as combination of the occurrence of grease, oxygen, thermal fuse fails and power switch failure, the critical path contributes with 53.33% to the occurrence of the unwanted event.

Actions such as regular oven cleaning to remove grease, avoiding placing combustible material near the oven, and preventive maintenance can reduce the likelihood of a fire in the kitchen.

When we Look at the fire the mitigations measure in use at CIS Nacala kitchen system (fire detention system, fire alarm system and fire extinguish), its conclude that in case of fire the consequences can be extensive damage and the people may escape with probability of 0.0012. The company used to conduct training and simulation of case of emergence twice per year to keep the employees already to respond properly in all scenarios include fire drill, however the company should be considering the installation of fire sprinkler system to improve even more the safety system.

5.2. Recommendations

The present study was limited only to analyzing the risk of fire considering the oven as a source of ignition, there is a need to continue the study to analyze the other components that use electricity, such as the stove, to understand how these can also contribute to the occurrence of the unwanted event of fire in the kitchen and finding ways to prevent and mitigate this type of risk.

Before applying the recommended controls for the different hazards, there is a need for the company to carry out a cost-benefit analysis of each proposal, as this type of analysis is relevant for decision-making in the management of health and safety in organizations.

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Annex

Annex 1: 5X5 risk matrix in use at CIS Nacala

	Consequence				
Likelihood	1 - Minor	2 - Medium	3 - Serious	4 - Major	5 - Catastrophic
A - Almost Certain	Moderate	High	Critical	Critical	Critical
B - Likely	Moderate	High	High	Critical	Critical
C - Possible	Low	Moderate	High	Critical	Critical
D - Unlikely	Low	Low	Moderate	High*	Critical
E - Rare	Low	Low	Moderate	High*	High*

Note: All risks that have a Critical risk classification from a qualitative analysis (using the risk determination matrix) must be re-evaluated using a Level 3 quantitative analysis.

*Consideration must be given to escalate all risks with a consequence of Major or Catastrophic and a classification of High to a Level 3 quantitative analysis.

Risk = consequence x likelihood

The fundamental rule is to define the consequence first, as different consequences have different likelihood.

Likelihood	Likelihood description	Frequency	Substance Exposure
ALMOST CERTAIN	Recurring event during the life-time of an operation/project.	Occurs more than twice per year.	Frequent (daily) exposure at > 10 x OEL.
LIKELY	Event that may occur frequently during the life-time of an operation/project.	Typically occurs once or twice per year.	Frequent (daily) exposure at > OEL.
POSSIBLE	Event that may occur during the life-time of an operation/project.	Typically occurs in 1-10 years.	Frequent (daily) exposure at > 50% of OEL. Infrequent exposure at > OEL.
UNLIKELY	Event that is unlikely to occur during the life-time of an operation/project.	Typically occurs in 10-100 years.	Frequent (daily) exposure at > 10% of OEL. Infrequent exposure at > 50% of OEL.
RARE	Event that is very unlikely to occur very during the life-time of an operation/project.	Greater than 100 year event.	Frequent (daily) exposure at < 10% of OEL. Infrequent exposure at > 10% of OEL.

Risk acceptance threshold

- Low (Class I): Risks that are below the risk acceptance threshold and do not require active management.
- Moderate (Class II): Risks that lie on the risk acceptance threshold and require active monitoring.
- High (Class III): Risks that exceed the risk acceptance threshold and require proactive management.
- Critical (Class IV): Risks that significantly exceed the risk acceptance threshold and need urgent and immediate attention.

Maximum Reasonable Outcome (MRO)

The MRO is based on the maximum reasonable consequence and the likelihood of that consequence occurring.

The maximum reasonable consequence is the largest realistic or credible consequence from an event, considering the credible failure of controls.

It is generally a higher consequence than the "most likely" consequence and less severe than the "worst case" consequence, which considers the failure of all controls.

Categories of consequence

The six HSEQ social and environmental (non-economic) consequence categories are:

- Health impact.
- Personal safety.
- Environment impact.
- Community impact.
- Compliance impact.
- Reputation (Rio Tinto or business).

There are five categories of operational (economic consequence that are to be considered as part of a HSEQ risk evaluation:

- Capital expenditure.
- Schedule.
- Operating cost.
- Production volumes.
- Revenue.

Annex 2:Consequences descriptors

Consequence descriptors

Consequence	MINOR	MEDIUM	SERIOUS	MAJOR	CATASTROPHIC
Non-Economic (Social and Environmental)					
HEALTH	Reversible health effects of little concern, requiring first aid treatment at most. Can include minor irritations of eyes, throat, nose and or skin, or minor unaccustomed muscular discomfort.	Reversible health effects of concern that would typically result in medical treatment. Can include temperature effects; travel effects; stress; and sunburn.	Severe, reversible health effects of concern that would typically result in a lost time illness. Can include acute/short-term effects associated with extreme temperature effects, or musculoskeletal effects, vibration effects, nervous system effects, some infectious diseases; and non falciparum malaria.	Single fatality or irreversible health effects or disabling illness. Can include effects of suspected carcinogens, mutagens, teratogens and reproductive toxicants, progressive chronic conditions and/or acute/short-term high-risk effects.	Multiple fatalities or serious disabling illness to multiple people. Can include effects of known human carcinogens, mutagens, teratogens and reproductive toxicants, and life-threatening respiratory sensitization and falciparum malaria.
SAFETY	Low level short term subjective inconvenience or symptoms. Typically a first aid and no medical treatment.	Reversible injuries requiring treatment, but does not lead to restricted duties. Typically a medical treatment.	Reversible injury or moderate irreversible damage or impairment to one or more persons. Typically a lost time injury.	Single fatality and/or severe irreversible damage or severe impairment to one or more persons.	Multiple fatalities or permanent damage to multiple people.
ENVIRONMENT (on site)	Near-source confined and promptly reversible impact (typically a shift).	Near-source confined and short-term reversible impact (typically a week).	Near-source confined and medium-term recovery impact (typically a month).	Impact that is unconfined and requiring long-term recovery, leaving residual damage (typically years).	Impact that is widespread-unconfined and requiring long-term recovery, leaving major residual damage (typically years).
ENVIRONMENT (off site)	Not applicable.	Near-source confined and promptly reversible impact (typically a shift).	Near-source confined and short-term reversible impact (typically a week).	Near-source confined and medium-term recovery impact (typically a month).	Impact that is unconfined and requiring long-term recovery, leaving residual damage (typically years).

Economic (operational) (based on annualised figures for operating, production and revenue)					
Capital expenditure	< 1.6%	1.6% - 5%	5% - 10%	10% - 30%	> 30%
Schedule	< 2.5%	2.5% - 7.5%	7.5% - 15%	15% - 45%	> 45%
Operating costs	< 0.6%	0.6% - 2.5%	2.5% - 7.5%	7.5% - 15%	> 15%
Production volumes	< 0.6%	0.6% - 2.5%	2.5% - 7.5%	7.5% - 15%	> 15%
Revenue	< 0.25%	0.25% - 1%	1% - 3.5%	3.5% - 7%	> 7%

Consequence	MINOR	MEDIUM	SERIOUS	MAJOR	CATASTROPHIC
COMMUNITY (community trust)	Tangible expressions of trust/mistrust amongst a handful of community members with no influence on public opinion and decision-makers.	Tangible expressions of trust /mistrust amongst a few community members with some influence on public opinion and decision-makers.	Tangible expressions of trust / mistrust amongst some community members with moderate influence on public opinion and decision-makers.	Tangible expressions of trust/mistrust amongst most community members with significant influence on decision-makers.	Widespread loss/ gain of trust across the community setting the agenda for decision-makers and key stakeholders.
COMMUNITY (stakeholders)	Key civil/political stakeholder(s) express support/ dissatisfaction informally.	Key civil/political stakeholder(s) express support/ dissatisfaction informally.	Key civil/political stakeholder(s) threaten to oppose or disengage/ strengthen offers to support or engage.	Key civil/political stakeholder(s) actively oppose or actively refuse to engage/actively support and engage.	Key civil/political stakeholder(s) actively oppose and actively get others to oppose/engaged and actively get others to support.
COMMUNITY (cultural heritage)	Reparable damage to site or item of low cultural significance.	Irreparable damage to site or item of low cultural significance.	Repairable damage to site or item of cultural significance.	Irreparable damage to site or item of cultural significance.	Irreparable damage to site or item of international cultural significance.
REPUTATION	Community complaint resolved via existing site procedures. Impact on reputation of several work areas within an operation. One off public exposure in local media, word of mouth or local mythologies.	Impact on reputation of Business Unit. Significant public exposure in local media.	Impact on reputation of Product Group. Comment from national NGO which impacts credibility with neighbours/ regional government. Public exposure in national media.	Impact on reputation of Rio Tinto Group. Comment from international NGO. Public exposure in international media.	Severe impact on reputation of Rio Tinto Group. Severe prolonged comment from international NGO. Greater than three years public exposure in international media.
CONFORMANCE /COMPLIANCE	Non-conformance with internal requirement with very low potential for impact. Non-compliance with external/ community commitment goes unnoticed by external party/ parties, requiring minimal effort to correct.	Non-compliance with external or non-conformance with internal requirement with low potential for impact. Non-compliance with community commitment, requiring limited effort to correct.	Non-compliance with external or non conformance with internal requirement with moderate potential for impact. Moderate penalties for breach of legislation, contract, permit or licence. Non-compliance with community commitment reported formally, requiring significant effort to correct.	Breach of licences, legislation, regulation or repeated non-compliance with high potential for prosecution. Breach of contract with significant penalty clauses imposed. Systemic non-conformance with Rio Tinto work cycles or standards with high potential for impact. Breach of community commitment with high potential to cause business interruption, requiring significant effort to correct.	Suspended or severely reduced operations imposed by regulators. Breach of community commitment results in direct loss of established consents with widespread secondary effects.

Annex 3:Classification of severity. Source: Soares (2015)

Punctuation	Usability	Ergonomics	Safety
10	May generate catastrophic problems or errors for the user, which the user cannot correct it. Results in the impossibility of successful completion of your task and can even affect efficiency and effectiveness. from other workers	Multiple and severe injuries. May cause disability	Death.
8-9	It may result in problems or errors. bass, very difficult for the user to correct. Affect efficiency and effectiveness of the procedure, which results in great frustration and dissatisfaction for part of the user.	It can generate complaints and absence from work. single injuries with some gravity. Can generate complaints and injuries. No there are gaps but the injuries need intervention	very serious injury and/or disability permanent.
6-7	It may result in errors or problems. moderates that generate frustration and fatigue. can compromise moderately the efficiency.	Not serious, can generate complaints for discomfort or minimal injuries	serious injury with waste of time Work.
4-5	It can generate small errors, frustration user without significant effects in the productivity or in the success of the assignment.	Multiple and severe injuries, may cause disability. He can generate complaints and absence from work. single injuries with some gravity.	moderate injury with loss of working time.
2-3	May result in minor, rare errors, that do not cause problems or miss of time	It can generate complaints and injuries. Does not exist absences but injuries need intervention.	First aid.
1	Non-significant effects	Non-significant effects	Non-significant effects

Annex 4: classification of probability or frequency of occurrence. Source: Soares (2015)

Punctuation	Probability	Frequency
10	failure is inevitable	always occurs
8-9	Very high probability of failure occur	occurs very often
6-7	high probability of failure to occur	occurs regularly
4-5	Moderate probability of failure to occur	occurs with some frequency
2-3	Slight probability of failure to occur	Occurs infrequently
1	There is no probability of failure to occur.	occurs very rarely

Annex 5:classification of the possibility of detection of the failure by the control. Source: Soares (2015)

Punctuation	**Criteria**
10	There are no known controls available to detect the failure mode.
8-9	Remote possibility that the current control detects the failure mode
6-7	Low chance that current control detects failure mode
4-5	Moderate possibility that the current control detects the failure
2-3	Very high possibility that the current control detects the mode of failure
1	The current control will almost certainly detect failure mode. Controls detection devices used in similar processes.

Annex 6:Selected Rules of Boolean Algebra. Source: Ling (1978)

Rule	Mathematical form
Commutative Rule	**A · B = B · A** **A + B = B + A**
Associative Rule	**A · (B · C) = (A · B) · C** **A + (B +C) = (A + B) + C**
Distributive Rule	**A · (B + C) = A · B + A · C** **A + (B · C) = (A + B) · (A + C)**
Idempotent Rule	**A · A = A** **A + A = A**
Rule of absorption	**A · (A +B) = A** **A + A· B = A**

Annex 7:OREDA data of fire detector failure rate. Source: OREDA (2002)

Taxonomy no		Item										
4.1.5		Control and Safety Equipment Fire & Gas Detectors Smoke/Combustion										
Population	Installations	Aggregated time in service (10^6 hours)						No of demands				
		Calendar time *			Operational time †							
103	1	3.2383			3.1580							
Failure mode		No of failures	Failure rate (per 10^6 hours).					Active rep.hrs	Repair (manhours)			
			Lower	Mean	Upper	SD	n/τ		Min	Mean	Max	
Incipient		**11***	**1.91**	**3.40**	**5.62**	**3.40**	**3.40**	**6.0**	**6.0**	**6.0**	**6.0**	
		11†	**1.95**	**3.48**	**5.77**	**3.48**	**3.48**					
Minor in-service problems		11*	1.91	3.40	5.62	3.40	3.40	6.0	6.0	6.0	6.0	
		11†	1.95	3.48	5.77	3.48	3.48					
Unknown		**2***	**0.11**	**0.62**	**1.94**	**0.62**	**0.62**	**4.0**	**2.0**	**4.0**	**6.0**	
		2†	**0.11**	**0.63**	**1.99**	**0.63**	**0.63**					
Unknown		2*	0.11	0.62	1.94	0.62	0.62	4.0	2.0	4.0	6.0	
		2†	0.11	0.63	1.99	0.63	0.63					
All modes		**13***	**2.37**	**4.01**	**6.38**	**4.01**	**4.01**	**5.7**	**2.0**	**5.7**	**6.0**	
		13†	**2.43**	**4.12**	**6.54**	**4.12**	**4.12**					
Comments												