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PhD Thesis Title

Development of Environmental Management Framework towards Sustainability in Oil and Gas industry in Libya

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Abstract:

Energy sources such as gas, oil and coal are significantly used due to worldwide energy consumption. Such use could be increased by 37 per cent in 2035. This increase comes from population growth, reaching 25 % in the next 20 years.

In order to apply sustainability systems in these institutions, an account of economically affordable and with minimum impact to the environment and technological viability must be considered. There are stringent regulations and scrutiny in the environment of using oil refining industries to be more sustainable worldwide.

Oil refining sectors produce huge amounts of waste that must be treated. This makes Waste management responsible for challenging the impacts of such waste on the environment and the high treatment costs.

This study reviews previous research and studies that have been carried out to investigate and address several issues regarding sustainability, especially the management of raw materials and waste, relying on management methods such as Lean six sigma. Furthermore, this study explores the difficulties that hinder oil companies and oil refineries from being more sustainable.

DMAIC, a component of the Six Sigma problem-solving approach, is one of the many methodologies used for quality improvement. This thesis demonstrates the empirical implementation of Lean, Six Sigma, and DMAIC for lowering the number of manufactured product faults inside the blending and filling of the mineral oils plant at the Zawia Oil refinery. This thesis employs the SPC approach to determine the factory's present performance, followed by the DMAIC methodology to examine faults and underlying causes and give solutions and suggestions for reducing or eliminating these problems. The SPC approach demonstrates that the factory's process is out of control and needs at least 22% improvement to achieve Quality standards. DMAIC and Lean &Six Sigma investigations indicate that obsolete machinery, bad material specifications, Lack of calibration of machines, and insufficient training have affected the number of faults and defects.

Also, the organic Rankine cycle is a well-established method for converting thermal energy from biomass combustion, geothermal reservoirs, and industrial waste heat. Nevertheless, its economic viability for petroleum applications has not yet been shown. This thesis investigates the feasibility of employing organic Rankine cycle devices to recover waste heat from the refinery chimney. This study mainly focuses on the refinery's problems: waste production and waste heat. The research contributes to solving this important environmental issue as a case study of the Libyan oil and gas industry.

Contents

List of Tables

List Of Figures

List of Abbreviations:

LSS	**Lean six sigma**
EM	Environmental Management
NOC	National Oil Corporation
I.N.C	Azzawiya Oil Refining Company
EGA	Environment General Authority
LGSS	Lean–Green–Six Sigma
LCA	Life Cycle Assessment
EIA	Environmental Impact Assessment
OGI	Oil & Gas Industry
PRI	Petroleum Refinery Industry
EU	European Union
GDP	Gross domestic product
USEPA	United States Environmental Protection Agency
GHG	Green House Gas
ORC	Organic ranking cycle
OECD	Organization for Economic Co-Operation and Development
DMAIC	(Define,Measure,Analyse,Improve and Control)
UN	United Nations
VOCs	Volatile organic compounds
QMS	Quality management systems
DPMO	Defects per million opportunities
DMADV	define, measure, analyse, design, verify
GE	General Electric Company
TPS	Toyota production system
DOE	Design of experiments
CSFs	Critical success factors
CAGR	compound annual growth rate
ICE	Internal combustion engine
CTQ	Critical to Quality

Chapter 1: Introduction

1.1 Background of Research

Sustainable growth and environmental and protection are not always regarded as being significant in order for businesses to generate profits. In the 1980s, environmental regulations were made strict to ensure compliance and all progressive organizations had to abide by these rules (Berry and Rondinelli 1998). The regulations were mainly produced to control pollution at the end of the pipelines during the 1980s (Stuart 2000). Dahlmann, F., Brammer, S., & Millington, A. (2008). Environmental management in the United Kingdom: new survey evidence. Azzawiya Oil Refining Company Retrieved from reported that between 1985 and 1995, environmental work in the manufacturing field was being driven more by internal strategy due to the increasing environmental expectations from the different stakeholders. According to other research (Rosen 2001), sustainability and environmental issues were then being regarded as strategically important.

The Brundtland Commission's report "Our common future", expanded the definition of sustainable development to include not just then-current environmental concerns but also economic and social considerations. (Sarkis et al. 2010). Significant pressure was placed on oil-producing countries in the Middle East by the United Nations Environment Programme (1997) to show a better environmental record. According to Ibrahim, (2006), Libya’s petroleum industry sector must recognize this demand, as the industry provides approximately 90% of Libya’s revenue. As reported in June 2014, Libya had Africa’s largest crude oil reserve: around 48.5 billion barrels (N.O.C, 2019).

The concept of sustainable development is now more widely recognized, as, according to the World Commission on Environment and Development, it is concerned with “meeting the needs of the present without compromising the ability of future generations to meet their needs. In this case, organizations were meant to manage their industrial operations, with the environmental impact and the sustainability of resources given full consideration. According to one study (Deegan and Gordon 1996), these expectations were put on environmentally sensitive manufacturing processes, including the oil and gas sectors. A lot of attention has been placed on those industries in connection with sustainability research to be related to scientific and technological advances (e.g., innovation in carbon technology and water efficiency, as well as engineering.

As human activity increases, the environment is one of the most important resource as human activity increases, yet it also faces several dangers and possible harm. However, the environment is a vast resource and the wellspring of all human endeavours (Roudneshin and Azadeh 2019). Waste management is one of the most important aspects of reducing environmental pollution and maintaining public safety, but some nations, like Libya, do not consider this of the most important aspects of reducing environmental pollution and maintaining public safety is waste management, but some nations, like Libya, do not take this into account. For instance, Otman and Karlberg (2007) found that the city of Jalo, which is located to the southeast of the city of Benghazi with a population of about 32,000 people, is a strategic and important centre for natural resources, such as gas and oil. Jalo suffers from environmental pollution due to the exploitation of non-renewable resources by various oil and gas firms. According to the National Oil Corporation and the human rights organization on noticeable climate change in the oasis area in general and the city of Jalo in particular (Lima et al., 2017). This conclusion was drawn during a study on the effect of waste on the natural environment. It was discovered that the waste from the oil fields adjacent to the city was causing environmental pollution. The study further revealed that various people in that region suffered from skin diseases and cancer, in addition to high rates of infertility and respiratory disease.

1.2 Research Problem

The abundant natural resources are the main sources of revenue in most developing countries, especially in Africa. Thus, the economies of these countries depend largely on resources such as oil, coal and gas. Utilizing and processing these resources could have a negative effect on the environment by causing air and water pollution. (Omoju 2014). However, for many countries, including Libya, maintaining and increasing financial growth and reducing poverty means that oil exploration and exploitation will be the main financial source of their national income.

Libya: The Urgent Transition to Environmental Sustainability Goodland, (2013) confirms that the petroleum sector struggles from several forms of primary environmental degradation. Furthermore, Goodland (2013) asserts that there are not enough studies in Libya that look into different ways of making the petroleum sector environmentally friendly. Irhoma, Su et al. (2014) agree with Goodland and suggest more studies need to be done in the petroleum field to provide better solutions and support decision making to make the sector more environmentally responsible.

Several studies have been carried out in Libya in the area of environmental sustainability, such as those conducted by (Bindra et al. 2014, Mohamed, Al-Habaibeh et al. 2013, Goodland 2013, Al-Drugi and Abdo 2012, and Saleh and Ibrahim 2006). Other study in the field of general quality improvement was carried out by Gibson, Hassan et al. (2013). However, it can be stated that this study was not specifically related to the petroleum sector. In this sense, the Libyan petroleum industries face many challenges if they are to implement sustainable development and tackle the air pollution that is caused by the refineries. Furthermore, environmental research conducted on one of the state-owned oil enterprises in populated locations such as Tripoli; home to a number of storage facilities and Az Zawiya; where the Az Zawiya refinery is located has indicated that there are high levels of soil contamination (Ragothaman and Anderson 2017).

During the economic sanctions imposed on Libya by the United Nations (UN) in the 1990s, there was a technological and equipment shortage in the refineries. Refineries are regarded as a potential source of atmospheric emissions of carbon monoxide (CO), methane (CH_4), volatile organic compounds (VOCs), which include hazardous substances such as benzene, sulphur, nitrogen oxides, carbon dioxide (CO_2), and heavy metals were reduced in supply (Rayegan, 2011). However, certain advances have been suggested for low-temperature sources of power, and in order to power freestanding units that makes use of resources which cannot be utilized effectively for direct thermal applications.

Two research problems were identified and the following research problem statements are addressed in this thesis based on a comprehensive literature analysis and consultation with individuals with extensive practical expertise in the same oil and gas sector.

- Determining the extent to which lean and Six Sigma methodologies and quality management systems (QMS) can assist Libyan oil and gas firms in overcoming their managerial and environmental issues and enhancing project performance.
- Defining the kind of lean and Six Sigma implementation framework that could guide Libyan oil and gas businesses in using these methodologies.

1.3 Research Gap

The geographical application of sustainability and a lean/Six Sigma approach hardly covers developing and developing countries, despite studies from underdeveloped, emerging, and developed countries having been conducted on lean/Six Sigma methodology and the sustainability issue that has been partially addressed by developed countries. In these countries, the relationships between sustainability and lean/Six Sigma have not been fully deliberated. In line with that, and the fact that many investors have moved their production to underdeveloped nations due to climate change and low labour costs, it is necessary to study these countries. According to Sandhu et al. (2012) and Economy and Lieberthal (2007) the governments of most developing nations place a greater emphasis on economic growth than on social and environmental issues, which contributes to rising rates of growth, especially in highly polluting and resource-intensive industries. Nevertheless, the Organization for Economic Co-operation and Development (OECD) (2012) asserted that the potential social and economic effects of environmental dilapidation are essential for developing countries to consider when they are fully independent (Cherrafi et al. 2016).

Integrating lean/Six Sigma with sustainability is a topic without enough studies. Lean/Six Sigma can help businesses improve their economic, environmental, and social performance, claims research Park and Linich (2008), it could also play a significant part in sustainability. Lean/Six Sigma and sustainability have produced any models, approaches, and framework sizable number of models, approaches, and frameworks when compared to other streams.

According to Folinas, et al. (2014), Hassini, al. (2012), Cabral, et al. (2012), Carvalho, et al. (2011), and Carvalho & Machado (2009), many of the studies in this area have focused on the supply chain context, whereas the paper, by Verrier et al. (2016) was designed to demonstrate the manufacturing areas and logistics. In order to produce consistent performance measures, summarise diverse and complicated indicators, and promote sustainable supply networks, a structure for sustainable supply chain metrics was developed by Hassini et al. (2012). However, no details were provided of the various sub-indicators and measures that different processes and industries could utilize because they rely on the nature of the strategies and operations followed by each partner. Thus, inadequate measurement methods and models are designed and tested for particular processes and industries.

Since there are specific processes and a variety of requirement, for specific metrics industries as indicators, Banawi and Bilec (2014) provided a framework based on the DMAIC; (Define, Measure, Analyse, Improve and Control) improvement cycle for integrating lean/Six Sigma and sustainability philosophies for the construction industry in order to decrease its environmental impacts. This framework has been developed and tested for industrial construction but the results might not be applicable everywhere across various countries and different sectors. In this study, a survey was sent out to the construction professionals in connection with the primary factors of waste in the activities in their industry. These factors were identified as design changes during construction, which are responsible for 60% of the waste that occurs during construction. It can be stated that the Lean–Green–Six Sigma framework offered a multi-stage and comprehensive approach to improving and minimizing life cycle environmental impacts (Banawi and Bilec 2014).

In order to improve and evaluate complicated products, Cluzel et al. (2010) offered a unique eco-design technique that incorporated Lean Six Sigma and Green concepts. This methodology is based on the DMAIC approach, which encapsulates the entire eco-design process and allows for an understanding of system complexity. The framework, however, was created and tested for an eco-design process and may not be suitable to various processes. Additionally, it might be expected that the suggested methodology could handle the eco-design project for complex systems; yet, it is still evident that some stages are still challenging, with the challenge arising during the life cycle assessment's goal, definition, and inventory phases (LCA).

Therefore, it can be said that most frameworks, models, and procedures are created for specific manufacturing processes and specifications. Lean/Six Sigma and sustainability models, processes, and frameworks must be developed methodically in this situation, and their applicability must be validated by testing it in real-world settings. Developing an integrated model that can be used in several industry sectors and various organizations with diverse functions and sizes is currently a very desirable aim. Therefore, the goal of this research is to create an integrated environmental management framework that will serve as a set of guidelines and inputs for an industrial organisation to increase performance in a sustainable manner and lower pollution levels. (Matteo 2012).

1.4 Research Questions

Q1: What is the environmental impact of oil refineries in Libya?

Q2: What impact does introducing the lean/Six Sigma technique into the waste management process have on lowering the environmental impact?

Q3: How can sustainability challenges and problems be addressed to reduce the environmental impact caused by oil refineries in Libya?

1.5 Research aim

The main aim of the research was to develop an environmental and management framework towards the sustainability of the oil and Gas refinery industry in Libya. This research was also aimed at implementing management methods, such as lean and Six Sigma, to develop a model for analysing results, improving internal practices, and reducing emissions emanating from the factories of the sector.

1.6 Research Objectives

The specific objectives of the research were as follows:

1. To carry out a critical review of relevant literature on the concept of systems of sustainability and environmental impact and waste management in the oil and gas industry.

2. To conduct research, describe the evolution of and explain the environmental business benefits that can be gained from using lean and/or Six Sigma (LSS) approaches towards sustainability.

3. To explore the extent of the practice of sustainability in industrial establishments in Libya as well as identifying the obstacles to the implementation of approaches towards sustainability through the gathering of qualitative and quantitative data in a case study.

4. To develop a novel framework to implement sustainability based on lean and Six Sigma methodologies in an oil and gas refinery.

5. To assess and authenticate the developed novel framework based on data collected from the Libyan oil and gas industry.

1.7 Structure of Thesis

The thesis is composed of seven chapters that each relate to a different set of study goals and the methodology that was chosen for the research, as follows.

Chapter One (1): A summary of the research project, research subjects and their importance, the purpose and goals of the research, and a summary of the thesis structure are provided in this introduction chapter..

Chapter Two (2): This chapter contains an introduction to the research and presents a comprehensive review of the literature, the methodology and an overview of the philosophy, strategy, and tools used in the conduct of the research.

Chapter Three (3): In this chapter, the research approach is introduced. It also gives a general summary of the technique and research strategy that were applied to the entire study. However, it describes in detail the process used to select the research methodology and the analytical tools and procedures that were utilised to validate the research.

Chapter Four (4): This chapter covers the development and validation of the integrated LSS model. The critical success factors (CSFs) required to implement LSS successfully are discussed after an explanation of the conditions for merging lean and Six Sigma approaches. The LSS model's development is covered in this chapter, along with its main component's definition and the steps necessary to implement it. It also describes the steps required to validate the model, shows the results of the data analysis, and, ultimately, offers a detailed analysis and some views on the conclusions made in the chapter.

Chapter Five (5): This chapter contains the application of Lean Six Sigma tools in the various stages of the proposed framework by verifying the causes that led to the problem of wastage in production and then suggesting appropriate solutions and recommendations for reducing waste.

Chapter Six (6): This chapter raises the problem of heat loss from oil facilities, especially those run by oil refining companies. Through a case study in Libya, the wasteful amounts of heat from chimneys are verified and treated by proposing solutions that ensure the installation of ORC systems.

Chapter Seven (7): This chapter summarizes the answers to the research questions and presents the contributions the study makes to the body of knowledge. The implications of the study are then discussed and the chapter concludes by offering suggestions for potential future lines of inquiry.

Chapter 2: Literature review

2.1 introduction.

There is a lot of pressure on companies worldwide from regulators, consumers and other stakeholders so that their operations can be managed responsibly to improve their environmental and social performances. Currently, many challenges face societies, such as climate change, pollution, poverty, population growth, inequity and energy costs, to name but a few. Therefore, reducing the negative social and environmental impact and improving sustainability performance is necessary (Reyes, 2015). There are some complex problems that companies are encountered, such as obtaining success via strategies which are supportive and compatible with social and environmental sustainability (Bae et al. 2011).

According to (Found 2009, Khor 2012, and Wilson 2010), efforts to improve the social and environmental sustainability of industrial processes have been seen traditionally as obstacles to the economic sustainability of businesses. However, recently several organisations found that such efforts result in improving the satisfaction of the employees and the reduction of operating costs (Simboli, et al., 2014); (Corbett and Klassen, 2006). According to Chiarini (2014), it has been argued that adopting management systems to address the current global sustainability challenge has been looked at. Six sigma and lean manufacturing have thus come to represent the core components of the sustainability solution.

This report has used papers and books before the year 1990. The relevant research articles have been found utilising search engines of renowned publishers' electronic databases such as ScienceDirect, google scholar, and google chrome. Various keywords like Lean Six Sigma, Six Sigma, Green Lean Six Sigma, sustainability, oil and gas refinery, waste management, and waste heat have been used to find the articles relevant to current research.

2.2 Review of the Petroleum Refinery Industry (PRI)

The oil refining industry is part of an integrated business that represents "The Oil Industry" as indicated in Figure 2.1.

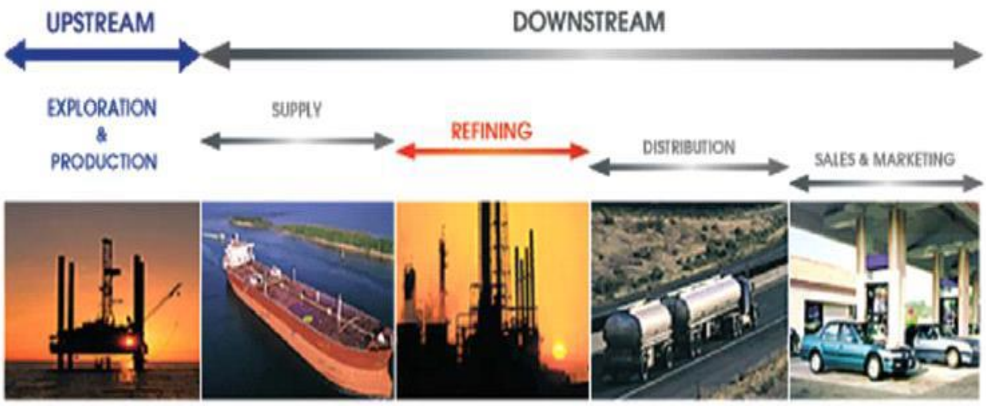

Figure 2.1 Refining in the oil industry context (Source: Europia, 2012, p 2)

A recent study on sustainability in OGI projects was carried out to integrate sustainability elements and explore threats and opportunities in oil and gas companies' settings (George et al., 2016). However, some other studies found an increase in spending on activities related to sustainability matters, including industrial energy management and environmental remediation among petroleum organisations based in the United States (Hasheminasab, Gholipour et al. 2018). It has been noted that rising expenditures do not reflect the determined efforts to embrace sustainability, particularly as new cost-effective methods of extracting unconventional adverse reserves impact the environment and have made renewable energy less competitive (Lozanova, 2014).

According to Pulver, 2007, companies such as Oil & Gas industry (OGI) have been blamed for 'greenwashing' in their corporate reports and marketing campaigns. They have realised that incorporating sustainability and long-term thinking into the operations of OGI could decrease their profits. Therefore, OGI firms' budget is wanted to be spent on competitive investment opportunities. In this case, these companies focus mainly on developing other cleaner methods by using fossil fuels, such as sequestration technology and carbon capture, instead of concentrating on renewable energies such as hydropower, solar and wind

(Webb, 2009). The huge worldwide reliance on non-renewable energy nowadays is the main source that leads the oil industry to have existed; however, any effort to minimise the negative impact of this manufacturing has to be encouraged and supported regardless of how little it is (George et al., 2016).

According to (Hasheminasab, Gholipour et al. 2018), there are many sectors within OGI. Petroleum Refinery Industry (PRI) is a main area because it provides crucial products for buildings, transportation and many other industries, to name but a few. There are a huge number of people who are employed by PRI worldwide. For instance, in the EU, there are approximately 140,000 people employed directly in various facilities of PRI; about 600,000 people are involved with the sale of products and distribution; more people have jobs that are indirectly related to PRI (Brussels 2015).

PRIs are vital contributors to GDP by providing technical know-how and high-skill jobs. PRIs are also a valuable, integrated part of the manufacturing supply chain. In Europe alone, this sector creates an annual income of 23 billion Euros, and the fuel taxes provide about 270 billion Euros in revenue (Brussels 2015). In addition to the production of transport fuels, PRI commodities are utilised as feedstock for further downstream processes, which contribute to a huge range of goods that are used daily. For example, the products of PRI are utilised as agricultural fertilizers, plastics in packaging, detergents in domestic cleaning, and synthetic fibres in clothing (Hasheminasab, Gholipour et al. 2018).

The close incorporation of PRI with other sectors, including petrochemicals, strengthens such valuable industries. In addition, it is difficult to change these products and their feedstock with any sustainable and valuable alternatives. Although this study focuses on PRI projects, it is also associated with OGI projects in several ways. Because of negative sustainability effects, especially long-term economic problems due to maintenance and safety costs as well as the human and environmental lifestyle effects in the area of construction sites, OGI is fundamentally an unsustainable industry. Thus, this study is aimed to reduce such negativity.

Oil refinery projects can impact the country’s social development, the environment and the sustainability of economic development. With this in mind, planned decisions of developing OGI projects could be done by considering all the features of the sustainability of the life cycle.

2.3 Main Environmental Issues in the Refining Sector

Refineries are important manufacturing places because they manage and deal with large amounts of products and raw materials. In addition, they use a lot of water and energy and water to carry out many industrial processes. Refineries produce air, soil, water, and atmospheric emissions in their refining and storage processes. The management of the environmental is becoming a main element for refineries. The refining industry is not immature, so much work has been carried out to reduce the emissions produced by these refineries. Thus, it can be said that there is a huge decline in emissions generated by refineries per tonne of crude processed, and the decline is continuous. The tables illustrate the refineries' most significant pollutants (Chaugny et al., 2015).

2.4 Atmospheric emissions

The European emission inventories [EEA] (Cheng et al., 2012), confirmed that oil refining is responsible for an important part of emissions. Such emissions are generated by industrial activities where the emission of sulphur oxides is around 7%.

Figure2.2: Emissions in air (T. Siddiqui, 2015)

2.5 Water emissions

Petroleum refineries use water continuously to keep water flowing in the steam, water for cooling, emergency water supply for fire fighting, circuits and utility service water. In addition, water is also utilised for process and the purposes of maintenance.

Figure 2.3: Emissions of water (T. Siddiqui, 2015)

2.6 Solid waste

Three types of materials for treatment of oil waste in refineries. Sludges, both non-oily examples from (wastewater treatment facilities) and oily type (from tank bottoms), another form of refinery waste, such as semi-liquid, miscellaneous liquid, or solid wastes (e.g. oily wastes, contaminated soil, incinerator ash, spent chemicals, spent caustic, acid tar, spent clay, spent catalysts from conversion processes) and; non-refining wastes including demolition, domestic and construction (Jafarinejad, 2017).

2.7 Soil and groundwater contamination

The historical losses of products somehow contaminate the majority of them. Previously, there was inadequate and low awareness of the risks of such contaminations. However, the present refineries are made to prevent leaks and spillages to the ground. It is vital to prevent and remedy any spillage and leakage in the refineries and the surrounding areas.

Table 2.1: Main solid wastes made by refineries. Source: [161, USAEPA 1995]

Non-oiled materials	Spent catalyst (excluding precious metals)	Residue conversion catalyst, hydrodesulphurisation/hydrotreatment) catalyst, fluid catalytic cracking unit catalyst, polymerisation unit catalyst.
Solid materials		Oil spill debris, contaminated soils, packing, lagging, tar rags, activated carbon, filter clay acid and filter materials.
Oiled materials	Oily sludges	Tank bottoms, interceptor sludges, biotreatment sludges, treatment sludges, waste water desalter sludges. Contaminated soils.
Drums and containers		Plastic, Metal, paint, glass.
Other materials		FGD wastes, resins, desiccants and absorbents, boiler feed water sludges, neutral sludges from alkylation plants.
Radioactive waste (if used)		Laboratory waste, catalysts.
Mixed wastes		Vegetation, domestic refuse.
Construction/demolition debris		Concrete, mineral fibres, asbestos, asphalt, plastic/ scrap metal, wood, soil.
Waste oils		Recovered oils, cut oils, Lube oils, engine oils transformer oils.
Pyrophoric wastes		Scale from tanks/process units.
Scales		Rust, leaded/unleaded scales.
Spent chemicals		Caustic, additives, acid, solvents, laboratory, MEA/DEA (mono/diethanol amine), sodium carbonate TML/TEL (tetra methyl/ethyl lead).

The main sources of oil contamination in groundwater and soil are often found along the pipeline from crude to finished products, where hydrocarbons are handled and processed before being lost to the earth. These are frequently related to the movement, handling, and storage of either liquid hydrocarbons or liquids containing hydrocarbons. There is also a chance that other substances, including trash or catalysts, could contaminate the water. (Barthe, Chaugny et al. 2015).

Figure 2.4: Untreated oily waste and oil sludge burial site (Edwan Kardena, 2015)

2.8 The environmental indicator

Table 2.2 Environmental sustainability factors (Hasheminasab, Gholipour et al. 2018).

Indicator	Factor
Atmosphere	➢ Level of noise pollution due to project/plant construction/Operation. ➢ Emissions of greenhouse gases per ton of refinery product (CO2, N2O, CH4, HFCs, CH3CCl3, CCl4, CCl3F, C2Cl3F3, CCl2F2) ➢ Levels of selected contaminants in air caused by to refinery operation: Acid Gas (SOX, NOX), VOCs, CO, Ozone, Hydrocarbons, H2S, NH3. ➢ Level of hazardous chemicals (HAPs) and wastes per ton of refinery production.
Water (Fresh Water, Ocean, Sea, Coast)	➢ Level of integrity in water resource management in different process units. ➢ Percentage of wastewater safely treated to standard levels: Sanitary Sewage water. Cooling Water, Storm Water, Process Water. ➢ Number of local businesses and households affected by water contamination. ➢ The proportion of wastewater contamination in the refinery output to absorbable pollution by water resource (sea, river, etc.). ➢ The refinery efficiency in water resource usage.
Land and Soil Pollution	➢ Level of soil degradation due to construction/operation of the project/plant. ➢ The amount of solid waste produced by refinery per ton of production. ➢ Level of Protection to landscape and historical sites.Recycling rate and percentage of industrial waste reuse. ➢ Per capita waste generation (in kg) for refinery employees. ➢ Residence status of the project area (the number of households within a radius of 50 km). ➢ Level of contaminants in soil per ton of refinery production.
Natural Resource	➢ Renewable energy share in the total energy of refinery final energy consumption. ➢ The extent to which the refinery can satisfy the demand of "non-solid fuel". ➢ Percentage of required refinery procurement with approved LCA sustainability assessment documentations (Equipment, material, etc.). ➢ Indicator of crude oil efficiency (ratio of crude oil to product). ➢ Natural resource utilization per refinery worker, as well as per unit production in the refinery.
Biodiversity	➢ Percentage of vegetation coverage in the refinery site and local region. ➢ Level of damage to fauna by refinery construction and operation. ➢ Level of damage to the flora by refinery construction and operations

PRI facilities contribute massively to the emissions of Green House Gas (GHG), bio-contamination, toxic chemicals, land and natural resource degradation, noise effects, ambient particulate matter, industrial sewerage, among other negative effects. According to USEPA (2015) and Hadidi et al., (2016), PRI helps to emit gases which usually contain groups of extremely reactive gasses as described by the National Ambient Air Quality Standard (NAAQS). This study divides environmental indicators into the atmosphere, soil pollution and land, biodiversity, natural resources and water (coast, ocean, fresh water, sea). The following table provides more explanation about these factors(Alexander, 2015).

2.9 The social indicators

Table 2.3 social sustainability factors (Hasheminasab, Gholipour et al. 2018).

Indicator	Factor
Health	➢ Annual number of project/plant manpower death because of cardiovascular disease, cancer, or chronic respiratory disease as a result of exposure to toxic gasses and other substances in the refinery ➢ Annual number of project/plant manpower getting sick because of poisoned and unhealthy food and water ➢ Population in local areas in the vicinity of the project/plant exposed to outdoor air, water, and soil pollution caused by the refinery.Total recordable occupational illness frequency (TROIF)
Safety & Security	➢ The extent of damage to local cultural heritage as a result of petroleum refinery project/plant construction/operation. ➢ Level of health and educational facilities in order to prevent accidents' occurrence. ➢ Number of people having accident in the project/plant per annum ➢ Frequency rates of fatal and non-fatal occupational injuries
Education& Training	➢ Number of people who are trained and develop practical skills in the project ➢ Participation rate of owner/operator in formal and non-formal education and training of staff ➢ Percentage of staff who are computer and information literate in the project ➢ Number of schools and training centers established in project/plant accommodation and local city

According to (Ehrenfeld, 2004), sustainable development is “the feasibility in which people and other creatures can flourish on the earth everlastingly”. Therefore, every development requires satisfying human needs and sustaining social development. In this case, the development of every construction, PRI and OGI project is meant to satisfy the various needs of humans. It has been reported that the growing sustainability framework and scope and the social dimension of such framework increasingly lack the scientific basis and operational considerations; hence, further development is needed(Christen and Schmidt

2012). What has to be known is that developing these projects should not result in difficulties for humans and unsustainable social development.

Social sustainability factors are first defined by the use of the United Nation's 2015 indicators (UN, 2016), and then they were translated by the needs of PRI projects**.** Social sustainability indicators include safety and security, education and training, and health. The following table shows the social sustainability factors.

2.10 The economic indicators

The tendency of petrochemical industries is focused on reducing production costs and consistently increasing product quality simultaneously. In addition, another major economic concern in the current market, which witnesses soaring unpredictability of energy costs, is the inadequate dependability in the estimations of earning (Neelis, 2008). This seems to complicate the stance of the economy in the projects of PRI. What is more is that the economy relies massively on worldwide political strategies and subsequently, an unstable economy with several fluctuations which affect profoundly the availability of raw materials. However, the economy's performance directly affects the availability of the petroleum products which, in return, will add to its complexity.

The projects of OGI are fascinating economically so that governments most of the time want to find any opportunity that helps to develop new projects. In this context, for instance, the USA petrochemical industry recruits approximately 160,000 people and creates product shipments of $83.2 billion and value added of $88.5 billion (Neelis 2008). Therefore, every operator and owner in this company seeks to improve profit margins, reduce costs and enhance product quality.

The consumption of energy, occupation, financial and the performance of the economy are the indicators for the development of the economy. The following table presents economic sustainability factors.

Table 2.4 Economic sustainability factors (Hasheminasab, Gholipour et al. 2018).

Indicator	**Factor**
Energy consumption	➢ Required energy intensity per unit of value added ➢ Achievement rate of the designed energy usage in the operation phase ➢ The efficiency of electricity production in the refinery (output to input) ➢ Achievement rate of the designed energy usage in the operation phase
Financial	➢ The level of international cooperation in the refinery project in order to facilitate access to clean and sustainable energy that is consumed in the project ➢ The amount of initial investment or forecasted budget of the project ➢ Net present value of refinery life cycle costs (including operating costs, maintenance, overhaul, etc.) ➢ Refinery internal return ratio (IRR) ➢ Net present value of refinery life cycle profits (including product sales, etc.)
Economic Performance	➢ Ratio of created jobs in the refinery project/plant to job opportunities in other available alternative projects ➢ Level of refinery participation in increasing GDP ➢ Amount of financial losses due to climate change and natural disasters risks in the refinery project/plant ➢ Growth rate of GDP per capita per employed person in the refinery Level of refinery participation in inclusive wealth
Occupation	➢ Number of illiterate and unskilled workforce who acquire skills in the refinery project/plant ➢ Number of job opportunities created by the refinery and local economic boom within different phases of the project ➢ Unemployment rate in different phases of the project due to different human resource demand (hiring and firing)

2.11 Libyan Petroleum Laws

The Libyan petroleum Law (25/55) was established in 1955. This law is regarded to be outdated because it does not include the new considerations and aspectsof sustainability practices and the development of natural gases (Petroluem Law, 1955). Presently, the ministry of Libyan energy is proposing a new law that can deal with the limits of the present petroleum legislations to produce a united national law that includes the whole aspects of the hydrocarbons sector (EIA, 2014). Concerning environmental protection, Libya has produced several legislations regarding the environment which are explained below:

2.11.1 The Environmental Law No. 7 of 1982

Law number 7 1982, which the Libyan government established, stresses environmental protection. This act is regarded as the first important act concerned with environmental stewardship. It provides full environmental meanings and definitions. There are eleven chapters within this legislation which split into 75 articles. Chapter One contains general provisions. The protection of air is dealt with it in Chapter Two. Chapter Three centres round protecting seas and marine. Protecting water resources is dealt with in Chapter Five. Chapter Six is dealt with social improvement and general environmental protection. Chapter Seven concentrates on disease protection. Chapter Eight looked at protecting plants and soil. Chapter Nine addressed the protection of wildlife. Transitional provisions are dealt with in Chapter Ten. Chapter Eleven looks at the offences and penalties (Hallett, 2002).

The legislation addresses protecting the environment in all characteristics, such as air, soil, water and food; it urges the governing bodies to employ the legislation in every sector and industry per Article (6) of the act. Article (7) requires establishing an independent monitoring centre to enforce regulatory compliance.

2.11.2 The Environmental Law No. 15 of 2003

No. 15 environmental law in 2003 on protecting and improving the environment is simply a renewing of No. 7 Environmental Act in 1982. It is regarded to be the major environmental legislation in Libya. The legislation consists of 12 Chapters which are split into 79 articles. The law expanded of the prior act with the addition of some details on protecting the biodiversity. Furthermore, controlling contamination; issuing license, the act need Libyan authorities and International Authorities to put plans in order to the protection the environment on order to controlling or reduce contamination such as educating environmental protection; recording all chemicals which could cause pollution, controlling and protecting water resources, preparing the necessary laws for protecting the environment and inspection and research; environmental disasters; (article 6). The Law also needs establishing police forces for the environment (article 9).

2.11.3 Legislation for Environmental Protection in Libya

In the last thirty years, Libya has produced several laws in connection to the environment indirectly or directly as an effect of the increase in awareness of the environmental implications which could arise from the dynamic pursuit of its developmental policies. This study is concentrated on the laws which are directly related to the protection of the environmental. Accordingly, the Environment Protection Act No 15/2003 and the Environment Protection Act No 7/1982 will be addressed, as indicated in the national legislation about protecting the environment in Libya; Environment General Authority (EGA, 2001).

2.12 Lean and Six Sigma

American Industrial Organizations have embraced numerous management programs within the last twenty years to enhance competitiveness. Two of the most common and well-known programs are Lean management and Six Sigma. The founder of Lean management is the Japanese Toyota company, and it has been utilised by several big companies in the USA, such as Harley-Davidson and Danaher Corporation. Motorola Corporation was the founder of Six Sigma, which was used by several companies in the USA, such as Allied Signal and GE. Therefore, Six Sigma and lean management have originated from different roots(Teich and Faddoul, 2013).

The key impulse for developing Six Sigma was the requirement to improve product quality, especially when such products are complex and have many elements, which usually result in a high possibility of defectiveness in the final products. Developing lean management was driven by eliminating waste, particularly in Japan, with limited natural resources.

Both lean management and Six Sigma have developed into comprehensive management systems. The effectiveness of implementing these two systems requires new approaches to servicing customers and production and cultural changes in organisations (from upper management to the shop floor). Both plans include common characteristics such as comprehensive and high-quality employee training and empowerment and an emphasis on consumer satisfaction(Salah et al. 2010).

Lean is aimed at increasing customer satisfaction via the elimination of waste from the value stream of the organization. Seven forms of waste can be observed in Lean culture: overproduction, inventory, rework, movement, motion, over-processing and waiting. The forms of waste have been explained clearly in the relevant literature (Lima, 2023). Skill is another form of waste that will be looked at later. This waste happens when people's knowledge, capabilities and talents are underutilized. Six Sigma is regarded as a data-driven methodology that concentrates on decreasing variation. Statistically speaking, Six Sigma uses a process output that does not have more than 3.4 defects in every one million opportunities. Implementing most Six Sigma follows the DMAIC cycle (Define, Measure, Analyze, Improve, and Control). DMAIC offers a structured way of improving activities and is a proven model for obtaining considerable performance improvements (Aktas et al. 2018).

2.12.1 Lean and six sigma methodologies

Six sigma and lean manufacturing are vital in the current business environment to ensure contemporary organisations/companies retain and acquire a competitive advantage. According to Tjahjono et al. (2010), such competitive advantages can be obtained when organisations control waste, maintain consistent practices with sustainable development strategies and implement socially and environmentally responsible practices. In this sense, it has been reported that modern organizations need to embrace sustainable development to stay competitive. Cherrafi et al. (2016), also noticed that both six sigma and lean have been recognised as significant methodologies for achieving sustainable development objectives.

As an industrial waste and cost management practice, lean manufacturing is constant with social responsibility and environmental aims to create sustainable development.

(Chiarini, 2014). In this context, it has been reported that an undisputed connection has been produced between lean manufacturing and environmentally responsible production (Hartini and Ciptomulyono, 2015). It has been argued that lean manufacturing enhances the innovative environmental system when production is carried out using lean manufacturing so that sustainable and social developments can be improved (Aguado, Alvarez et al. 2013).

Regarding the connection between sustainable development and six sigma, there is a clear understanding that six sigma can indirectly influence sustainable development by implementing its tools in environmental management systems. A study by Guerrini et al. (2009), indicated that six sigma had been associated directly with environmental protection. The study showed that 2096 pollution prevention programs asserted that six sigma methodologies successfully solved problems and developed pollution reduction strategies (Guerrini et al. 2009).

Furthermore, (Sagnak and Kazancoglu 2016) maintained that the production of environmentally responsible goods (goods which can reduce pollution and be recycled) lean and green practices might be unable to manage and identify variations in processes such as waste management, storage and inventorying practices. Thus, integrating six sigma with lean and green initiatives is more efficient in creating sustainable development (Sagnak and Kazancoglu, 2016). In this sense, Integrating six sigma or lean manufacturing with sustainability can have many advantages, including economic performance, environmental sustainability and performance and social performance. In this context, organisations familiar with six sigma or lean can easily embrace and grasp the concept of sustainability (Cherrafi et al., 2016).

Six sigma and lean are tools to improve delivery processes and create quality products and services (Nave, 2002). Products in modern business and quality in services are a reflection of the way that organisations prioritize production and results. Modern organisations assimilate quality with environmentally and socially responsible business operations such as protecting and respecting the environment. Furthermore, lean and six sigma are among the major methodologies available to companies to utilise efficient and successful constant improvement of product processes and services (Alhuraish, Robledo et al. 2017). The consistent improvement and efficiency of services and products are essential for attaining the production aims (Indrawati and Ridwansyah 2015). According to Alhuraish et al. (2015) and Tjahjono et al. (2010), several modern firms constantly use six sigma and lean to reduce waste and improve efficiency. (Myers et al., 2016) maintains that implementing lean six sigma could be affected by critical factors, including insufficient support from top management and inadequate training and skills.

2. 13 Meaning of Six Sigma

Six (6) is a standard deviation on either side of the process mean. In statistical science, six standard deviations make up the normal distribution for every piece of data. Statisticians use the Greek letter sigma to measure how different things are. Sigma is also the name of the standard deviation measure (Mehrjerdi, 2004). Mehrjerdi (2011) says that a Sigma level also shows how many mistakes are likely to have happened. However, the lower the number of errors, the higher the Sigma level of the process. So, the Six Sigma goal is that there should be no more than 3.4 faults per million chances defects per million opportunities (DPMO) when using the Sigma method. Table 2.5 shows how each level's DPMO and expected return connect to the Sigma level.

$$\text{DPMO}=\frac{Total\ Number\ of\ Defects\ found\ in\ sample}{Sample\ Size * Number\ of\ Opportunities\ per\ Unit\ in\ the\ Sample}$$

Table 2.5 Sigma levels, DPMO and the Yield process (Hassan, 2013)

Yeild of Process	DPMO	Sigma level
68.26	690 000	1.0
95.46	308 000	2.0
99.74	66 8000 3.0	
99.9936	6 210	4.0
99.99994	320	5.0
99.9999996	3.4	6.0

Strategies, procedures, and measurements make up the three main components of the strict discipline known as Six-Sigma (tools and methods). It consists of several sets of statistical measurement tools and management techniques. (Snee and Hoerl, 2005).

2.14 Concepts of Six Sigma

It is crucial to offer a relevant theory about Six Sigma since this thesis will also cover how to use the Six Sigma approach. The Six Sigma approach is utilised in many fields to enhance organisational and commercial processes; as a result, it is sometimes referred to as a problem-solving methodology (Barnard, 2004).

Six Sigma, a project methodology, has been adopted by many firms to achieve world-class performance since it is a customer-based approach to interpretation (Barnard, 2004). The goals are to eliminate process variation and attempt to deliver goods with no flaws. Six Sigma is employed as a company strategy and science since it integrates statistics with business approaches to concentrate on continuing and innovative breakthroughs to lower manufacturing costs, boost client pleasure, and create top-notch goods and services. (Noone and Heather 2010).

Six sigma is a statistical measurement unit that represents the process's capacity. The Sigma measurement scale is probably related to faults per unit, parts per million, or error probability. So, the fundamental principles of Six-Sigma are:

Focusing on the client implies being proactive in understanding their wants and taking the appropriate steps to satisfy them completely. These needs are identified and determined utilising Critical to Quality CTQ methods or Quality Function Deployment QFD.

Reduce variation; production and service processes should be configured to create as little variation as possible to satisfy customer demands. The collection of quality and statistical instruments used to reduce process variation

Reducing defects; the goods and services must be produced or provided without errors, or 3.4 DPMO at most.

The emphasis is centred on delivering outstanding outcomes and achieving an unheard-of improvement (Six-Sigma breakthrough).

2.15 The requirements for implementing Lean Six-Sigma

Essentially, businesses continuously seek methods to increase their bottom line; this is often only possible by acquiring superior products or services. The production of goods or services required to achieve competitive advantages. Consequently, the strategic programmes and administrative procedures have been Six Sigma, for example, have evolved dramatically over the last three decades. TQM, Lean management. This diversity of procedures usually strains a company's leadership in identifying the best approach for dealing with a certain issue. problems (Johannes, 2013). Currently, organizations must function at the

Develop a higher ability to provide the lowest cost, with more speed and dependability. To achieve a competitive edge, evolving and pursuing continual improvement is necessary data in addition to (Roy, 2011).

Continuous process improvement is a core tenet of total quality management (Chem et al., 2015). Lean Manufacturing is a multifaceted approach to production optimization encompassing many management strategies to reduce waste and enhance operational performance (Roriz, 2017). Evidence of the approach's adoption in the industrial sector includes non-tangible change aspects, such as introducing a supportive learning environment and developing organizational leadership, in addition to quality and productivity gains (Gupta et al., 2018). To retain consumers and increase their market share, firms are increasingly adopting a strategy of continual product/service quality improvement (Chen et al., 2015). Immediately after introducing TQM, the lean six-sigma is included in the model as a component of TQM, representing the current stage of progress in quality management (Gupta et al., 2012). Today, the assertion that lean and Six Sigma have a complementary connection is generally acknowledged, and more firms are implementing lean Six Sigma (LSS) programmes, particularly after GE and Toyota demonstrated the effectiveness of lean and Six Sigma (Salah et al., 2018). Following the DMAIC framework, LSS is an approach that focuses on removing waste and variation to improve customer satisfaction regarding quality, delivery, and cost (Crawford, 2004). It focuses on enhancing processes, delighting consumers, and attaining objectives.

2.16 The difference between lean and six sigma

- Six sigma is one of the tools used by lean Six sigma
- Six sigma concentres on decreasing variability and randomness,
- Lean sigma concentrates on using principles of process improvement and six sigma for operational improvement
- Utilization of six sigma may not be applicable for all cases, as cost is high. Lean sigma can be used for operational improvements at a lower cost.
- Lean sigma centres around improving the current process by cutting waste, repetition, utilization optimization

- Six sigma centres around improving the quality and reducing the variation in quality by statistical measurements.
- Six sigma is only a tool that helps identify what is wrong, not how to fix it. This is where Lean six sigma can help identify solutions.

2.17 Approaches used in Six Sigma

DMAIC and DMADV are the two basic methodologies. By its definition, DMAIC is a data-driven quality approach utilised throughout the development stage of a current business process. A different description of DMADV is a data-driven quality approach used to design goods and procedures. It is used to create new product designs or process designs, resulting in a performance that is more expected, developed, and error-free (Thomas and Keller 2010).

2.17.1 DMAIC Method

Define, Measure, Analysis, Improve, and Control are the acronyms for DMAIC.

DMAIC is regarded as Six-most Sigma's potent method in problem-solving inside an existing process. Its effectiveness is a result of the effectiveness of its five phases, which are define, measure, analyse, improve, and control.

Define:

- Customer prerequisites and anticipations
- Project objectives and constraints
- Business process
- Method by mapping

Measure:

- Collection of data information in the present circumstances
- Compare data to identify mistakes and flaws
- Evaluate the defects that were caused
- Determine the source of the problem

Analysis:

- Examine the phase of quality endeavour to determine the source of the issues.

- Evaluate the most crucial defect cause

Determine the primary variables that most likely contribute to process variation.

Improve

- Objectives and constraints of the project
- Business flow
- Customer prerequisites and anticipations

Control

- Confirmation of the critical variables and assessing their effects
- Adjusting the variation process to remain within the mean.

2.17.2 DMADV Methodology

This methodology has five phases: define, measure, analyse, design, and verify (Rumane, 2013).

Define: This identifies the project's issue or objective that must be addressed.

Measurement: This determines the wants and requirements of the clients.

Analyze: This examines the procedure used to meet the client's demands.

Design: The creation of a process that satisfies client demands.

Verify: This validates the design's functionality and performance in relation to meeting client demands.

2.18 Tools and Methods Used in Six Sigma

(Sunder, 2016) says that the Six Sigma project is all about using numeric data, process thought, and statistical tools and methods to find differences in the process. In their reactions, Henderson and Evans (2000) and Pande et al. (2000), says that projects that want to use Six Sigma should have three groups of tools: the team, the process, and the data. This was because they had done Six Sigma work for General Electric Company (GE). These tools may give the Six Sigma team and the people in charge the skills they need to handle the projects and help the people in charge build and keep the project team together. Henderson and

Evans (2000) put together a list of all of the most common Six Sigma tools and processes. They are as follows:

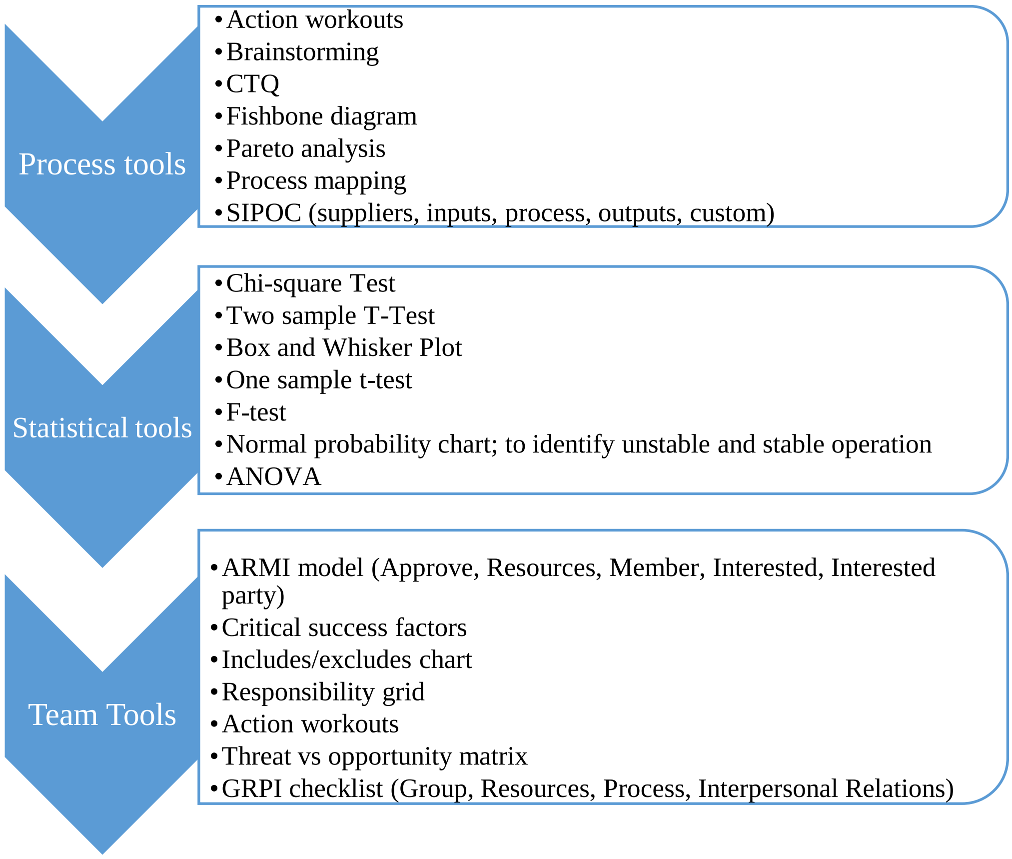

Figure 2.5 Six-Sigma Tools and Techniques

2.19 The Lean Manufacturing Approach

Due to the post-World War II industrial crisis, Japanese production was severely damaged, and the Japanese market became inaccessible. The Japanese manufacturer was forced to adopt a methodical strategy to modernise the production system and boost the value of its products as a result of the rise in the unemployment rate and the loss in the size and value of Japanese products on the worldwide market (Drohomeretski et al., 2013). All waste must be eliminated according to the lean manufacturing production philosophy. Ford's mass production framework and other industrialists' contributions to operation strategy at the time served as the foundation for the Toyota Corporation's lean development. It seeks to increase production efficiency and reduce waste. Just-in-time manufacturing evolved into lean manufacturing, formerly known as the Toyota production system (TPS). By producing only the products necessary to satisfy market demand, this attitude enables industrial organisations to reduce production lead times and conserve various resources. (Reichhart and Holweg, 2007).

2.19.1 concept of lean methodology

Lean manufacturing is a concept that aims to reduce the number of resources needed for manufacturing operations inside organisations while also eliminating waste from the operating process (Papadopoulou et al, 2005). Identifying and eliminating all non-value-added operations is the technical definition of lean. Lean manufacturing is founded on two ideas: first, reducing costs by getting rid of waste, and second, making the most of employees' talents (Reichhart et al.,, 2007). Consequently, the theory put out through the years demonstrates that Lean's results include reducing human effort, inventories, lead time, manufacturing area, and related costs without sacrificing quality (Staatsa et al., 2011). Lean's primary goal is to eliminate all waste, defined as everything that occurs throughout the production process that does not contribute value to the process or the final product. Waste comes in seven forms: Waiting, Over process, Defects, Over inventory, Overproduction, Rework and Motion.

2.19.2 Lean methods and tools

According to Sharam (2003), Value stream mapping (VSM) is the most significant strategic approach in lean operations. While lean operations employ a range of tools and techniques, each one contributes to eliminating waste and delivering improvement in a particular area. By removing all resource and labour inefficiencies across the business process, lean manufacturing seeks to significantly optimise each process step. Furlan et al., (2011) wrote about the system's future state. Wilson, (2009) said that for a business to use Lean, it needs to have a set of shared tools and ways of doing processes.

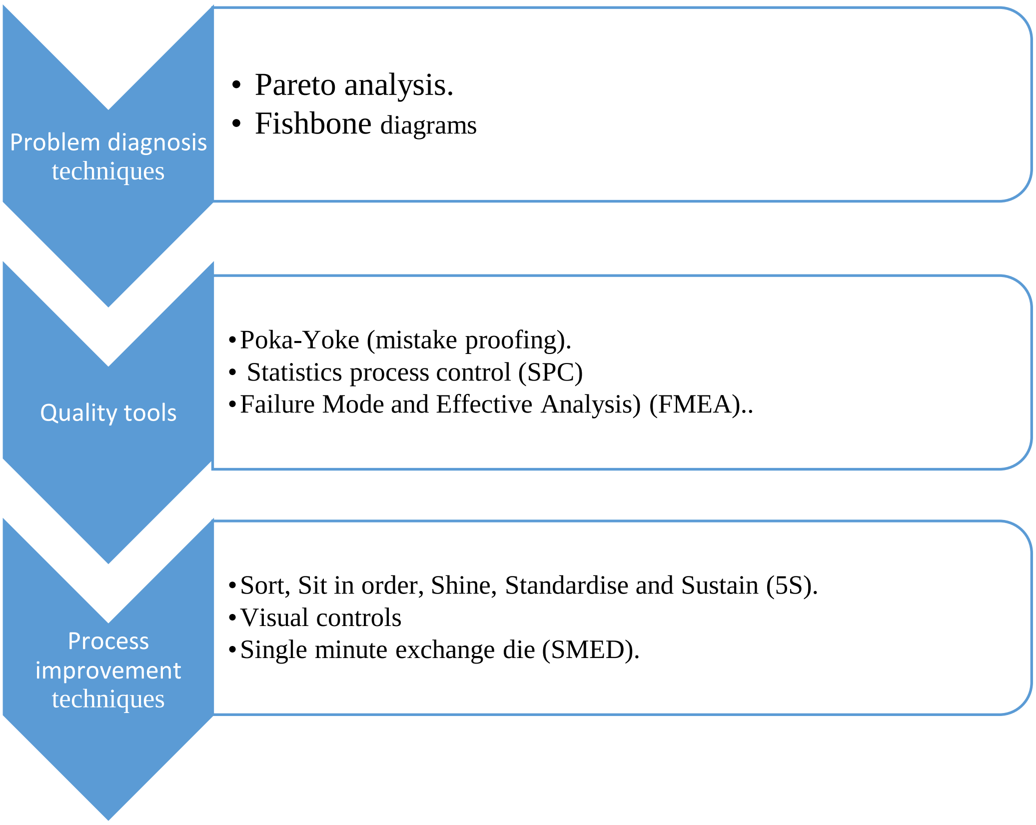

Figure 2.6 Lean methods and tools

The definitions and explanations of both Six-Sigma and Lean concepts are required to compare and contrast the two methodologies. Andersson et al. provide standard definitions for each approach.

With the use of the industrial process known as Six Sigma, a company can improve its bottom line by constantly monitoring and managing its internal operations to better utilise resources, eliminate errors, and satisfy customers.

Lean manufacturing is a business philosophy and approach that emphasises continuous improvement through streamlining the manufacturing process to achieve excellence. Waste is being sought after and removed. It is clear that although the definitions vary, the principles and goals are fairly similar. Both concepts attempt to reduce wasted resources while achieving continuous improvement, customer happiness, and financial success.

The establishment of quality management in Japan during World War II served as the foundation for both of these approaches, according to Dahlgaard (2006); however, the methods used to accomplish the goals of each idea vary after researching the similarities and differences between Six-Sigma, Andersson et al. (2006).

2.20 Project-Specific Motivators for Integrating Lean and Six-Sigma

The two integrated methodologies that are most frequently studied are lean manufacturing and six sigma, as was previously discussed in this study. According to Johannes (2011), numerous studies were carried out to combine Lean and Six Sigma to improve the procedure and get rid of both methods' shortcomings. The bulk of the research came to the same conclusion that is supported by Bendell (2006), Brett and Queen (2005), and Chen, et al., (2010), that Six Sigma using DMAIC methodology can act as the main catalyst for process improvement and weed out quality concerns. Therefore, both strategies are comparable and work best together in many aspects. However, analysing similarities and differences reveals numerous justifications for combining Lean and Six Sigma as the key project motivations for integrating Lean and Lean and Six Sigma listed below.

- According to Douglas (2015) and Salah et al. (2010), the DMAIC approach is the key technique that offers the potential for quality improvement and can be utilised to establish a strong plan for improving the operational and business processes. Kaswan (2020) claim that by integrating Lean and Six Sigma, the DMAIC technique may be used to successfully complete the organization's goals. The process planning and management strategy supports this theory.
- Value Stream Mapping (VSM), when used with Lean and Six Sigma techniques and the DMAIC approach, may help the operational process and achieve high performance. According to Kaswan (2020), Singh (2019), and Douglas (2015), Value Stream Mapping (VSM) using DMAIC methodology may be utilised as a platform for assessing the operational process, and Lean and Six Sigma tools and methodologies may be the best course of action for optimising the process performance.
- Another justification for integrating the two systems is to allay fears of complicity while achieving high performance in streamlining quality issues and continuous improvement, which can be done by merging Lean

tools and methodologies with Lean and Six Sigma's sophisticated statistical capabilities. Organisations looking to apply LSS must first create a quality improvement process, which necessitates specific tools and techniques like Six Sigma statistics according to (Singh, 2019 and Kaswan, 2020).

2.20.1 Six Sigma and Lean: Similarities and Differences

Definitions and descriptions of Lean and Six Sigma concepts are needed to compare and contrast the two techniques and supply standardised definitions for each strategy (Kaswan, 2020).

A corporation can increase its bottom line by using the Lean and Six Sigma business process, which involves continuous monitoring and control of internal operations to reduce resource usage, eliminate flaws, and improve customer satisfaction.

Lean manufacturing is a philosophy and business strategy that emphasises continual improvement by optimising the production process in response to client demand. It makes an effort to find and get rid of waste materials. It is clear that although the definitions vary, the principles and goals are fairly similar. Both concepts attempt to reduce wasted resources while achieving continuous improvement, customer happiness, excellence, and financial success

2.21 Integration Approach in Quality Management

To solve the challenges in a quality system and to gain competitive advantages, the integration approach in quality management is a strategy that combines one or more quality management methodologies or approaches. Integrating the relevant quality management methodologies and techniques to enhance the operational process is what (Gijo et al. 2005) termed integration quality management. According to Johannes (2013), integration in quality management is the simultaneous application of the relevant quality management techniques to accomplish substantial business process improvement while enhancing the system. Siva et al. (2016) said that integrated quality management requires discipline while improving the business process to prevent flaws in the quality management approaches.

2.22 The necessary components for implementing integrated methods

The core components for developing the integration method in quality management include five primary parts, this holistic approach to integration method in quality management was discussed by Johannes (2013).

- Eliminating some quality management systems' flaws to allow for the interchange of findings that resulted in value addition is the synergy between quality management methods.
- Procedure model: the series of steps to modify and improve the quality system.
- The term "consistency" refers to harmony and compatibility in the behaviours of the techniques combined and the process model employed; it is a logical order of the activities in the procedure model that guarantees the tasks are accomplished, and conflicts are avoided.
- Adding value to the quality system entails expanding the activities in the whole procedure to raise the standard of the delivered goods and services and, as a result, meet customer expectations.
- Completeness: All parts of the suggested techniques, including method elements, for the integration of quality management approaches, procedure models and consistency in process models must be adequate.

2.22.1 Process of integrating methods and techniques in quality management

The three primary integration approaches in quality management are method with the method, method with the method, and method with method (Al-Haddad, 2015). The body of research shows that the integrated method's common mechanism for quality management is based on the potential for eliminating method or technique flaws, the occurrence of synergies between homogeneity methods and or techniques, and the necessity of improving one method to another in the way to exchange the results (Ritchie, 2015). This viewpoint is highlighted by Al-Haddad, (2015), who said that removing flaws and the potential for method synergies serve as the primary catalysts for an integrated approach.

2.22.2 The key motivation for an integrated approach to quality management.

According to Johannes (2013), there are four main reasons to use integrated techniques in quality management:

- Removing the areas of weakness in the systems and procedures used for quality management. The flaws and shortcomings of quality management techniques and strategies are a strong argument for combining them with other approaches to fix them.
- One method is an existing precondition complementing another; if a method's flaws cannot be fixed or if they may be successively eradicated by another method, then methods or techniques need to be merged.
- Existence of synergies between quality improvement techniques and methodologies; benefits of quality management approaches are viewed as the foundation of the integration approach when the synergy is the stage of exchanging results between QMMs and methodologies, resulting in additional value.
- Fear of missing quality management trends: Improving the quality management process can be greatly aided by being concerned about quality management processes that are lacking or nonexistent.

2. 23 Lean and Six Sigma (LSS) Review of Environmental Perspectives

Notably, there are many previous studies in connection with Lean and six sigma with environmental such as managing the complexity of environmental assessments of complex manufacturing systems with a Lean and Six Sigma approach (Cherrafi, 2016). In Complex Systems Design and Management (Cluzel, et al. 2010), this study aimed to develop an eco-design technique based on the LSS approach to handle the complexity of environmental assessments for manufacturing organisations. The suggested methodology has the advantage of including environmental criteria as the fourth dimension of the quality, costs, and time triangle and systematising the eco-design process.

Other studies have indicated that waste processing is a waste treatment by LSS, resulting in positive results. According to (Besseris, 2011). In his previous study, he developed a model to demonstrate how environmental waste and process efficiency are dealt with in a lean-and-green project driven by hardcore LSS tools. The model was validated through a case study conducted in a maritime transport company, and an insignificant factorial design with three performance-influencing components was created using the DOE methodology (Ruben, et al. 2018).

In this context, (Garza-Reyes, 2015) conducted a detailed review of the Green Lean approach, examined the compatibility of Lean and six sigma and the green concepts, and provided a new approach called Green Lean Six Sigma. The proposed framework and insights provided a richer and broad knowledge on deploying lean and green approaches integrated with six sigma methodologies towards environmental management.

Also, (Yusof, 2012) conducted a study in an automotive organization to explore the relation between the environmental management system and organizational performance. The study showed that ISO 14001 certification does not significantly moderate the relationship between organizational performance and LSS but provides extra insights to promote organizational performance.

In a related context, (Banawi and Bilec, 2014) developed a model that can be used to integrate green, lean and six sigma to improve the quality and environmental impacts. This framework assisted in identifying the environmental wastes and processes and offers a comprehensive, multilevel approach for minimizing environmental impacts and process improvement (Sreedharan, 2018).

2.24 Lean and its impact on environmental performance

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Table 2.6 lean with environmental management (Yang, etal., 2011).

Waste Type	Examples	Environmental Impacts
Defects	Scrap, rework, replacement Production, inspection	• Raw materials consumed in making defective products • Defective components require recycling or disposal • More space required for rework and repair, increasing energy use for heating, cooling, and lighting
Waiting	Stock-outs, lot processing delays, equipment downtime, capacity bottlenecks	• Potential material spoilage or component damage causing waste • Wasted energy from heating, cooling, and lighting during production downtime
Overproduction	Manufacturing items for which there are no orders	• More raw materials consumed in making the unneeded products • Extra products may spoil or become obsolete requiring disposal
Movement	Human motions that are unnecessary or straining, carrying work in process (WIP) long distances, transport	• More energy use for transport • Emissions from transport • Move space required for WIP movement, increasing lighting, heating, and cooling demand and energy consumption • More packaging required to protect components during movement
Inventory	Excess raw material, WIP, or finished goods	• More packaging to store work in-process • Waste from deterioration or damage to stored WIP • More materials needed to replace damaged WIP • More energy used to heat, cool, and light inventory space
Complexity	More parts, process steps, or time than necessary to meet customer needs	• More parts and raw materials consumed per unit of production • Unnecessary processing increases wastes, energy use, and emissions
Unused creativity	Lost time, ideas, skills, improvements, and suggestions from employees	• Fewer suggestions of P2 and waste minimization opportunities

Companies can reduce their environmental impact by applying Lean and Six Sigma to their organization without even trying. They probably already have, and not realized it, or captured the benefits. Epa.gov. (2019).

2.25 Barriers to imbloment LSS

Businesses may incur costs if LSS is inadequately deployed (Pulakanam, 2012). Due to the inherent danger, there is a reluctance to embrace contemporary tactics that could help with corporate expansion. However, if the constraints are recognised immediately, any new company plan can be adopted successfully (Campos, 2013). As costs rise with each subsequent phase, identifying barriers is a wonderful way to develop solutions to get around them initially (Raghunath et al. 2013); (Gibbons et al. 2010).

Ambekar and Hudnurkar (2017) say a frequent barrier is a lack of communication and involvement on all levels. Management policies and daily operations need to be in sync, which depends a lot on top-level management's commitment, participation, and attitude. Positive interactions between people who make decisions and people who do the work encourage and inspire everyone to do good work and work more efficiently. Any new business strategy can't be implemented without strong connections between the organization's goals and what customers want, which is why strategic planning is so important, as it is directly linked to quality and productivity (Psychogios et al., 2012).

Common barriers to training include "poor training," "insufficient training," and "selection of the wrong employees for training" (Ambekar et al. 2017). Because Six Sigma employs mathematical calculations, and the framework requires the analysis and processing of statistical data, the individual in this capacity must be adequately trained to perform the necessary tasks. Employees are responsible for completing daily tasks in the workplace; therefore, the appropriate training must be provided to the appropriate employees (Lande et al., 2016). Only through appropriate training can the employee who makes decisions and manages data acquire the required abilities. Insufficient industry specialists exist to guide practitioners if they require assistance with their next steps (Ambekar and Hudnurkar, 2017; Antony et al., 2005). There aren't enough industry specialists to offer guidance, and training expenses are comparably higher (Ambekar and Hudnurkar, 2017; Antony et al., 2005).

2.26 Overview of literature-identified critical success factors for Lean Six Sigma

Yadav et al., (2021) introduced the concept of the Critical Success Factor (CSF). CSFs are those factors essential to the success of any programme or technique, in the sense that if objectives are not met, the programme or technique will not be successful. If the conditions associated with the factors are unmet, the technique may fail catastrophically. (Sreedharan V & Sunder M, 2018) CSFs include issues vital to an organization's current activities and future success.

The literature (Antony and Banuelas Coronado, 2002; Brun, 2011; Näslund, 2008) has identified several crucial success elements for efficient and effective Six Sigma deployment. According to an assessment of the literature, there are several key success factors for implementing six sigma and lean manufacturing. The crucial success components are top management commitment, culture change, and communication. Although it should be mentioned that they are more frequently stated in the literature as crucial success elements for six sigma.

Coronado and Anthony (2002) further clarified Anthony and Banuelas' analysis of the "key ingredients for the effective implementation of a Six Sigma programme" in organisations, these specific factors are listed below:

- Involvement and dedication of management.
- Knowledge of the six sigma approach, equipment, and methods.
- Connecting six sigma to clients
- Connecting six sigma to corporate strategy.
- The choice, evaluation, and monitoring of projects.
- Infrastructure within the company.
- A Culture change.
- Skills in project management.
- Connecting suppliers to six sigma.
- A training and Education.
- Communication
- Monitoring and evaluation of performance

2.27 Lean, and six sigma sustainability

Waste reduction is an undisputable universal aim that organisations seek to implement. In this case, six sigma aims to reduce waste by decreasing variations in processes, such as lean manufacturing and waste production. Therefore, lean manufacturing offers methods to successfully eliminate waste associated with environmental degradation (Chiarini, 2014). For instance, 5S has been found to successfully enhance waste management and reduce oil leaks, while value stream mapping was found to be successful in ascertaining the environmental impact of production (Chiarini, 2014). According to Fliedner, (2008), total productive maintenance (TPM) can reduce waste emanating from equipment and machines, and it also has the advantage of improving environmental outcomes. The 5S and TPM systems can assist in better health and safety practices and help avoid injuries. They are also linked to social practices (Verrier et al., 2016, Sarkis et al., 2010). Correctly employing the Kaizen "continuous improvement" procedure can assist in managing environmental waste (Miron et al., 2006).

It has been stated that involving employees in these programs has produced environmental advantages (Piercy and Rich, 2015). It has been found that lean manufacturing firms improved their environmental and financial management practices. In addition, implementing lean manufacturing was positively correlated with deploying environmental management practices (Yang et al., 2011).

In the Brazilian companies (Sobral, Sousa Jabbour et al. 2013), lean manufacturing has been found to correlate more positively with environmental management practices than human resources in connection with its capability of driving and improving sustainable development strategies. (Asif et al. 2013) also, lean manufacturing and six sigma can be utilised to improve business management systems in corporations with social responsibility initiatives. According to (Harris et al. 2017), lean six sigma has been considered from an environmental viewpoint, such as identifying essential components of the technique which provide sustainable environmental practices.

The possibility of integrating LSSigma, and sustainability received increasing attention, in which more than 100 publications have been produced to develop this field. However, only a few literature articles are up to date, and only six articles (among those which have been read) have attempted to study the relationship between LSS and sustainability ((Johansson & Sundin, 2014) (Garza-Reyes, 2015a); (Garza Reyes, 2015b) and (Cherrafi et al. 2016). The existence of knowledge of potential synergies and conflicts between lean, six sigma and sustainability is seen to be in its infancy. There is no single full review where the drivers, benefits, critical success factors (CSFs) and barriers for a feasible integrated model are analyzed. Furthermore, the patterns, frameworks and methods proposed for integrating these three strategies have not been examined; since there is insufficient knowledge of a specific integrated model, an inclusive literature study has been conducted to collect systematically and critically analyse all suitable information in the area of lean, Six Sigma and sustainability and present ways to provide a possible model.

Many studies have demonstrated the advantages of Lean, Six Sigma or Lean Six Sigma initiatives (L&SSi) in various fields (Henrique, Rentes et al. 2016); (Costa and Godinho Filho 2016); (Godinho Filho, Ganga et al. 2016); (Albliwi, Antony et al. 2015); (Kumar, Antony et al. 2011); (Grima, Marco-Almagro et al. 2014); (Zu, Fredendall et al. 2008). However, there is insufficient literature on implementing L&SS in the oil and gas sector. Thus, the appropriateness of L&SSi for improvement in the oil and gas fields is unknown. It has been maintained that there was a clear interest by directors in oil and gas organisations in such continuous improvement initiatives (Scott, Wilcock et al. 2009); however Schug (2017), acknowledges the continuous challenge in terms of translating the success of the program in the oil and gas sector (Costa et al. 2018).

2. 28 Waste Heat Recovery in the Oil and Gas Sector

Waste heat recovery is a method of recovering heat from an existing industrial process for use in other heating applications, such as power generation. According to Technavio, the worldwide waste heat recovery market in the oil and gas sector would develop at a CAGR of 7.6% from 2014 to 2019. The major waste heat sources are the discharge of hot combustion and process gases into the environment (e.g., melting furnaces, cement kilns, incinerators), cooling water sand conductive, convective, and radiative losses from equipment and heated products. A waste heat reclamation unit is built and required to describe the stream in terms of availability, temperature, pressure, and the presence of impurities such as particles and corrosive gases. Thermal energy recovery (both within and outside the facility) and electrical power production are the two major purposes of recovering waste heat from industry. Improved exploitation of low-temperature heat streams, especially for thermal applications such as heating, ventilation, cooling, and greenhouses, is increasingly critical for total energy system efficiency.

2.29 Information on the organic Rankine cycle (ORC)

Coal and nuclear fuels have long been used to generate electricity using the Rankine cycle, sometimes known as the steam power cycle. For boiler temperatures below 370 °C, the thermal energy-to-power conversion efficiency of a Rankine cycle utilising water as the working fluid becomes uneconomically low. Using organic Rankine cycle (ORC) technology, most waste heat available at low temperatures can be recovered to provide electricity (Jung et al. 2014). The ORC system is similar to the traditional Rankine cycle, except instead of using water as the working fluid, it uses refrigerants (like R-123) or volatile organic liquids (like pentane). Organic working fluids can collect energy from low-temperature waste heat sources because they have lower boiling temperatures than water. Compared to ammonia, propane, isopentane, benzene, and n-heptane, the water cycle showed the lowest potential for power generation at heat source temperatures ranging from 100 °C to 225 °C (Jung et al., 2014).

Compared to recent renewable energy technologies, power generation from industrial heat waste has many advantages.

- Unlike wind energy, waste heat power generation can be simply utilised on-site and does not need to be connected to the grid.
- Compared to solar or wind energy, it has a higher potential utilisation factor.
- It does not call for the exploitation of resources like wind or hydro energy or land development.
- Unlike ocean or tide energy, it may be constructed and run in a safe setting with operational maintenance on-site.
- Unlike second-generation biofuels, wave power production, or hydrogen, it does not require any innovative technical or material breakthroughs.

Lack of expertise in prospecting, designing, and operating plants in each industry with prospective resources is the greatest obstacle to developing industrial waste heat for power generation. Standardisation results from experience, bringing about economies of scale and proof of a profitable investment. These accomplishments are required for government-sponsored incentive programmes for green energy and to draw money for investment. For the analysis of a potential resource, the concept design of the heat extraction unit and the ORC cycle, the selection of the components and fluid, the modelling and simulation of the components and system, and the assessment of the technical and financial viability, development and application research are required.

2.30 Explanation of Different Methods for Recovering Waste Heat

Many different types of technology can convert waste heat into useable energy in the form of power, cooling, and heat. The incorporation of waste heat recovery technology presents a number of new difficulties as well as opportunities to increase the amount of waste heat that is utilised at processing locations to enhance those locations' energy security. A rundown of the many methods for waste heat.

2.30.1 Types of prime movers for CHP systems

Using waste heat can bring financial and environmental advantages while simultaneously elevating energy efficiency at industrial sites. Recovering usable energy from waste heat is possible using various commercially available devices. In addition, there are several end-uses for energy recovery, on-site and off-site, in different locations. Finding the right proportions of different technologies is the difficulty here. Potential applications for reclaimed energy consider the amount and nature of heat and waste sources, interactions with interrelated systems and limits on the deployment of money.

2.30.2 Steam turbine

One of the earliest and most well-known types of heat engines is the steam turbine, which is also known as the Rankine cycle. A high-energy heat source, such as fossil fuels or a nuclear reaction, is used to bring water to a boil and then superheat it. Water serves as the working fluid for this cycle. After passing through the turbine in a single or several stages, the high-energy fluid is expanded, resulting in mechanical power generation. While the high-temperature and low-pressure water vapour is condensed via the condenser by a heat sink, the turbine shaft is linked to the electrical generator so that the mechanical work may be converted into electrical power. Applications that need heating make advantage of this latent form of thermal energy. In order to keep the cycle going, the condensed water has to be pumped to the boiler using a liquid pump that operates at a high pressure (Hesketh et al., 2005).

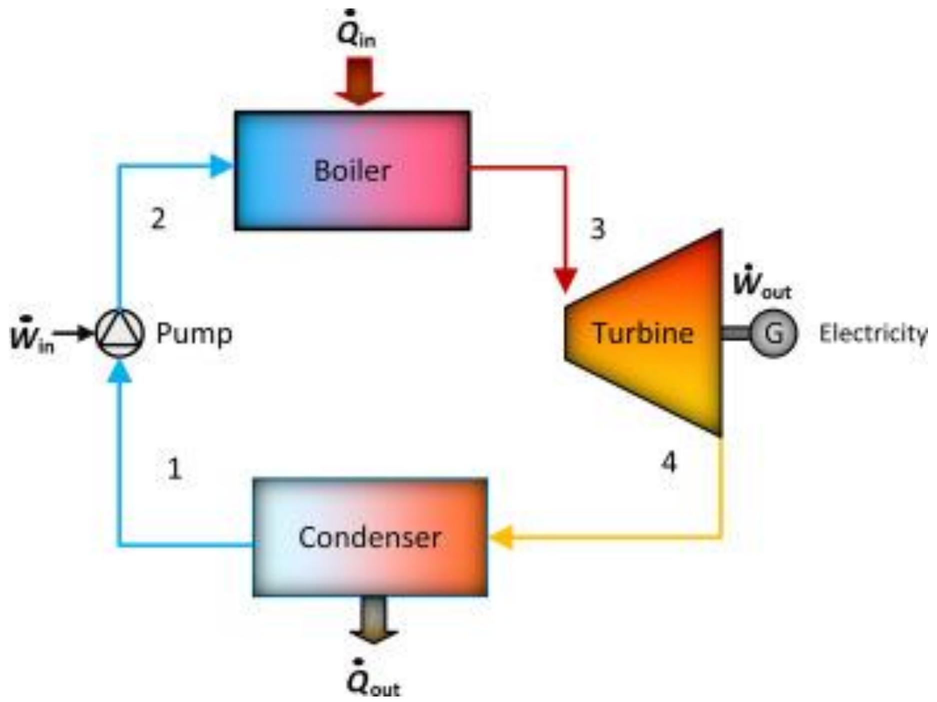

Figure 2.7: Steam rankine cycle

2.30.3 Gas turbine

The Brayton cycle is a thermodynamic cycle used to operate gas turbine cycles. As shown in Figure 2.7, it comprises a compressor, a turbine, a combustion chamber, and an electric generator. All of these components are interconnected. The surrounding air is forced into the compressor and mixed with gasoline.

To create high pressure and heat, a combustion process was carried out to create electricity; the combustion products are expanded by the turbine with temperature and gases released. Using mechanical power in conjunction with a motor generator produces electrical power. The elevated temperature exhaust gas stream at the turbine exit (450-600 degrees Celsius) can potentially harm the environment.

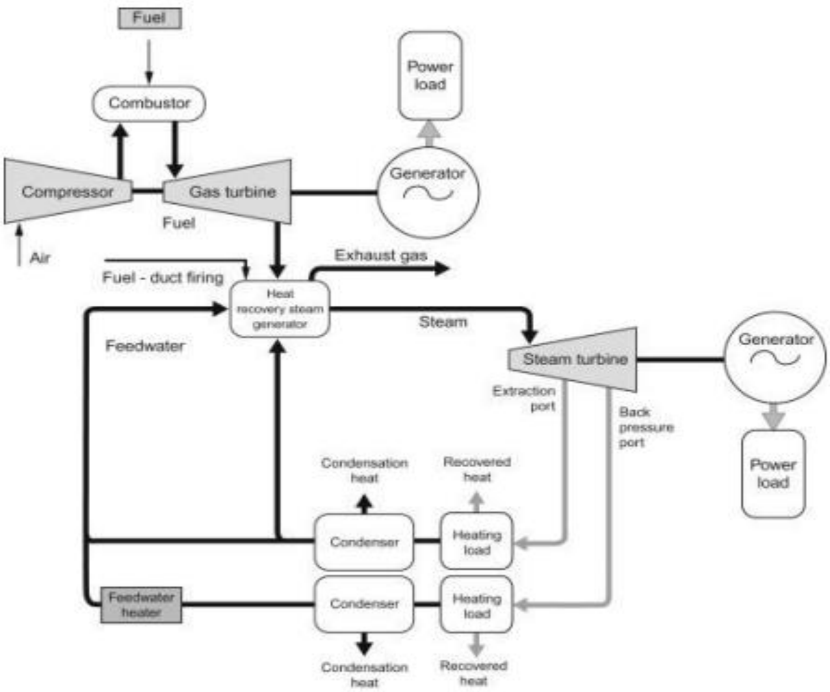

Figure 2.8 Schematic of a gas turbine combined CHP cycle Balli, O., & Aras, H. (2007).

2.30.4 Reciprocating internal combustion engines

In a conventional internal combustion engine (ICE), the engine's pistons go through four primary processes collectively called strokes to transform the energy produced by the combustion reaction into mechanical power. The spark ignition engine, which may run on either natural gas or gasoline, and the diesel engine, which ignites its diesel fuel during the compression stroke, are the two most prevalent kinds of internal combustion engines (ICE) used today.

The second rule of thermodynamics states that the amount of heat that can be converted into useful mechanical work is limited because the combustion process produces more heat than can be used. It has been discovered that the temperature of the coolant fluid within the engine jacket may reach between 80 and 90 degrees Celsius, whilst the exhaust stream from the combustion products can reach between 400 and 600 degrees Celsius. It is estimated that the internal combustion engine (ICE) wastes around 55% of the energy accessible in fossil fuel, of which 30–40% is present in the exhaust gases and 15% is contained in the jacket water (Ameli & Potts, 2007). As seen in Figure 2.2, this lost energy can be reclaimed by the CHP system, which may create electricity, heating, and even a cooling effect simultaneously.

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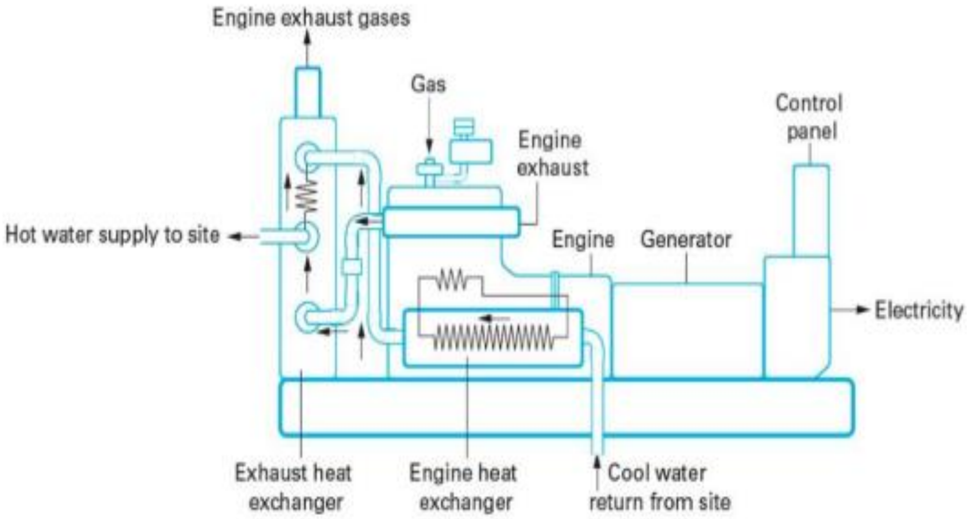

Figure 2.9: A packaged internal combustion engine CHP system(Ameli, Agnew, & Potts, 2007)

2.30.5 Stirling engines

The Stirling engine is a type of heat engine that functions according to the Carnot cycle principle. In this cycle, the working fluid, which could be air or helium, is subjected to the following four thermodynamic processes: compression, heating, expansion, and finally cooling. Stirling engines have an overall efficiency of around 30 percent when it comes to transferring heat into mechanical power. When the rejected heat from a Stirling engine that is being utilised as a micro CHP is recovered, it is anticipated that the engine's efficiency in converting fuel to electricity may approach 38% (Harrison, 2011). However, there are some drawbacks associated with the generation of electric power that are encountered. These drawbacks include low electric efficiency, difficulties in controlling the power system caused by the various types of heat exchangers that are used, and the requirement for high-pressure working fluid.

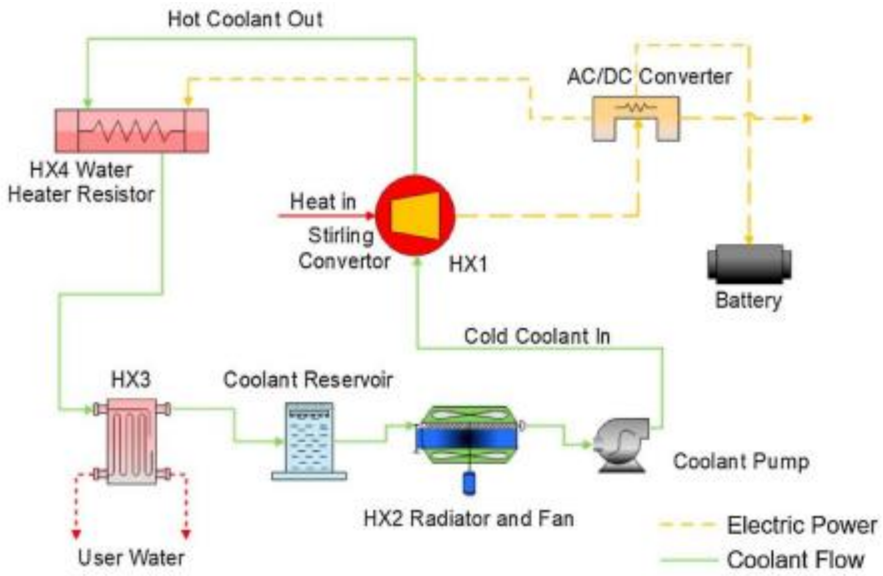

Figure 2.10: Configuration of the CHP system with an SE prime mover (Abbasi,et al.2018)

2.30.6 Organic Rankine cycle

Because organic fluids have lower boiling points and higher molecular masses, organic Rankine cycles have the potential to convert low-grade thermal energy (less than 230 degrees Celsius) into useful mechanical work. This is possible due to the fact that organic fluids are used as the refrigerant in organic Rankine cycles rather than water. An organic Rankine cycle is a type of heat engine that is comparable to a steam turbine. In addition, to operate an ORC cycle, a lower evaporation pressure and a higher degree of superheated working fluid at the exit of the evaporator are needed, compared to the Rankine cycle. In addition, the chosen working fluid should preferably be a dry fluid to prevent condensation of the working fluid during the expansion process (Rahbar et al. 2017)

. An evaporator, a turbine, a condenser, and a pump are the essential components that make up an ORC. The evaporator is a kind of heat exchanger that may also be referred to as a boiler. Its primary function is to evaporate the working fluid by exchanging thermal energy with the source of the heat. A high-pressure and high-temperature refrigerant vapour is produced as a byproduct of the evaporation process. This vapour will expand as it passes through the turbine, resulting in mechanical power generation. After that, the condenser heat exchanger will begin the process of condensing the refrigerant by transferring the heat of vaporisation from the refrigerant to the coolant. In order to get the cycle going again, a liquid pump moves the condensed liquid refrigerant from the condenser to the evaporator. A recuperator, a heat exchanger used to transfer heat between the refrigerant at the expander exit and an evaporator inlet, may be added to an ORC to increase the cycle's efficiency. This is one of the additional elements that can be added to an ORC (Astolfi, 2017)

2.30.7 Comparison between ORCs and steam Rankine cycles

Comparisons between the organic Rankine cycle (ORC) and the traditional steam Rankine cycle are described in this section. These comparisons focus on working medium, operating conditions, the size and complexity of system components, prices, and overall performance. ORC power systems can utilis

e low-grade heat sources with temperatures as low as 80-150 degrees Celsius, which is one of the most significant and distinctive benefits of ORC power systems (Habibi et al, 2019).

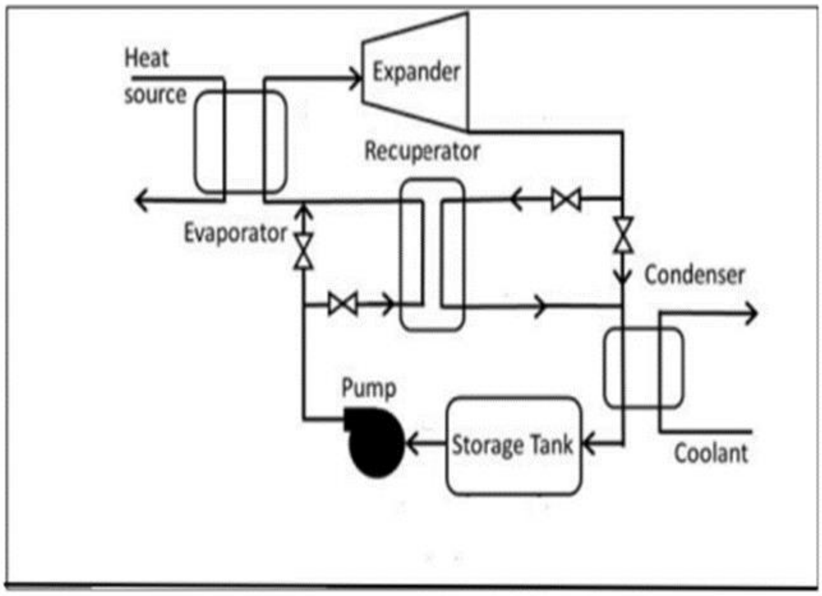

Figure 2.11: Comparisons between the organic Rankine cycle (ORC)

The method may also be used with any other external thermal energy source, provided that the difference in temperature between the heat source and heat sink is between about 30 and 500 degrees Celsius (Habibi et al, 2019). Therefore, ORC systems are technically suited for converting renewable energy sources such as solar, geothermal, biomass, and industrial waste heat. These types of energy sources include: As a result, the ORC technology contributes to reducing climate change brought on by greenhouse gas emissions generated by the combustion of fossil fuels.

Several recent research (Andreasen et al. 2017) have indicated that organic Rankine cycles, or ORCs, offer a variety of advantages over conventional Rankine cycles in addition to the benefits described above.

The following are some points that may be used to describe these advantages:

• Compared to steam Rankine cycles, which only become viable in bigger units, ORCs are more cost-effective in small-scale systems (up to a few MW), making them a more attractive option (above 1 MW).

• The production of moist droplets after the expansion phase, which might be responsible for the turbine blades' erosion, is the superheating process's primary objective. Due to the poor heat transfer properties of the gaseous/vapour medium, this necessitates the use of a superheater that has a relatively high surface area for the transmission of heat. This results in an increase in the cost of the power system. After the expansion process, the majority of the organic fluids are found to have remained in the dry area; hence, superheating is not necessary.

The evaporation temperatures and pressures at which ORCs run are often substantially lower than those at which steam Rankine cycles do.

Because of this, thermal loads and safety measures imposed on system components are greatly reduced, and as a result, the complexity and expense of the equipment are decreased.

- Air leakage into the condenser is more likely because the condensation pressure of steam Rankine cycles is below atmospheric pressure, often less than 0.1 bar. Technical problems follow, adding to the burden and lowering system performance. However, the ORC can function at condenser pressures greater than atmospheric pressure thanks to organic fluids with low critical temperatures.

Because the pressure ratio across the turbine is so high in steam Rankine cycles, multi-stage turbines are a popular piece of equipment to see employment in these cycles. This ratio is much smaller in ORCs, allowing for simple turbine designs with a single stage.

When organic fluids are used in the turbine, the enthalpy loss is reduced, leading to larger mass flow rates and greater isentropic efficiency. In addition, a smaller enthalpy drop results in a lower turbine rotational speed, enabling the electric generator to be driven directly without needing a gearbox.

In contrast to steam cycles, an additional kind of water treatment is not required in ORCs. It is not necessary to use a deaerator to prevent corrosion of the metallic components of the system brought on by the presence of dissolved oxygen in the water used to feed the boiler. Additional benefits of the ORC technology include its straightforward construction, minimum required maintenance, independent functioning, and high levels of adaptability and safety. On the other hand, traditional Rankine cycles provide various benefits that outweigh the ones offered by ORCs (Zhang et al., 2021). The following are some points that may be made about these:

In comparison to ORCs, steam Rankine cycles often have an efficiency that is more than 30 percent, making them the more efficient option. The efficiency of today's high-temperature ORCs can't go much higher than 24 percent.

Steam cycles demand a lower pump power consumption in comparison to the output power of the turbine.

Water has a number of benefits that make it an ideal working fluid. It is inexpensive, readily accessible, chemically stable, non-flammable, non-toxic, and environmentally beneficial. Other desirable characteristics include these: Water also has a low viscosity, which means that it causes less friction and, as a consequence, reduced pressure drops and losses in the heat exchangers and the piping of the system.

In conclusion, organic Rankine cycles (ORCs) are more desirable than typical steam Rankine cycles when a low-temperature heat source is employed and/or when small to medium-scale power systems are needed.

The comparison between the Organic Rankine Cycle (ORC) and the Steam Rankine Cycle reveals that the latter exhibits notable potential for achieving elevated efficiency, particularly in scenarios where high-temperature heat sources are utilized. Nevertheless, the Organic Rankine Cycle (ORC) demonstrates greater efficiency when utilized with heat sources operating at lower temperatures, typically within the range of 80°C to 300°C. In the context of lower temperature ranges, the Organic Rankine Cycle (ORC) exhibits enhanced efficacy in the conversion of thermal energy into electrical power.

2.30.8.Comparison of ORC and Kalina Cycle

The Kalina Cycle, employing a blend of ammonia and water, exhibits the potential to deliver somewhat superior efficiency in comparison to the ORC, mostly because to its enhanced heat exchange qualities (Rodríguez et al., 2013).

2.30.9 Comparison of ORC and the Thermoelectric Generators

When comparing ORCs to Thermoelectric Generators (TEGs), it is observed that TEGs exhibit poorer efficiencies in larger-scale power generation applications, particularly when compared to ORCs. Thermoelectric generators (TEGs) exhibit greater suitability for low-power applications as a result of their inherent design and material restrictions (Aliahmadi et al., 2021).

2.30.10 The comparison between Organic Rankine Cycle (ORC) and Combined Heat and Power (CHP) systems

reveals that CHP systems exhibit a notable level of efficiency due to their ability to harness waste heat for both electricity generation and heating reasons. The efficiency of a system can exhibit significant variability contingent upon the particular configuration and the extent to which waste heat is efficiently utilized (Yaglı, et al., 2016).

2.30.11 The comparison between ORC and Photovoltaic (PV) Systems

reveals that the efficiency of Photovoltaic systems is subject to variability due to factors such as solar intensity, geographic location, and system design. In the realm of waste heat recovery applications, it is often observed that Organic Rankine Cycles (ORCs) exhibit higher levels of efficiency when compared to Photovoltaic (PV) systems (Patil et al., 2017).

2.30.12 Costs of energy recovery systems

The cost associated with the implementation of these systems exhibits considerable variation and is contingent upon a multitude of parameters, which encompass:

- The initial capital costs associated with an Organic Rankine Cycle (ORC) system may be relatively higher in comparison to some alternative systems. This can be attributed to the intricate nature of the ORC cycle, the careful selection of suitable working fluids, and the need for specialized components.
- Operating and maintenance expenses: Organic Rankine Cycles (ORCs) typically exhibit reduced maintenance costs as a result of their streamlined designs and fewer mechanical components in comparison to specific systems such as steam Rankine cycles. Nevertheless, the operational expenses can fluctuate depending on variables such as the expense of the heat source, the size of the system, and the maintenance prerequisites.
- The costs associated with the installation and site-specific factors play a significant role in determining the overall expenses of adopting an energy recovery system. Various factors, such as site conditions, complexities involved in the installation process, and the requirement for extra equipment or infrastructure, can have an impact on the total cost.

In numerous instances, although the initial expenses associated with an Organic Rankine Cycle (ORC) system may be costlier, the operational efficacy and subsequent reduction in energy expenditures, particularly when utilizing low to medium-grade waste heat, can render it a financially viable option in the long term. The examination of economic feasibility plays a critical role in identifying the most suitable option for a particular application, taking into account factors such as efficiency, cost, and overall return on investment (Zhang, et al., 2017).

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2.31 The environmental impact of the organic ranking cycle for waste

More recently, the investigation and use of waste or renewable fuel sources have drawn attention to the organic Rankine cycle (ORC) system's potential to generate electricity, even if sustainability is often disregarded and there are just a few sparse and scattered studies on it. The working fluid and heat domain features of this study's ORC environmental effects (EIs) have been thoroughly exposed for the functional definition of impact categories. The environmental performance evaluation includes the influence of ORC refrigerant leakage elements, which are often disregarded in prior ORC studies and are crucial for working fluids with high global warming potential (GWP). A steady turbine output power reveals GWP, the most significant EI (30 kW). Leakage characteristics result in a total emission of around 30% for R227ea (GWP100 3220), 24% for R236ea (GWP100 1200), 28% for R245fa (GWP100 950), and 60% for SES36 (GWP100 3710), in that order. In general, the highest emissions are from energy use for pump power, followed by yearly leakage of refrigerant, end of refrigerant life, etc. A working fluid may prefer lower emissions with a greater critical temperature, a higher heat domain, a lower condensing temperature, and a lower evaporating pressure. Utilizing fluids with a lower GWP may result in a 50–84% decrease in emissions compared to those with a higher GWP, and adding the yearly leakage rate of 2–8% for fluids with a higher GWP results in a 60–124% increase in emissions overall. From 75 to 90% more efficient pumps or turbines may reduce emissions by 10 to 16% (Fergani et al., 2016).

2.31.1 Sustainability dimensions which have been addressed in the research papers:

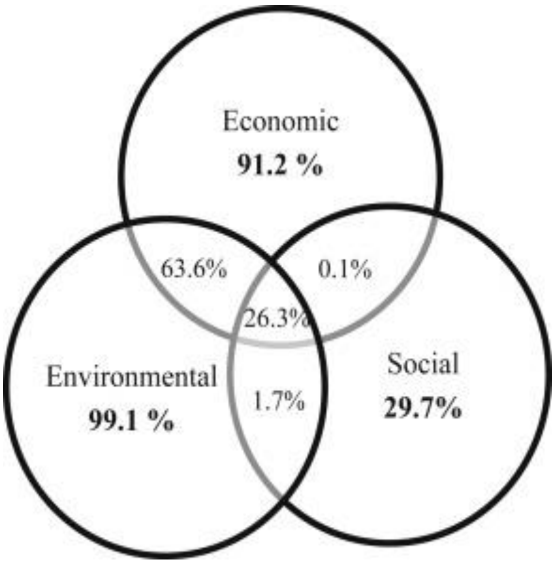


Figure 2.12 : According to the three dimensions of sustainability.(Brown, Dillard et al. 2006).

Out of the cited sources, 99.1% of the publications have discussed environmental problems, as shown in Fig.2.12 It is also clear that several researchers are still developing more studies regarding environmental issues. Indicated that researchers are less interested in studying the social aspect of sustainable development. The social aspect is shown with the least attention from the researchers compared to the environmental and economic issues. (Simboli, Taddeo et al., 2014) However, these three aspects are pillars in the Sustainability system whereby if any one is weak, the system as a whole is unsustainable. Furthermore, these three dimensions of the sustainability system must be satisfied simultaneously to obtain good market results (Gladwin et al. 1995). As a result, the social pillar has to be taken at the centre of discussions about sustainable development and lean, Six Sigma. Other researchers dealt with the challenges of combining the three pillars of sustainability, where they obtained results related to measuring the system performance of the employed method (Schilizzi, 2002).

2.32 Summary of the Chapter

This chapter introduces quality management, with environmental management as the research's primary focus. It then moves on to a discussion of the definitions and significance of quality management methods and techniques and the core elements of any quality management system. The review conducted above provides details in the second section, including definitions, guiding principles, essential elements, and the key tools and methodologies of the main quality management approaches investigated by Lean and Six Sigma production. Moreover, a comparison of the rising quality techniques gives a detailed analysis of the strengths and weaknesses of each idea, as well as the most prevalent distinguishing characteristics, to illustrate the degree to which these approaches may be compatible. The literature study revealed that writers and academics generally agree that the offered methodologies may be integrated and synergy can emerge between them.

The conceptual model of source-receptor impact interactions has been addressed. This chapter also examines the environmental effect with examples of its definition and idea. In addition, this chapter defines and examines the notion of sustainable development. It also clarifies the environmental laws stipulated in the Libyan petroleum sector.Based on the preceding evaluation, the study concludes that it plans to integrate quality management approaches toward sustainability, which has provided new ways for establishing quality management systems over the last several years. The next chapter, chapter 3, will emphasise the research methods used in this study. The section's background is directly important to the research issues of this thesis since it serves as the foundation for the suggested framework and its components.

Chapter 3: The Research Methodology

3.1 Introduction

The research systematically examines materials and sources to determine facts and achieve fresh decisions. Others have characterized research as systematic. Procedures and organized attempts to examine a specific issue requiring investigation and providing solutions. (Mengist, 2020; Johnson, 2011; Oxford English Dictionary Coed, 2004).

In addition, methodology for research is described as a discipline that involves the cultivation of skills in inquiry, experimental design, data collection, analysis, and measurement. (Chanysheva, 2021) and Arbnor and Bjerke (2008) asserted that methodology illustrates how techniques are formed and how the framework evolves. In addition, Robson and McCartan (2016) noted that the methodologies and procedures of the research strategy must be chosen correctly to answer the research questions. However, a research technique is a collection of hypothetical techniques used to examine a specific academic discipline. Regardless of the methodology, the study must be methodical, rigorous, integrated, and focused (Basile, 2021).

A study's primary aims and objectives guide the selection of the study approach and data processing strategy. Tolmie et al. (2011) assert that selecting the most appropriate study design and data-gathering instruments is more significant than selecting data analysis techniques. The phrases "research technique" and "research design" are sometimes used interchangeably, leading to confusion. The research design serves as the foundation for a system used to gather and evaluate information, while the study approach focuses on the validity of information (Bryman and Bell, 2015). According to Karlsson (2002), the procedure indicates well-proposed research. Robson (2002) notes that no definitive rule defines the choice of study approach or the duration of the research regarding how to conduct research and which technique to apply. Based on the acquired empirical data, the data analysis is achieved, and decisions are drawn to establish the study's reliability and validity and evaluate its quality.

3.2 Linking of objectives to methodology:

This table, Shows how to link methodologies to research objectives and the technique that was used to answer the objectives of the study outlined in Chapter

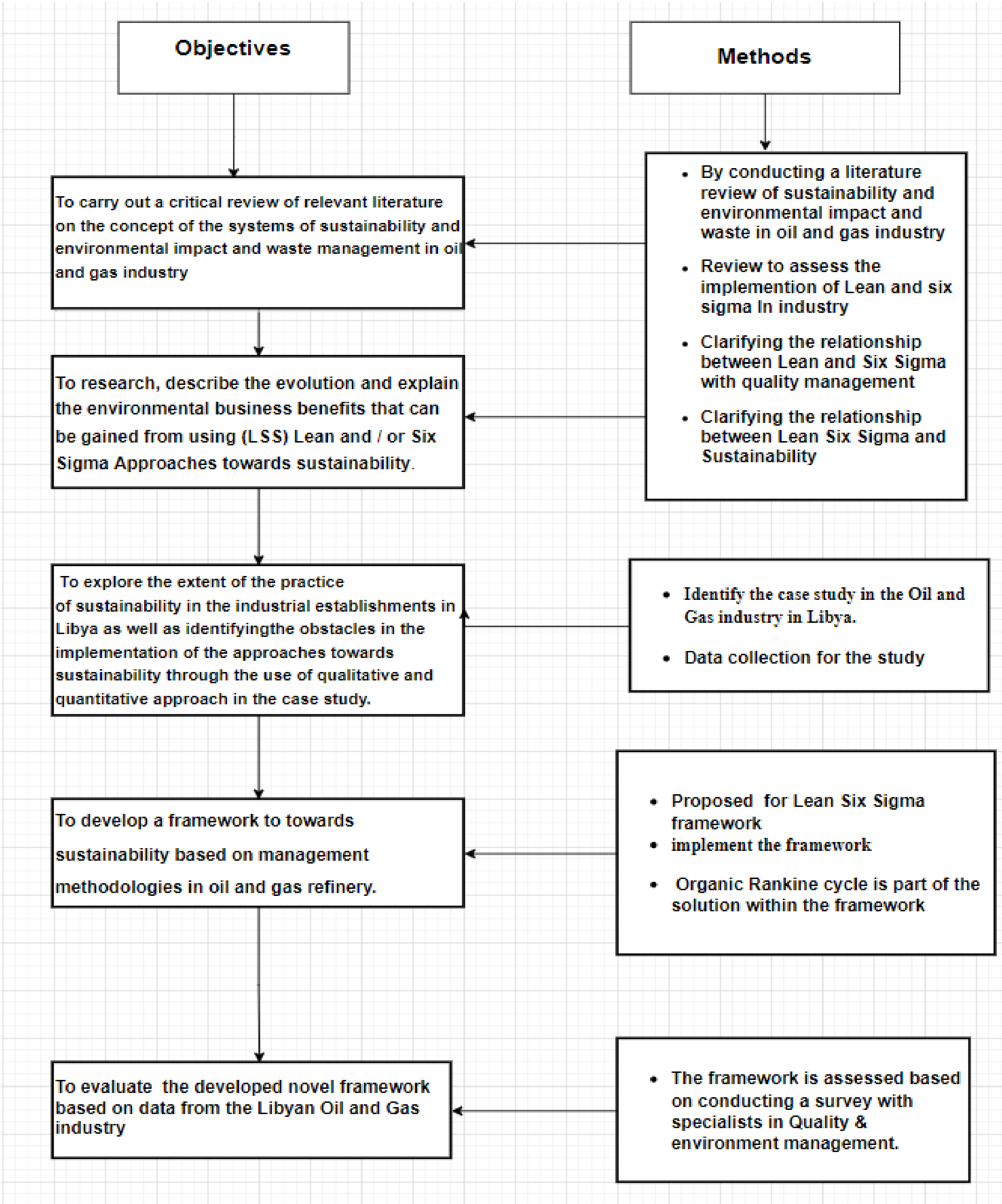


Figure 3-1 Linking of objectives to methodology

3.3 Data Collection

For conducting a balanced study in the Oil industry survey and data collection, efforts must be made to guarantee that a suitable methodology of the study is used, which includes appropriate techniques of the study to ensure high legitimacy of study, dependability, and clarity, and that the study goals and objectives are met. Data collecting procedures are the numerous approaches a researcher employs to acquire and analyse data to assure the research's legitimacy and dependability via knowledge expansion and generation (Creswell, 2013). Using proper statistics-gathering procedures in research is essential since it contributes to the overall advancement of the study. The data-gathering procedures for this study are derived from the research paradigm, methodology, and strategy that will assure the achievement of the study's goals and objectives. The data-gathering process can also be viewed as the strategy of the study, which entails organised techniques hired to guarantee an active and effective method that guarantees order in the manner in which information is composed, studied, and examined, with the goal and purposes of the research in mind (Jankowicz, 2005).

3.4 Methodology for data collection

To present a convincing rationale for the techniques used in the study, it became necessary to describe the main ways to control the research process (Iliemena, 2020). (Blumberg et al., 2005) The research strategy is concerned with the methodologies used to perform the study. There are 3-major types of study procedures: measurable (quantitative), participant-subjective research (qualitative), and mixed research (Saunders et al., 2012).

Quantitative research approaches are two distinct forms of research (Newman and Benz 1998). Qualitative data consists of in-depth descriptions of circumstances, events, and individuals. Thus, this strategy can elicit information about various persons' experiences, attitudes, perceptions, and thoughts. Quantitative data offers information about the numbers, frequencies, or amounts of data distributed. Qualitative approaches are observed with the primary goal of comprehension, and the method employs various data collection techniques to better understand the researched problem (Kumar, 2011). Quantitative methods, being more structured and formalized, give the researcher greater control. Statistical tools significantly boost quantitative research. Because the advantages and disadvantages of each method complement one another, combining the two methods can be effective.

This research will contain qualitative and quantitative data and information about a possible Six Sigma implementation at the ALzzawia Oil Refining Factory. During the qualitative data collecting stage, interviews, a focused group, and qualitative techniques in developing project DMAIC are used. However, quantifiable data and information are also collected, most notably during the measurement and analysis phase of the DMAIC development tool's factorial experimentation phase.

The researcher can triangulate the data using the mixed technique in this study. Triangulation refers to using many investigation methods to examine an event or situation (Amaratunga et al. 2002). (Denzin 1978) defines “triangulation” as combining techniques to investigate phenomena. The triangle shape is the most widely used approach to mixed techniques is the manner (Creswell, 2009). According to Creswell and Plano (2007), "Triangulation research is relevant now due to the complexity of issues that must be addressed, the growing interest in qualitative research, and the practical requirement to collect several kinds of data for varied audiences."

Triangulation is the act of using data commencing from several sources to point out on findings of a topic (Cresswell, 2007). It employs two or more research methods to lessen and remove each technique's problems while simultaneously getting each method's benefits (Amaratunga et al., 2002; Jick,1979; Fellows & Liu, 2008). According to (Saunders et al. 2007), it also implies using numerous data-collecting methods within a single research to guarantee that the data is exact and removes any doubt about uncertainty. According to (Amaratunga et al. 2002)

3.5 Challenges Utilizing Data

Acquisition of statistical data from Libyan refineries is difficult since oil and gas companies are silent about their developmental tactics for competitive reasons and to avoid disclosing sensitive data; this was particularly noteworthy given that the conduct of research in nations' petroleum companies did not have a great environmentally friendly track record.

From December 2019 to February 2020, the researcher conducted fieldwork in Libya. He was able to acquire and supplement all relevant data. The researcher visited the Libyan National Oil Corporation (LNOC) and Environment General Authority (EGA) to investigate the environmental elements of the petroleum business and create contacts with important employees during the first trip to Libya since the beginning of the research.

All the information and sources desired were not fully accessed. The research team was referred to the environmental departments of the LNOC's affiliates, who refused to answer some of the research concerns. Since there was less freedom of information, it wasn't easy to get all the necessary information for the study and interview all the important individuals in the oil and gas businesses, which was the fundamental factor that led to developing a questionnaire survey to gather primary data from the diverse workforce.

3.6 The Research Strategy

The researcher's broad approach to solving the study questions involves deciding the appropriate method to take, for example, whether to conduct a survey or experiment, do action research or another proper method. The objective of the research approach is to answer the question; of what nature of the study is suitable (Saunders et al., 2009).

Robson (2002), differentiated three main methods; experiments, surveys, and case studies. Experiments research measures the consequences of altering variable X on variable Y even if it is more strongly associated with various social science studies, such as psychology, about natural sciences. Surveys research gathers information from respondents using standardized formats by groupings of individuals. Typically, surveys are coupled with a deduction. Equally, case studies develop an intensive and in-depth understanding of a single example (or a limited set of similar cases). Typically, case studies are excellent for exploratory work (Yin, 2003).

Two types of data that might be collected throughout the research are primary and secondary data sources.

3.7 Research approaches

Stage 1: Involves the review of literature review and conduct of a pilot study in Oil and Gas, which will be finalized to comprehend the issues faced by the industry of Oil & gas industries in general and Libya in particular. The research is conducted through a case study and a sample survey.

On the other hand, instance studies may be used to get rigorous and thorough information about a single case or more (Robson, 2002). Case study assists researchers in identifying underlying issues in the phenomena under investigation. Case studies are useful for addressing 'how' and 'why' questions (Yin, 1994). The characteristic of case studies enables the development of an understanding of the meaning in the context of the researcher's assumptions, ideas, and viewpoints (Meredith, 1998). Case studies research was regarded as the most critical research method, particularly if the creation of a new theory is involved (Flynn et al., 1990).

Stage 2: Proposal of a conceptual framework designed to reduce solid waste and harmful emissions, based on Statistical analysis for Lean and six sigma tools by Excel and Minitab Software, SPSS software and Arena software to simulate the current state of production processes and develop innovative solutions to reduce defects by using Lean Six Sigma methodologies on DIMAC cycle and simulation by Simulink Matlab software for temperature recovery used by organic Rankine cycle (ORC).

Stage 3: The questionnaire was divided into three sections based on the case study's results, findings and questionnaire analysis. The assessment will test the possible application and integration of LSS for addressing the problems and achieving improved operational services.

3.8 Secondary data

Secondary data sources are government and academic publications, databases, and the Internet. Using secondary data gives essential context information and enhances the research's credibility. Moreover, if the secondary data is particular, exhaustive, and accurate, it may solve a problem. In addition, secondary data may be categorized into three groups (Saunders, Lewis and Thornhill,2009)

• Documentary secondary data consisting of written papers (reports, etc.), minutes, books, and journals) and non-written records (videos, photographs, and diaries).

• Secondary data from several sources - a blend of documentary and supplementary data gathered through a survey and field visits.

- Secondary data sources were used to gather the daily and for a months records for output/number flaws experienced in the relevant documents. Semi-structured interviews with the work team in the company via telephone, online, and email were also used.

3.9 Primary data

Multiple questionnaires might be used to evaluate and gather information on workers. The online questionnaire via Email has been selected as the kind of questionnaire for this study. This questionnaire style was selected since it is more known to the company's management. The response rate for this selection is quite high. In general, postal and email surveys are cheaper and more efficient than in-person interviews (Saunders, 2009)

Email surveys, in which respondents request to finish the survey while the researcher is absent, are included among the questionnaire types.

In questionnaires, there are two sorts of questions: open-ended and closed-ended. Closed-ended or 'closed questions' are ones in which a researcher poses a series of questions with preset answers (such as 'Yes' or 'No'). As a consequence, quantifiable data is created. In an open-ended (or 'open question') questionnaire, the responder does not get a collection of answers from the researcher. Instead, respondents are prompted to submit their responses, yielding qualitative data (Mathers and Hunn, 2009).

3.10 Questionnaire research

The questionnaire translates the study goals into specific questions, and the responses to these questions would provide data for answering a portion of the research questions. The study included three sections for inquiries based on the concept; each was designed with some thought to address all of the issues necessary to complete the study to achieve the goals.

The first section of the questionnaire is based on the background knowledge of the participants and the use of Lean and Six Sigma (LSS) methods. In addition, the section of the questionnaire attempts to ascertain the participant's engagement with LSS tools and methods used in their organisation or by them, as well as the utility of these tools. The investigation belongs to a trustable aim audience that can deliver reliable \sresponses to the survey query. Questionnair respondents are the operational and quality administrators from the selected manufacturing organisation.

Second section of the questionnaire aimed to verify Al-Zawiya's business framework. The objective is to understand and suggests the LSS implementation procedures applicable to manufacturing organizations, identify potential implementation challenges and assess the proposed model's contents in assisting manufacturing organizations in achieving long-term competitive advantage. The model will be sent to responders, who will be asked to assess the proposed framework.

The third section intended to ascertain the 'critical success factor' (CSF) required for a successful Lean and Six Sigma implementation and the impediments that could impede the implementation process within the organisation.

3.11 Pilot study

Experimental studies are essential for pre-testing and evaluating the questionnaire survey or interview content, clarity, and question design (Sauders et al., 2009). The purpose is to supply responses that enable the recognition of any doubt and offer chances to revise the survey, thereby aiding in establishing content validity. Nonetheless, the primary purpose of the pilot test is to determine that the questionnaire is simple to comprehend (Collis et al., 2013).

1: Ensure that every inquiry is crystal clear and easily understood.

2: Ensure that rating scales are easily understood.

3: Determine the length of time required to finish the survey. Performing the first evaluation on dependability and validity of the measurements.

4: A pilot study was conducted to check the clarity of questions and to increase the survey validity, which was carried out before the questionnaires were distributed to respondents.

Three procedures have been completed to effectively perform the pilot study for this research. The questionnaire was designed based on the following objectives, referenced to its topic/ title regarding the simplicity of questions and the contents of the questionnaire. Where possible, the structure and some adjustments have been made, including modifying the content of some questions and shortening the questionnaire's length to improve its design. Finally, the research director discussed and analysed the questionnaires regarding the issues mentioned earlier; the supervision's response resulted in further development and improvement of the questions.

3.12 DMAIC Methodology:

The methodology consists of five steps; define, measure, analyze, improve, and control (DMAIC).

The defining stage: This stage/process is characterised by issues, itself; according to Harry and Schroeder (2000), they are; project charter, which outlines the issues at hand, the project's requirements, and the intended outcomes, may be considered one of the main products of the define phase. Thus, this entails defining the issues or project goals that must be addressed; SIPOC and flowcharts are the most used tools (Ramly and Yaw, 2012).

The measure phase entails quantifying the issue and mapping the manufacturing process to establish a baseline for the capability data. The often-used tools include SPC and cause-and-effect diagrams (Ramly and Yaw, 2012).

The analysis phase is described as the phase that aids in analysing data and processes to pinpoint the primary influences of flaws and possibilities. The steps and the issue dictate which tools should be used (Harry and Schroeder, 2000).

The improvement phase is when a process is developed by coming up with ideas on how to solve, lessen, and avoid issues in the future. This stage's focus is innovation and finding practical ways to carry out tasks (Pyzdek, 2003).

The control stage comprises the function, management, and upkeep of innovations and fixes to keep the procedure on its new path (Pyzdek, 2003). According to Harry (1998), the control plan's goal is to ensure that performing level enhancement will be maintained throughout the monitoring plans and the documentation.

3.13 The Statistical Programs Used in the Social Sciences (SPSS)

SPSS is a predictive and analytical software for numerical data analysis. SPSS is one of the most extensively utilised software packages for numerical data analysis; it provides a variety of statistical analyses and guidance on how to translate data. SPSS is one of the most popular quantitative data analysis software programmes. According to Field (2013), SPSS is a method developed to evaluate and analyse numerical data, the majority of which is gathered as a questionnaire consisting of a series of questions. Consequently, this programme has been selected as a dependable and efficient method for analysing the quantitative data acquired in questionnaire1, questionnaire2, and questionnaire3 for this study.

3.14 Validation of research

The procedures have been carried out to gather trustworthy and accurate knowledge to ensure the authenticity of the research and to justify and verify the context and conclusions of the research study. (Shenton, 2004) validation is the procedure of methodically gathering data to support the set of inferences that are meant to be made from scores produced by an instrument. Therefore, reliability and validity analysis are the most frequent methods that may provide proof for validating any research investigation (Flick, 2009),

While legitimacy is involved with the reliability or accuracy of the study outcomes, reliability evaluates the accuracy of the results in terms of regularity, strength, and ease with which another researcher can replicate the study (Afifi et al., 2014).

3.14.1 Analysis of Reliability

An instrument's capacity to provide consistent quantities is tested for dependability; the internal reliability for a series of measures shows how similar the objects are. Field (2009). (2009). The Cronbach alpha index is used to determine the internal reliability of the research tools; ideally, Cronbach alpha should be greater than 0.7 for the items being measured to be considered consistent and reliable. As a result, it is the most widely used indicator of reliability for quantitative data (Field, 2013). Therefore, this test aims to determine if there are any measurement mistakes in the items and scales. Field (2009).

The Cronbach alpha calculation formula is as follows:

$$\alpha = K.c \,/\, v + (K-1).c \text{............} \textit{(Equation 3.1)}$$

K= Number of items

c = The average of all covariance between the items.

v = The average variance of each item

Cronbach alpha test is undertaken to check the reliability of the measures used to the evaluate LSS integrated model.

3.14.2 Validity assessment

The validity test essentially evaluates two key points: the degree of accuracy of the instruments employed and the degree to which they measure what is intended to be measured (Flick, 2009); the extent to which a quantity is associated with the outcome is known as criteria reliability, and constructed validation refers to whether the tools assess what is intended to be considered. Content validity is not quantitatively evaluated but relies on assumptions usually developed in the literature analysis. Yusof and Aspinwall (2000); Thompson and Daniel (1996). Construct validity is the most crucial type of validity in this study. The CSFs for each model and framework are assessed based on construct validity for each element, as shown in the following section

3.14.3 Validity of the construct

According to (Kimberlin, 2008), construct validity is a measuring strategy that tests whether or not the scales on the instrument behave similarly to the characteristics being assessed. Therefore, to determine whether or not the instrument scales measure what they are intended to measure and establish construct validity, it is necessary to do a factor analysis on the CSFs that comprise the framework.

The test is most frequently used to examine the concept validity and establish whether or not instruments are acceptable (Pallant, 2010). In addition, (Mokkink, 2018) said that component analysis and construct validity are related and that in published literature, the concept of "factorial validity" is believed to be the same.

This chapter will review the statistical measures used to analyse the validity of the research instruments and the outcomes; this was done to make the thesis easier for the reader and prevent unnecessary repetition.

3.15 Factor analysis

According to Field (2013), one of the main applications of component analysis is to look at and understand the structure of latent variables. Factor analysis is an important technique for evaluating concept validity (factors). Additionally, Williams et al. (2012) state that factor analysis is a statistical technique that explains the variation among observed correlated variables to investigate and confirm a set of correlation coefficients in three steps: reducing many variables into a small number of factors, establishing underlying dimensions between the measured variables and latent construct, and providing construct validity evidence for self-reporting scales. This work evaluated the CSFs using exploratory factor analysis (EFA), the most effective method for producing latent variables and determining construct validity (Williams et al. 2012).

In light of the preceding idea, this test seeks to assess the validity of the instruments and comprehend the structure of the latent variables (factors). The author also desired to understand the relationship between latent variables and model components in each data analysis.

3.16 The evaluation criterion for factor Extraction

Extraction is used to break down a large number of objects into their constituent parts (Williams et al., 2012). the component analysis is often used to get scale dimensionality and reduce the component solution (Thompson and Danial, 1996). In this sense, the most often used criteria by researchers to produce unidimensionality are:

The Kaiser-Meyer-Olkin test (KMO), often known as the factorability test, determines whether a data set is suitable for factor analysis. The correlation matrix is the basis for this test calculation, and the higher the correlation between variables, the better the data are for conducting a factor analysis test (Field, 2009).

Barlett's sphericity test also determines if the data exhibits equal variation across the variables. One can tell if the observed variables are redundant by examining whether the correlation matrix (R) significantly differs from the identity matrix. By using the determinant of the correlation matrix |R|, one may calculate the degree of divergence from |R|=1, shown by Barlett's test of sphericity. Since the variables are tightly correlated if |R|=1, the test shows how far the variables have deviated from that value. Essentially, this is calculated utilising the formula from Field (2013) as follows:

$$X^2 = \left[1 \frac{(2P+5)}{6} - n\right] n(1 - |R|) \text{.........} \textit{(Equation 3.2)}$$

Where.

R=Correlation matrix
N=number of observations.
P= number of variables.
X^2 = Chi-square

Factor rotation: The test produces loading patterns that are easier to understand, and the Oblimin methodology is the most popular method for creating more linked factors (Williams et al., 2012). According to Hair et al. (2006), a factor loading of 0.3 is negligibly significant, 0.4 is moderately significant, and 0.5 is very significant. When avoiding bidimensionality, the author of this study eliminated any item with a factor loading of less than 0.5. (Habibah et al., 2014).

3.17 Arena Simulation Software

The arena is a simple software program built on the SIMAN simulation language. Arena provides interchangeable templates of graphical simulation modelling and analysis components to create different simulation models. The modules are often arranged into panels. Switching panels allows you to access new modelling capabilities and structures. Modules from many boards can frequently be merged in a single simulation model.

Industrial manufacturing or service simulation mostly simulates measuring performance using Arena Rockwell. Arena software has good specifications and allows users to put real system data in a virtual environment. So, considering our data and system flexibility, Arena is appropriate. So, the whole task simulation will be done through Arena Rockwell.

3.18 The Simscape simulation software

The Simscape toolbox, a piece of simulation software that operates in the MATLAB/Simulink® environment, is used to simulate the operation of the existing ORC power system. MathWorks Engineering created this toolbox to design, optimise, and dynamically manufacture the behaviour of complicated thermodynamic systems with a user-friendly interface. It is devoted to modelling diverse thermodynamic applications, including fuel cell and chemical reaction systems, heat pump and refrigeration systems, HVAC systems, and power generation. The toolbox offers MATLAB command line functions for thermodynamic calculations and balancing of the simulated models, as well as a Simulink block set for system simulations.

A complete thermodynamic model comprised of pipes, pumps, compressors, turbines, valves, heat exchangers, tanks, chemical reactors, burners, fuel cell stacks, etc., may be built using the block set's Simscape and Simulink blocks, which are saved as icons in a large visual Simulink library.

Users of this visual library can create setups by dragging and dropping the necessary icons (components). Each block may be double-clicked to open a dialogue box where all the information and settings required for the element can be quickly entered. The programme also enables designers to use Simscape and Simulink to create a conceptual design for new members or make various alterations to current ones. This benefit allows the user to carry out additional calculations, such as the precise component geometrical design and sizing, which cannot be easily simulated using the conventional Simscape and Simulink blocks. Simscape also offers an expandable database of thermo-physical parameters.

Many pure compounds and mixes employed in thermodynamic systems can be found in this database. Especially when computing the compressibility factor and liquid density, the Simscape model can thus provide good accuracy close to the critical point and close to condensation. For accurate calculations involving water and steam, notably in power plant models, it can also handle generic flash calculations, such as the temperature glide of mixes.

3.19 Summary of the chapter

This part of the study focuses on the primary methods used in conducting investigations of an organisation. The principal features of the research methodology explored include research philosophy, strategy, and procedures, referred to as Methodological choice in research method (Saunders et al., 2013).

As a result, the research design and strategy section outlined the selected research approach for carrying out the study and achieving the research objectives. The chosen research strategy is outlined in three parts that follow:

1: A study of the relevant literature to gather secondary data and create the recommended framework.

2: The key research questionnaire was suggeet to gather the primary data for verifying the suggested models, and a multicriteria decision-making approach was utilized to assess and rank the framework's components.

3: Analytical processes was conducted to check and validate the outcomes of the data acquired for the framework, establishing the research's validity.

In addition, the chapter emphasised the sample selection and presented the research's pilot study. The next chapter focuses on creating and validating the LSS integrated framework, discussing how it was built and outlining the key phases and techniques for validating the model.

This chapter also explains the tools used in the simulation, the most important of which was Arena Software, which was used to simulate the reality of the production process inside one of the refinery factories.

Also, the simulation model on Simscape Software is represented in analysing the waste heat from the smokestacks of oil refining.

Chapter 4: Development Proposal of Lean Six Sigma Framework and validation

4.1ntroduction

Maintaining quality and dependable performance has become a priority for manufacturing businesses to promote customer satisfaction as product demand rises (Gupta et al., 2018). To comply with market competition, companies must define, monitor, evaluate, make improvements, and implement control over their current production processes (Gupta et al., 2018). Diverse strategies, tactics, and instruments continuously enhance productivity and quality (Gupta et al., 2018). Additionally, each business or industry of production must employ a proper combination or selection of several approaches or tools (Sokovic et al., 2010). Variations and downtime are unavoidable in creating any product; however, the primary objective of process management or process capability analysis in any business is to explore the causes of rest in the production process Pearn and Chen, (1999); this assists industrial firms in monitoring and measuring the process's potential (Wu et al., 2004).

4.2 Lean Six Sigma framework

DMAIC and DMADV are the two primary quality management tools used in Six Sigma (Kumar & Sosnoski, 2009; Jones et al., 2010). Define-Measure-Analyze-Improve-Control is the abbreviation for Define-Measure-Analyze-Improve-Control. This technique is based on process improvement by the Deming cycle. It is the enhancement of several processes. The DMAIC cycle consists of five interconnected phases (Sokovic, et al.,2010; Sin, et al., 2015). Sections throughout the organization.

The purpose of the suggested approach is to simplify LSS installation so that manufacturing organisations can overcome their apprehensions regarding the high cost and complexity of LSS implementation. By adopting step-by-step guidance, the approach aims to utilise the organisation's knowledge and remove the barriers thwarting individuals from using statistical problem-solving methods. The suggested model is based on the DMAIC strategy, which enables the implementation procedures to discover quality improvement opportunities, raise process performance, and minimise variability and waste in a product or process using statistical techniques. However, the DMAIC phases in this approach are merged to streamline the operating system and implementation processes.

4.3 DMAIC Cycle

DMAIC and DMADV are the two primary quality management tools used in Six Sigma (Kumar & Sosnoski, 2009; Jones et al., 2010). Define-Measure-Analyze-Improve-Control is the abbreviation for Define-Measure-Analyze-Improve-Control. this technique is based on process improvement in accordance with the Deming cycle. It is the enhancement of several processes. sections throughout the organization. The DMAIC cycle consists of five interconnected phases (Sokovic, et al.,2010; Sin, et al., 2015).

The purpose of the suggested approach is to simplify LSS installation so that manufacturing organisations can overcome their apprehensions regarding the high cost and complexity of LSS implementation. Adopting a step-by-step guidance, the approach aims to utilise the organisation's knowledge and remove the barriers thwarting individuals from using statistical problem-solving methods. The suggested model is based on the DMAIC strategy, which enables the implementation procedures to discover quality improvement opportunities, raise process performance, and minimise variability and waste in a product or process using statistical techniques. However, the DMAIC phases in this approach are merged to streamline the operating system and streamline the implementation processes.

4.3.1 Define phase

Establishing the objective and its requirements: designing required resources and responsibilities, defining an organisational structure conducive to achieving the goals, identifying the project's components, and estimating its completion date (Khamkham, 2017).

A project charter was established during the 'define' phase of this project's implementation. Definitions were based on prerequisites such as the project's objectives, scope, and required resources, laying the groundwork for subsequent stages. For organising the project's structure, which aimed to reduce the number of complaints about the delivery process, different roles were assigned to other people in various locations. According to George and George (2003), the fundamental principle of LSS is that a defect is anything that dissatisfies a customer, including poor quality, high costs, and lengthy lead times. The initial step in resolving these issues is to examine how the organisation meets customer needs from a process perspective. A SIPOC diagram (Figure 4.1) creates a high-level map of such a process by listing suppliers, inputs, processes, outputs, and customers. A SIPOC diagram was designed to identify potential internal and external customers and specify their distribution process requirements and inputs and outputs. Based on an analysis of information and process variables, quality standards were evaluated based on the work of processes, allowing for the implementation of enhancements. Requirements and values were defined based on product, time, quality, and quantity.

The model is used in this process to organise and plan the implementation process, which consists of the following four steps: (1) To improve the quality of products, analyze the market to gather the Voice of the Customer (VOC), assess the business process to determine the Voice of the Business (VOB), and translate the VOC and VOB into Critical to Quality (CTQ): (3) Establish the overall improvements, including process improvement using Supplier Input Process Output Customer; (2) create a high-level functional team; and (3) specify the ultimate goal (SIPOC).

4.3.2 Measure phase

This phase tries to improve the procedure and prepare the workplace for change, which can be accomplished by gathering the necessary data to determine the behaviour of the process, choosing the bottleneck and identifying the waste area utilising VSM, as well as establishing present performance using process capability metrics and measuring Sigma. At the end of this stage, assess the measurement system using the Six Sigma approach, a statistical tool for calculating the amount of variance in the measurement system.

The measure phase entails obtaining information on procedures that will be enhanced. It focuses on the information required to better comprehend all company operations, as well as the identification of potential issue areas. The primary objective of the measure phase is to gather and analyze the data required in the control phase to demonstrate differences and evaluate progress, which will be provided to management. (Shankar, 2009). and measuring the existing procedure, determination of accurate and trustworthy metrics, determining whether there are sufficient data to measure, and evidence of present performance and effectiveness.

4.3.3 Analysis phase

During the analysis phase, many tools and techniques as cause& effect diagram and cause and-effect matrix, to identify the root causes of problems, prioritize the causes that contribute to using the Prioto analysis and apply 5 why's and brainstorming to identify the potential solution are utilized to identify underlying causes, evaluate risk, and analyze data for corroborating the study, samples must be taken, and apparent issues must be confirmed to be actual issues. This phase requires defining process capacity, clarifying objectives based on real data gathered in the measure phase, and initiating root cause analysis about process variability. By calculating process capacity, which is defined as the "sigma" of the process, the process's ability to satisfy client requirements is determined. The capabilities of the process will be a focal area of planned upgrades

4.3.4 Improve phase

This phase's objective is to gather the information essential to design and construct an action plan to enhance the organization's operations. The action plan's potential solutions should be presented and implemented. Before implementing the answers on a broad scale, pilot solutions are implemented to check the validity and correctness of the analytical work and to allow for any necessary adjustments. Improving the process, executing the modifications that remove the flaws, developing and testing potential solutions, choosing the most effective one, and establishing the implementation plan.

4.3.5 Control phase

Implement control systems, such as statistical process control. The purpose of the control stage is to validate that the modifications done during the improvement stage are adequate and ongoing by evaluating the process's quality. In addition, it regulates the future state of the process to limit departure from the goals and guarantee that the correction is made before hurting the process's outcome. The procedure must be checked regularly. In the control phase, control charts are used to determine whether or not the process is controllable.

During the Improvement and Control stages, the entire process is monitored via a controlled plan utilizing the necessary LSS tools to achieve continuous improvement for the operational practice. Lastly, a balanced scorecard and key performance indicators confirm that the organization has met its business objectives

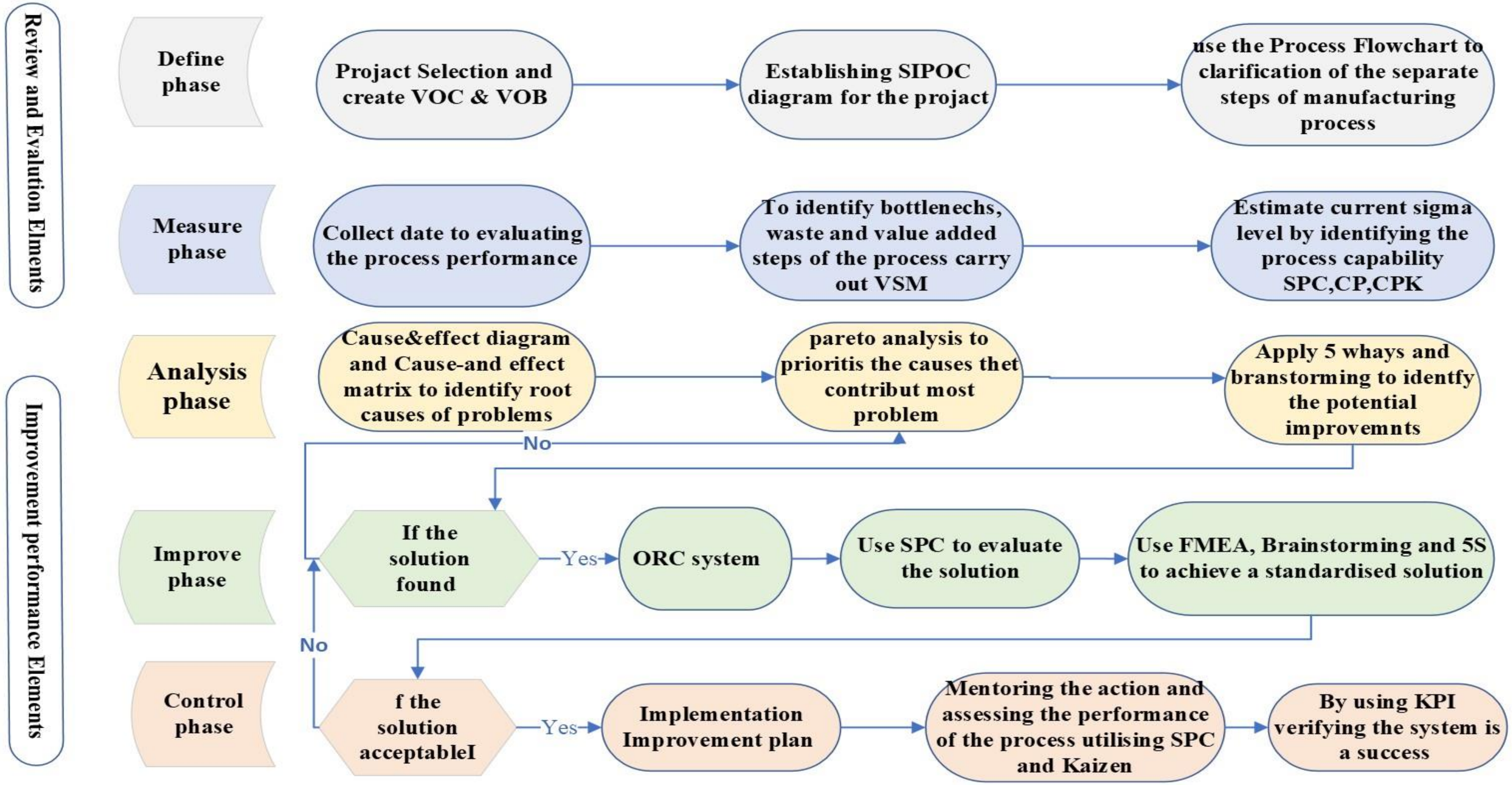


Figure 2.1: Lean and Six Sigma framwork

4.4 Verification of the LSS integrated framework

For this study, a questionnaire was made based on what was already known from the source material. The form had five main parts with 12 (See the Appendix) important questions in each. The main goal was determining if the suggested plan could be used in the Oil and Gas business. The main purpose of the questionnaire is to find out how LSS is being used in manufacturing companies right now, as well as how it is being used, what people think its benefits are, what factors are important for success, and what gets in the way of its successful application.

The first part of the questionnaire asked about the respondent's background and whether or not they were familiar with the LSS method. The part that was looked at looked into how well Lean Six Sigma would work for the responder company in terms of long-term strategy thought. It will also show how top managers and other workers see the LSS plan.

The second section was all about evaluating the proposed model. It was supposed to consider the proposed model based on eight criteria: model content, suitability and capability for oil and gas companies, the model's ability to increase competitiveness, the framework's ability to overcome natural LSS implementation difficulties, and the section looked into how Oil and Gas manufacturing organizations knew about and used LSS tools and techniques.

The final section of the questionnaire evaluates the significance of CSFs in effectively implementing the LSS model and the possible hurdles that might delay the implementation process. The CSFs were derived from the literature on the Lean and Six-Sigma methodology, as indicated before in this research; the CSFs collected consist of 8 primary elements deemed essential for LSS implementation. The inhibiting factors, which include the typical reasons that impede the successful application of the LSS strategy, consist of 9 variables selected from the literature review (Johannes, 2013; Antony, 2009).

4.5 Methodology of data collection

A total of 50 research surveys were issued to various management workers at an Oil and Gas company on Az Zawiya; 44 questionnaires were completed and returned within the allotted time frame, a rate deemed acceptable (Saunders et al., 2009). Collecting the statistical software package used to analyse the data is an appropriate way for providing robust and structured analysis. Bryman (2005) states that the Statistical Package for Social Science is the most suitable statistical programme for social science and engineering research . Therefore, SPSS V26 was used to analyse the data collected in this study, 44 usable questionnaires were coded and entered into the (SPSS V26) software programme, and basic statistical analysis for the observation of frequencies, percentages, means, and standard deviations was performed to evaluate the data.

4.6 Data preparation

In order to begin with the first phase, which is data editing and coding, and then entering the data into SPSS, the data should be adequately prepared for analysis from the outset.

In order to find mistakes and omissions in data, the first step is to carefully edit the data; this phase also includes the repair of data to ensure the minimal standard was met. The surveys were examined for quality and completeness; they underwent a variety of preliminary analyses, such as error checks and data editing. Non-response, inconsistent answer, and erroneous entry were the most frequent problems. Following up on non-responses, it was discovered that the non-respondents were comparable to other respondents. The inconsistency of an answer was rectified based on the researcher's best judgement after comparing it to other replies of the same kind.

The second stage is to study and have a comprehensive understanding of the variables that were entered into SPSS V26 formats and will be utilised as an analytical tool.

Error-free data from the questionnaire were then entered into SPSS V26 and made ready for analysis as the last step.

4.7 Discussion of the results

This section of the study describes the descriptive analysis of the data collection and statistical analysis applied to the output of the data collected by measures of the central tendency, including mean, percentage, and standard deviation; consequently, the results of the data were collected and presented in the subsequent sections as tables, charts, and various statistical figures.

The survey results of the respondents are described in this section. According to the authors, the management staff that participated in the survey represents a reliable demographic that can provide truthful answers to the questionnaire. Most respondents comprised operational managers, quality managers, technical managers, and a Project Lead.

Investigating the understanding and use of LSS tools and procedures in Manufacturing Organisations. This questionnaire section aims to ascertain the participant's involvement with LSS tools and procedures used by them or in their organization, as well as the value of these tools for manufacturing organizations and the processes used to deploy them. The goal is to provide a basic understanding of LSS implementation methods appropriate for industrial companies.

4.8 The responders were asked to specify their position within the company

11.4% of respondents are quality managers, 36.4 % are operational managers, 43.2%Technical manager and 9.1% are led manger, including quality professionals, who work in fields related to industrial engineering, as shown in Table (4.1).

Table4.1: position in your C ompany

What is your position within your company?					
		Frequency count	Percent %	Valid Percent	Cumulative Percent
Valid	Operational Manager	16	36.4	36.4	36.4
	Technical manager	19	43.2	43.2	79.5
	Quality Manager	5	11.4	11.4	90.9
	Led manger	4	9.1	9.1	100.0
	Total	44	100.0	100.0	

4.8.1 The responding organisations' quality management system type

Table 4.2 Position/quality management system type

Elements	***Operational Manager %***	***Technical manager %***	***Quality Manager %***	***Project Lead %***
ISO Series	*33*	*47*	*20*	*25*
Lean Six sigma	*30*	*32*	*30*	*25*
Lean	*11*	*5*	*10*	*10*
Six sgma	*19*	*6*	*20*	*15*
TQM	*8*	*10*	*20*	*25*

Table 4.3 shows that the respondents were asked to name the organisation's current quality management system. 40.9 % of respondents' firms utilise the ISO series, followed by 29.5% by TQM, 9.1 % by Six Sigma, 2.3% by Lean and Lean Six Sigma 18.2%.

Table4.3 :Quality management system in your company

What is your company's existing quality management system?					
		Frequency count	Percent %	Valid Percent %	Cumulative Percent %
Valid	ISO Series	13	40.9	48.5	29.5
	Lean	1	2.3	5.3	31.8
	Six sgma	4	9.1	6.1	40.9
	Lean Six sigma	18	18.2	5.9	81.8
	TQM	8	29.5	34.2	100.0
	Total	44	100.0	100.0	

4.8.2 The amount of knowledge of the LSS method

The respondents were questioned about their familiarity with LSS. The tebole reveals that 86% of respondents are aware of LSS, whereas 14.0% are unaware or have never heard of LSS.

Table4.4:Using the Lean and Six Sigma in your company

How long have you been using the Six Sigma or Lean methods?					
		Frequency count	Percent%	Valid Percent %	Cumulative Percent%
	6 months or less	2	4.5	4.7	4.7
	1-2 years	4	9.1	9.3	14.0
	2-5 years	11	25.0	25.6	39.5
	5-10 years+	20	45.5	46.5	86.0
	Never used Lean and/or Six-Sigma	6	13.6	14.0	100.0
	Total	43	97.7	100.0	
Missing	System	1	2.3		
Total		44	100.0		

Table 4.5. position of respondents

Elements	***Operational Manager %***	***Technical manager %***	***Quality Manager %***	***Project Lead %***
1-2 years	*6*	*11*	*0*	*0*
2-5 years	*25*	*21*	*40*	*25*
5-10 years+	*44*	*47*	*60*	*25*
6 months or less	*13*	*0*	*0*	*0*

4.8.3 Respondents were asked if they had ever used or put Lean Six Sigma tools

The practices to use in their business. The Likert scale had a range from 1 to 5, with 1 meaning "never used," 2 meaning "just once," 3 meaning "rarely used," 4 meaning "often used," and 5 meaning "very used."

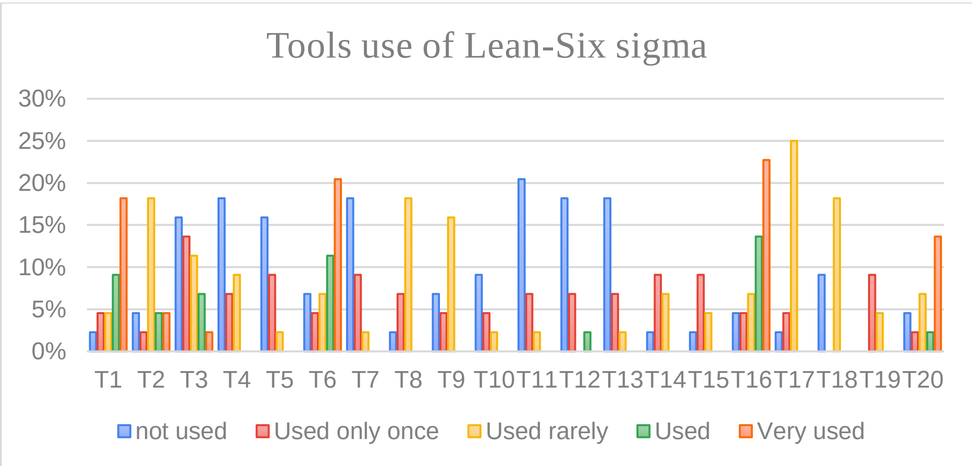


Figure 4;2:Use Lean and Six sigma Technologies

Table 4.6. Tools of lean-Six sigma

T1	**Pareto Analysis**	**T11**	**FMEA Failure mode effeects analysis**
T2	Value Stream Mapping(VSM)	T12	Process capability analysis
T3	5S methods (sort, set in order, shine, standardize, and sustain the cycle)	T13	SIPOC (suppliers,input, process,, output, customers)
T4	Total Productive Maintenance (TPM)	T14	PERT chart ((program evaluation and review technique)
T5	Design of Experiments(DOE)	T15	Cause and Effect diagram
T6	Brainstorming	T16	Statistical Process Control(SPC)
T7	Kanban	T17	PDCA (plan, do, check, act)
T8	Cause-and-effect matrix	T18	ANOVA
T9	Poka-yoke	T19	Process flowchart
T10	Kaizen	T20	Key Performance Indicators (KPI)

the figure demonstrates that participants' use of tools and methods varies; nonetheless, several Lean tools and techniques, such as Total Productive Maintenance (TPM), Poka-yoke, and Kaizen events, have been rated unused, while 5S, VSM, and Kanban are also not much use.

Among the LSS tools and methods, The most well-known quality tools and methods are SPC, Process planning, brainstorming, and Pareto.

4.8.4 Organisational utility of LSS tools and strategies for responses

On the Likert scale, '1' indicates 'not useful ', '2' indicates 'less useful', '3' indicates'moderately useful', '4' indicates 'useful', and '5' indicates'very useful '. Participants were asked if they believe LSS tools and procedures to be beneficial for their organisation.

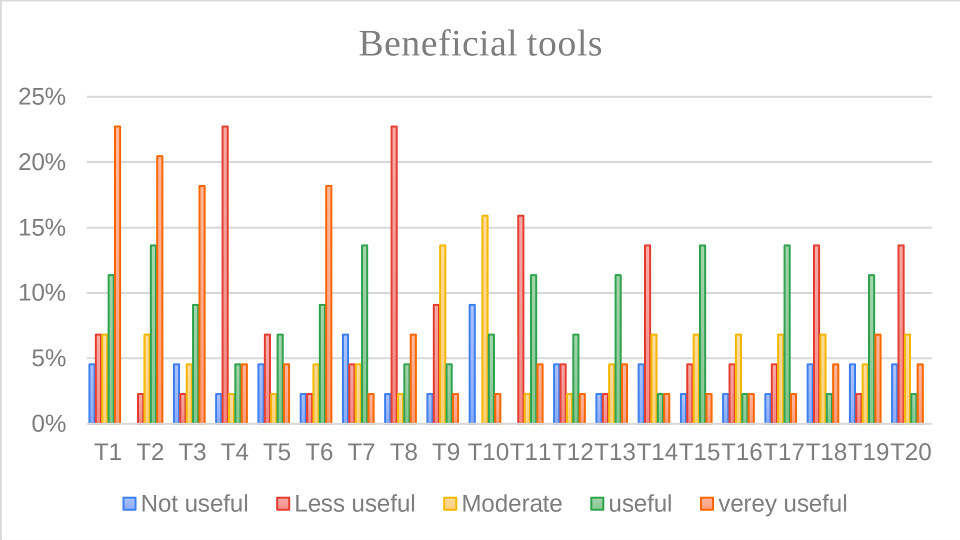


Figure 4.3:Benefiit of Use Lean Six Sigma

showed that the volunteers had very different ideas about how important tools and methods were. Most of the people who answered the survey said that 5S, Brainstorming, and Pareto analysis were very important tools.

VSM and SPC were ranked as the most useful tools for their companies. But most of the people who answered said that the rest of the tools are not very useful.

4.8.5 The possible advantages of using the LSS methodology

The primary advantages of adopting the LSS strategy include the quality goals of both techniques. The Likert scale ranged from 1 to Very Low. 2– Low . 3– Moderate. 4– High. 5 – Very High . on the Likert scale, most of the people who answered chose "agree" or "strongly agree." However, the people who answered chose the following things as the most helpful:

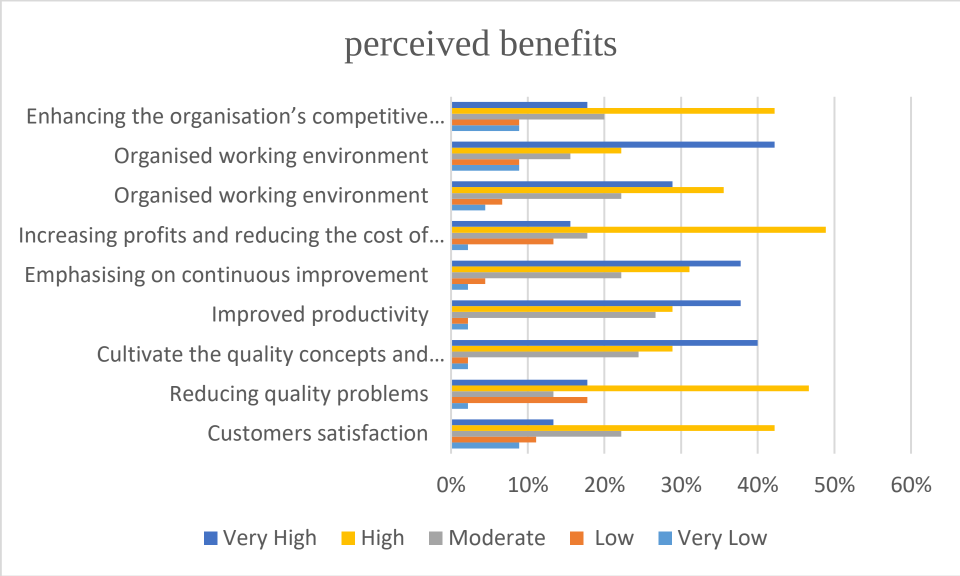


Figure 4.4: perceivd benefits

This figure shows the perceived benefits the company can reap from implementing an integrated Lean Six Sigma framework,The answers were close to each other, and yet it was organised working environment, cultivate the quality concepts and awareness, Improved productivity and Emphasising on continuous improvement It is the highest in the rating.44%,40%,38% and 36%.

4.9 Evaluation of the LSS framework

This component of the questionnaire was intended to verify the suggested manufacturing model. The objective is to understand the LSS implementation procedures applicable to manufacturing organisations, identify potential implementation challenges, and assess the accuracy of the contents of the proposed Model in terms of assisting manufacturing organisations to achieve long-term competitive advantage. The model was given to the respondents, who were requested to assess the model based on the ranking of the following claims regarding the proposed model.

4.9.1 Evaluating the adequacy of the suggested LSS model for industrial firms

Table 4.7 shows that 13.6% of respondents strongly agreed with the content of the LSS model, 52% agreed, 27.3% moderately disagreed, and 6.8% strongly disagreed. In the same way, 86.4% of those who answered agree that the plan suggested is good.

Table 4:7:Precedence in the use of tools

Do you agree with the precedence In the use of tools?					
Statistics		Frequency count	Percent%	Valid Percent%	Cumulative Percent%
N	Valid 44				
	Missing				
Valid	Strongly disagree	3	6.8	6.8	6.8
	Neutral	12	27.3	27.3	34.1
	Agree	23	52.3	52.3	86.4
	Strongly agree	6	13.6	13.6	100.0
	Total	44	100.0	100.0	

Table 4.8. position of respondents for the content of the LSS framework

	Operational Manager %	*Technical manager %*	*Quality Manager %*	*Project Lead %*
Strongly agree	*13*	*16*	*20*	*0*
Agree	*38*	*53*	*80*	*75*
Neutral	*31*	*32*	*0*	*25*
Disagree	*10*	*0*	*0*	*0*
Strongly disagree	*6*	*4*	*0*	*0*

4.9.2 understand of proposed framework

This table 4.9 shows that 50% or respondents they understand most of tools of Lean six sigma

But in other hand ther are 22.7 not understand and % they are not fully understand the framework.

Table 4.9: Understand this propsed framework

Is it easy to understand this proposed framework?					
		Frequency count	Percent%	Valid Percent%	Cumulative Percent%
Valid	Strongly disagree	10	22.7	22.7	22.7
	disagree	6	13.6	13.6	36.4
	Neutra	6	13.6	13.6	50.0
	Agree	13	29.5	29.5	79.5
	Strongly agree	9	20.5	20.5	100.0
	Total	44	100.0	100.0	

Table 4.10 . position of respondents for framework understanding

Elements	***Operational Manager %***	***Technical manager %***	***Quality Manager %***	***Project Lead %***
Strongly agree	*0*	*26*	*40*	*25*
Agree	*88*	*58*	*60*	*50*
Neutral	*0*	*11*	*0*	*25*
Disagree	*6*	*0*	*0*	*0*
Strongly disagree	*0*	*0*	*0*	*0*

4.9.3 What is the degree to which you agree or otherwise whether this proposed framework is relevant to your company?

The table 4.11 shows the 54.5 % respondent are agree for this framework is relevant in there combany, 11.4% was strongly agree and 25% neutral. While the opinion poll results were that the model has no connection with its institution, it is weak at 4.5%.

Table 4.11: framework is relevant to appropriste for your company

Statistics					
		Frequency count	Percent%	Valid Percent%	Cumulative Percent%
Valid	Strongly disagree	2	4.5	4.5	4.5
	Disagree	2	4.5	4.5	9.1
	Neutral	11	25.0	25.0	34.1
	Agree	24	54.5	54.5	88.6
	Strongly agree	5	11.4	11.4	100.0
	Total	44	100.0	100.0	

Table 4.12 . position of respondents for framework is relevant

Elements	*Operational Manager %*	*Technical manager %*	*Quality Manager %*	*Project Lead %*
Strongly agree	*6*	*16*	*20*	*0*
Agree	*63*	*37*	*60*	*100*
Neutral	*19*	*37*	*20*	*0*
Disagree	*0*	*11*	*0*	*0*
Strongly disagree	*13*	*0*	*0*	*0*

4.9.4 Do you anticipate any challenges in implementing Lean-Six Sigma using the suggested framework in your company?

Demonstrates that 54.5% of respondents responded that they do not anticipate any implementation difficulties with the proposed paradigm. However, 18.2% cited challenges, such as the availability of an excessive number of models. Some markets are more sensitive to pricing than to quality, process, or internal processes. Other important concerns were the scale of the organisation, the high cost of training and the fact that the model can be used by businesses that sell different things or provide different services.

Table 4. 13:Challenges in implementing Lean-Six Sigma

Do you anticipate any challenges in implementing Lean-Six Sigma in your company using the suggested framework?					
		Frequency count	Percent %	Valid Percent%	Cumulative Percent%
Valid	Strongly disagree	8	18.2	18.2	18.2
	disagree	7	15.9	15.9	34.1
	Neutral	5	11.4	11.4	45.5
	Agree	13	29.5	29.5	75.0
	Strongly agree	11	25.0	25.0	100.0
	Total	44	100.0	100.0	

Table 4.14 . position of respondents challenges to implementing LSS

Elements	Operational Manager %	Technical manager %	Quality Manager %	Project Lead %
Strongly agree	19	16	20	50
Agree	50	37	60	50
Neutral	0	37	20	0
Disagree	25	11	0	0
Strongly disagree	6	0	0	0

4.9.5 Do you have any suggestions for improvement?

Evaluation - Identifying any missing elements that should be added to the proposed model's content.

89% of respondents stated that the model's contents are comprehensive. Only 11% thought that the model was missing anything. They recommended that the conceptual model include proper training, that ANOVA be used to compare the results of DOE to the real forecast, and that incentives be put in place to encourage teamwork.

4.10 Evaluation of CSFs and Obstacles Limiting the Proper Deployment of LSS

This part of the questionnaire was meant to find out the Critical Success Factors (CSFs) that are needed for Lean Six Sigma to be implemented successfully, as well as the problems that could get in the way of implementation in an industrial company.

4.10.1 Assessing the significance of CSFs in the adoption of LSS:

This section's primary objective is to evaluate the CSFs necessary for the effective deployment of LSS. In the poll, respondents were asked to rank the significance of 8 CSFs using the following Likert scale

1 - Not important 2 – Slightly important 3 – Important 4 – quite Important 5- Very important

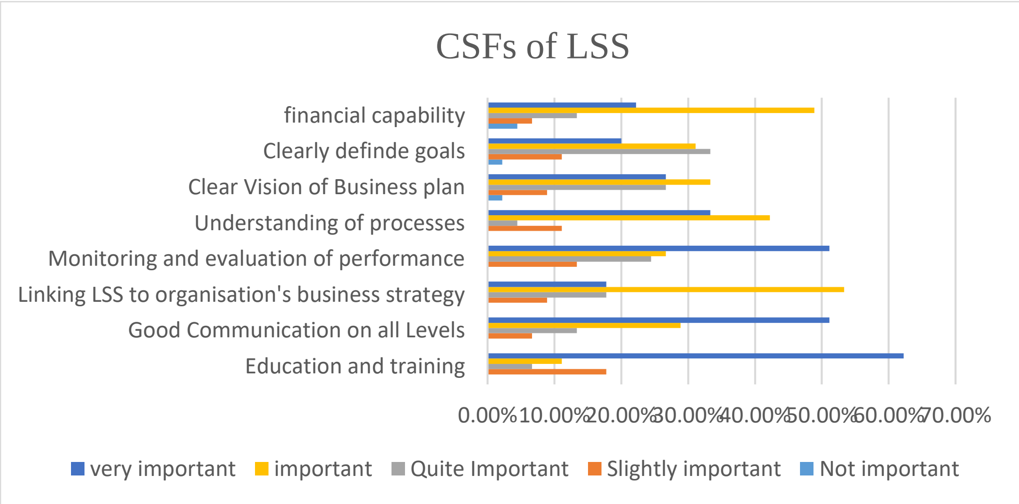


Figure 4.5 Lean Six Sigma CSFs

This figure 4.5 shows the following the majority of respondents responded that the largest percentage level (%) on the scale fell between Moderately Significant and Very Important, indicating that most CSFs were deemed important. Nevertheless, Some CSFs were ranked as more important than 50%. These included training and education, linkink Lss to organistion business strategy , monitorinig and evaluating performance, and good communication. at 63%, 52%, 51%, and 50%, respectively. These are the most essential CSFs for the effective deployment of Lean Six Sigma.

4.10.2 Obstacles to LSS implementation

Respondents were asked to assess the degree to which the nin identified hurdles may inhibit the effective deployment of LSS in Oil and Gas manufacturing organisations. The present literature analysis identified eleven impediments (Johannes, 2013), (Antony, 2009), and (Andersson etal., 2006). On a Likert scale from 1 to 5, these hurdles were ranked as follows: 1 = very low, 2 = low, 3 = moderate, 4 = high, and 5 = very high.

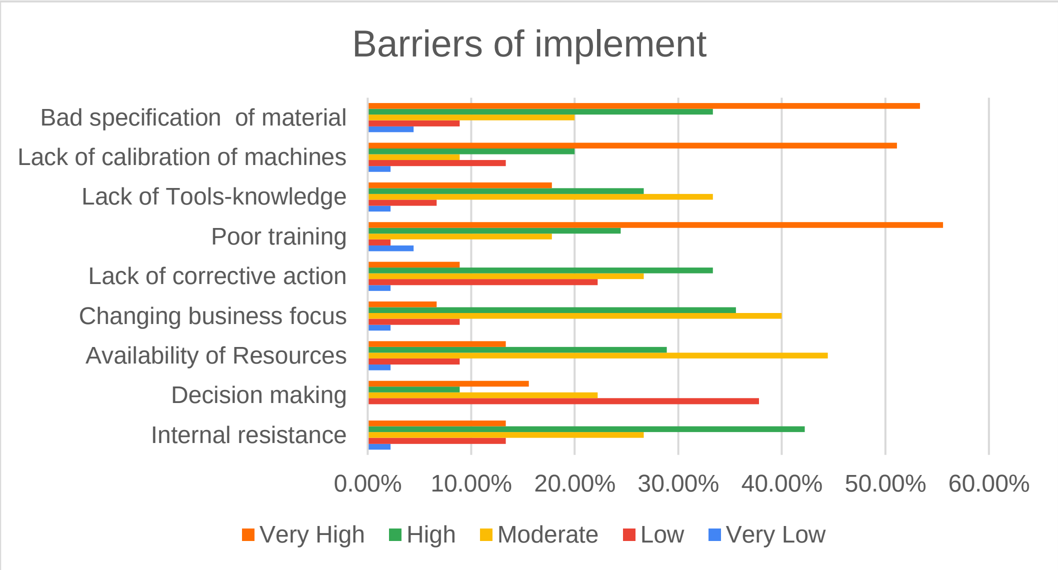


Figure 4.6 Obstacles to LSS implementation

The answers were similar in this regard, but the highest percentage was for lack of calibration of machines, ,and bad specification of material and poor training was seen as the main inhibiting obstacles to LSS adoption.

4.11 The reliability and validity of the instrument

Reliability and validity are crucial factors when designing and conducting any study. But dependability refers to how readily someone else might replicate the study. Validity refers to the clarity of the aim and procedure regarding the achieved findings and whether or not they measure what was intended (Flick, 2002).

4.11.1 Reliability test:

The method confirms the data's validity required to validate the LSS framework. However, the Cronbach alpha must be better than 0.7 for the reliability of the items being tested to be considered (Ali, 2020).

The computation of Cronbach's alpha entails the derivation of the mean covariance, which is subsequently divided by the mean total variance. Hence, a higher alpha value necessitates a higher covariance in relation to the variance of the item. Put simply, the majority of the overall variability can be attributed to the links between the questions. The general rule of thumb is that a Cronbach's alpha of . 70 and above is good, . 80 and above is better, and . 90 and above is best. So, a Cronbach alpha test was done to determine the reliability of the measures used to test the LSS conceptual model. The coefficient alpha is 0.827, and the enlarged item alpha is 0.845, as shown in Table 4.15. The small difference between the alpha numbers is how the subjects and the poll scored, but both are higher than 0.7.

Table 4.15:reliability statistics

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.827	.845	4

The resulting number is higher than 0.7. So, it's safe to say that these tools have a high level of internal uniformity, which made the writers more sure that their results were accurate.

Table Inter-Item Correlation Matrix showed how the item measures were related. It was clear that most of the things were described well.

Table 4.16: Correlation Matrix

Inter-Item Correlation Matrix				
	Agree with the precedence In the use of tools	understand this proposed framework	Appropriateness of the proposed framework	Implementing Lean-Six Sigma in your company using the suggested framework
Agree with the precedence In the use of tools	1.000	.517	.699	.396
understand this proposed framework	.517	1.000	.561	.712
Appropriateness of the proposed framework	.699	.561	1.000	.576
Implementing Lean-Six Sigma in your company using the suggested framework	.396	.712	.576	1.000

Table of Item-total Statistics: According to Field (2009) and Pallant (2010), the numbers in the column headed Corrected Item-Total Correlation show the link between the item and the overall questionnaire score. The Table illustrates the effect of the total statistics. All values must be more than 0.3, and all things should be connected with the overall scores in trustworthy circumstances. Consequently, the Table displays the data that Cronbach alpha deemed accurate, demonstrating that each item correlates with at least 0.3.

Table 4.17: The internal correlation of the items measured

Item-Total Statistics					
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Agree with the precedence In the use of tools	10.02	11.372	.590	.524	.815
understand this proposed framework	10.57	7.832	.735	.573	.748
Appropriateness of the proposed framework	10.05	10.975	.710	.595	.778
Implementing Lean-Six Sigma in your company using the suggested framework	10.41	8.201	.686	.565	.775

4.12 Validation of the important success elements

To confirm the CSFs, the questionnaire instruments must be checked for their validity to make sure that the results are correct and true and that the instruments measure what they are supposed to measure. As stated in unit (3.18) of chapter 3, factor analysis was used to analyse the CSFs and prove their construct validity (Khamkham, 2017).

A. The first stage is a factorability test, which examines the suitability of the data for factor analysis. The outcomes in table (4.18). KMO =0.795 and the sphericity test is significant, demonstrating that all conditions have been satisfied.

Note; (df) in this test is essentially determined by the following formula:

df = ((number of items)*(number of items-1))/2

Table 4.18 :KMO Test

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.802
Bartlett's Test of Sphericity	Approx. Chi-Square	247.985
	df	28
	Sig.	.000

B. Second-factor extraction: The results of the first test were pretty good, since PCA could only find two hidden components (table 4.19). Eigenvalue greater than 1.00 and accounting for 74.76% of the total variance is needed to meet the standards. Latent factors are the basic factors or variables that can't be seen directly. Still, statistical calculations based on the study of variables are often used to find secret factors. Also, the latent variable is linked to the set of measured variables, and Williams et al. (2012) say that latent factors in factor analysis are a way to measure construct validity. In this study, the next step will be to find, examine, and name two hidden components.

Table 4; 19:Total Variance Explained

Total Variance Explained							
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	Variance %	Cumulative %	Total	Variance %	Cumulative %	Total
1	4.974	62.175	62.175	4.974	62.175	62.175	4.601
2	1.007	12.590	74.766	1.007	12.590	74.766	3.481
3	.670	8.376	83.142				
4	.487	6.092	89.234				
5	.422	5.272	94.506				
6	.207	2.590	97.096				
7	.158	1.969	99.065				
8	.075	.935	100.000				
Extraction Method: Principal Component Analysis.							
a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.							

C:Third-factor rotation: On the other hand, the factor loads from the pattern matrix, shown in table (4,20), showed that only two of the eight items, the eight CSFs, are loaded on two latent factors (bi-factorial): understanding of processes.

Also, Cost decrease, another item, had a low loading of 0.351%. In this case, the two things could be taken away (Pallant, 2010). (Hair et al., 2006).

So, the survey tools for the CSFs are valid because all of the items in both factors are one-dimensional and have a high loading, which is more than 0.6. Also, the internal consistency of each factor was checked and found to be greater than 0.70. As shown in the table of the Pattern matrix, this means that the results are statistically significant and dependable.

Table 4; 20: Pattern Matrix

Pattern Matrix[a]		
	Component	
	1	2
Monitoring and evaluation of performance	.975	
Clear Vision of Business plan	.949	
.Clearly definde goals	.802	
Linking LSS to organisation's business strategy	.779	
Understanding of processes	.627	.340
Cost reduction	.406	.351
Education and training		.969
Good Communication on all Levels		.906
Extraction Method: Principal Component Analysis. Rotation Method: Oblimin with Kaiser Normalization.		
a. Rotation converged in 5 iterations.		

The author finally explained the results of the factor analysis by naming the extracted latent factors. This explanation is based on the table's structure matrix, which shows how the variables and the factors are related. So, here are the main factors.

Table 4:21: Structure matrix

Structure Matrix		
	Component	
	1	2
Clear Vision of Business plan	.945	.528
Monitoring and evaluation of performance	.891	.401
Clearly definde goals	.826	.493
Understanding of processes	.818	.693
Linking LSS to organisation's business strategy	.793	.464
. Cost reduction	.604	.580
Education and training	.500	.943
. Good Communication on all Levels	.565	.937
Extraction Method: Principal Component Analysis. Rotation Method: Oblimin with Kaiser Normalization.		

Latent Factor 1, performance factors for improvement,These components, which together explain 62.175% of the diversity (see table 4.19), have a great deal to do with latent factor 1, as seen in table 4.21. The items have a significant impact on the effectiveness of the LSS model and are tied to how it operates. With an internal consistency of 0.802, these characteristics are considered to be the primary success drivers in this study for implementing the LSS paradigm. The relationship between the visible items (CSFs) and the hidden factor is depicted in Table 4.21 and Figure 4.7.

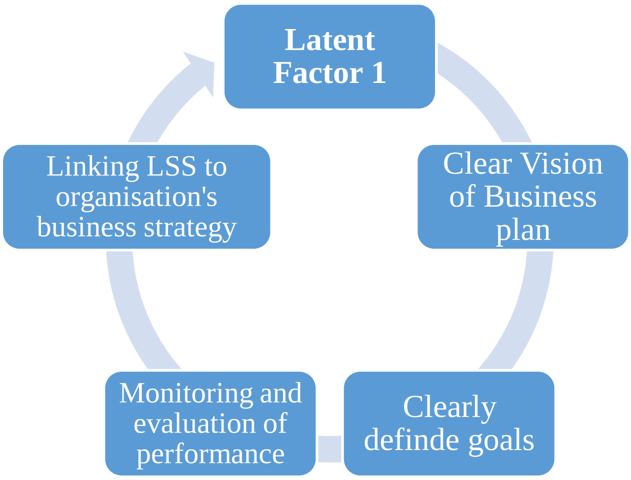


Figure 4. 7. The correlation between Latent factor 1 and CSFs

Latent Factor 2, The elements of review and evaluation. As indicated in table (4.21), these elements have a strong relationship with latent factor 2, and table (4.19)' data indicates that they are responsible for 74.766 percent of the variation. The things are related to and have a positive impact on the LSS model's strategic facets.Due to their influence on business performance, the items are recognised as key successful strategic components of the LSS model, as evidenced by this factor's internal consistency score of 0.802. The association between the observed items and the latent component is displayed in Table 4.16 and Figure 4.8.

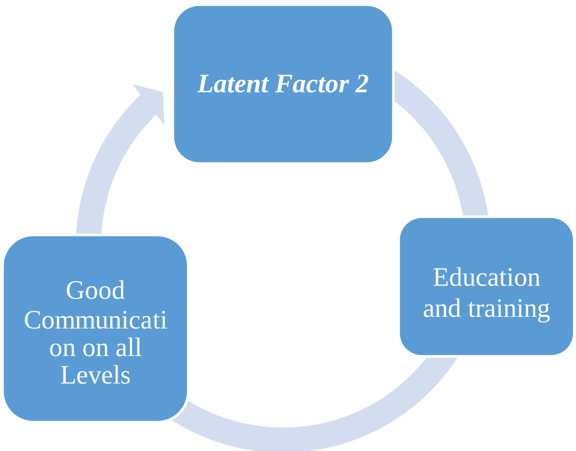


Figure 4. 8. The correlation between latent factor 2

4.13 Summary:

A questionnaire was utilised to gather data for this investigation. The survey was designed in accordance with Oppenheim's (2000) recommendations on the format of questionnaires. The questionnaire was then sent to the largest refinery in Libya.

Questionnaire replies were gathered. The data was analysed and the results were assessed in order to establish the essential components, variables, and the link between performance and practises. On the basis of the results as mentioned above, improvement suggestions are given.

This study answered the main question of the research, which was how to create a Lean Six-Sigma implementation framework for an Oil and Gas business that makes things, and how to reach the main goals. Lean Six Sigma must be put into place with the full support of top management and all employees. Lean Six Sigma should be used in companies that think strategically about the long term if they want to stay competitive in the long run. This will produce the management's strategy and goal, which they must be committed to, and help the staff improve processes, reduce waste and variation, and meet or beat customer standards. Lean Six Sigma has been used in many industrial businesses around the world, but many others have only just learned about it, and their Lean Six Sigma implementation is still in its early stages.

Most companies haven't yet put Lean and Six Sigma together as a combined strategy and worked this project into their strategic planning, which is why the suggested model is needed. Most companies already have the right mindset to make acceptance easier, but most managers need a lot of training and education to understand LSS and its possible benefits. It is hoped that the proposed model would bridge the gap between the theory and practise of Lean Six-Sigma implementation in manufacturing companies, which would have a positive economic effect on their strategy direc.

Chapter 5: Framework implementation

5.1 Introduction

This chapter describes the empirical research conducted to understand the nature and breadth of oil and gas firms in Libya and their operating procedures. The purpose is to determine the main aspects and variables that impact the firm's operational performance and the degree to which LSS techniques could assist oil and gas companies in addressing the operational issues they face and enhance their performance in this competitive sector. The ultimate objective is to offer a framework for an integrated model that includes an LSS framework for Libya's oil and gas sector.

This chapter compares the existing working methods at the Az Zawiya Oil Refining Plant (Figure 5.1) with the Six Sigma approach by emphasizing issues and their main causes to determine where the greatest attention is required. Suggestions will then be made for how Lean Six Sigma could be implemented within the Az Zawiya Oil Refinery Factory and the steps that must be taken to function successfully inside the organization. The practical portion of the project will address quality deficiencies in the manufacturing process by analysing their root causes and proposing solutions. Using the DMAIC technique, the recommended solutions of a practical advancement project must be used to assist in achieving the project's goals (N.O.C, 2019) .

Figure 5.1. Pictures inside the refinaries oil mixing plant in Az Zawiya Company

5.2 Implementing the Lean Six Sigma Methodology

The researcher assembled a small project team consisting of three members, data related to the production line the team collected operations while they were originally working inside a refinery factory oil, and conversations with concerned individuals and reviews of official records. The scope of the case study was to reduce the number of defects in the manufacturing process and the quality of the goods. The organization of the case study was based on proposals put forward by George and George (2003), George et al. (2005) and Nabhani and Shokri (2009). Suitable statistical tools were applied in a synergistic and integrated application of LSS methodology to detect causes and defects, attain customer requirements, provide solutions and enhance the delivery process. The process guideline applied a range of tools and technologies in the various phases of LSS methodology The execution of this project started with the define stage when a project charter was established. Definitions were developed of criteria such as the project's aims, its scope and the resources necessary, thus establishing a framework on which the succeeding phases might continue. According to George and George (2003), the essential idea of LSS is that a flaw is anything that causes a consumer to be dissatisfied, such as poor quality, exorbitant cost and lengthy wait times. The first step in dealing with these difficulties is establishing a systematic picture of how the company fulfils customer needs. A SIPOC flowchart (Figure 5.2) (which details suppliers, inputs, processes, outputs and consumers) is the tool for constructing a high-level map of such a process. A SIPOC graphic was made to identify possible internal and external clients and outline their needs for the distribution process and the inputs and outputs. The output of procedures was used to analyse the quality standards so that changes could be made based on an examination of inputs and process factors.

5.3 The define Phase

Table 5.1: The process for creating a SIPOC diagram

	S	I	P	O	C
	Line of cans manufacturing				
1	Supplier	Raw material	Feeding machine	Work piece	Cutting machine
2	Feeding machine	Work piece	Cutting machine	Work piece	Body maker machine
3	Cutting machine	Work piece	Body maker machine	Work piece	Edge machine
4	Body maker machine	Work piece	Edge machine	Work piece	Bottom lid seaming machine
5	Edge machine	Work piece	Bottom lid seaming machine	Work piece	Arranging machine
6	Bottom lid seaming machine	Work piece	Arranging machine	Work piece	Filling machine
7	Arranging machine	Work piece	Filling machine	Work piece	top lid seaming machine
8	Filling machine	Work piece	top lid seaming machine	Work piece	packaging department

Table 5.1 shows the process flow within a mineral oil mixing and filling plant. The daily observation report of the operation was collected, and the main problems were as follows. An examination of the notes indicated that the issues related to scrapped items were stops and delays in production and the exit of damaged cans and others that do not conform to the specifications. Most of these problems occur at the stages involving the body-maker, bottom lid seaming, and filling machines.

5.4 Measure Phase

A strategy for collecting process-specific data to confirm the business issue is developed at this step. A typical LSS instrument is value stream mapping (VSM), one of the objective approaches suggested for assessing the validity of a data measurement system in minimizing the contribution of the measuring gauge to process variance (Larsen 2003). The processing capability (on the Sigma scale) is then calculated using Cp and Cpk Six Sigma tools.

Table5.2: Definition of Tools for VSM

Terms	Definition
Take time	Frequency or pace of production required to meet customer demand. Defined as available time divided by customer demand. Sometimes, the term customer takes time marks the difference from the production pace (production takes time).
Cycle time	The time required to complete one cycle of an operation; or a function, job, or task from start to finish. For automated or compound processes, the cycle time is the time between each output from the process.
Lead time	The number of minutes, hours, or days that must be allowed to complete an operation or process or must elapse before a desired action occurs.
Process time	The total time needed to handle an item correctly throughout a process phase includes the time spent setting up orders, running them, moving them, inspecting them, and putting them away. Cycle and process times can be used interchangeably for straightforward processes. (See adding value time.)
Value-adding time	Time spent on activities that add value to the product, i.e., what the customer is prepared to pay for. Usually indicated by the processing time.
Non-value-adding time	Time spent on activities that do not directly add value to the product. These activities are usually needed to support value-adding activities.
Waste	Anything that slows down the value stream without benefit. Usually defined as unnecessary transportation, inventory, motion, waiting, overprocessing, overproduction, and defects.

5.4.1 Value stream mapping VSM

Value stream mapping is a technique for displaying and assessing the logic of a manufacturing process. The word derives from the manufacturing process as a metaphor for a river and a constant flow of goods in which value is added at each point along the distribution chain. This metaphor and the vocabulary reinforce the concept of continuous flow as the ultimate form of production – at least in terms of productivity.

A value stream map is a graphical representation of the material and data flow in a manufacturing process; this is a solid foundation for comprehending how activities and operations are interconnected and provides a platform for process evaluations. Nevertheless, a graphical depiction alone is insufficient. It is important to note that the whole point of doing VSM is improvement. Table 5.1 provides definitions of the tools used for VSM.

A lean management technique called value stream mapping is used to evaluate the current status and plan for future steps required to deliver a good or service. VSM provides a potent representation of all activities necessary to supply a service or product. Consequently, VSM gives a holistic view to optimise a whole process instead of just a section of it. For example, VSM for the present state of the mixed oil sector (see Figure 5.2) reveals a total duration of 600 minutes, value-added time (480 minutes) and non-value-added time (4382 minutes), comprising stages that use more time and are candidates for optimization.

Defects are an additional source of waste that has a direct effect on process capacity. Defective parts requiring repairs will strain the system or need a separate repair procedure. Faulty discarded products will also need to be replaced, raising the process output requirements. However, waiting is also a waste, so strategies must be examined to eliminate it – or turn wait time into time that adds value. However, it is important to avoid overproduction, which necessitates rebalancing the process.

Note:

Take time = Available time / Customer demand

Inventory lead time = Inventory * Take time

Cycle time = Net production time / Number of units produced

Lead time = Inventory / Daily demand

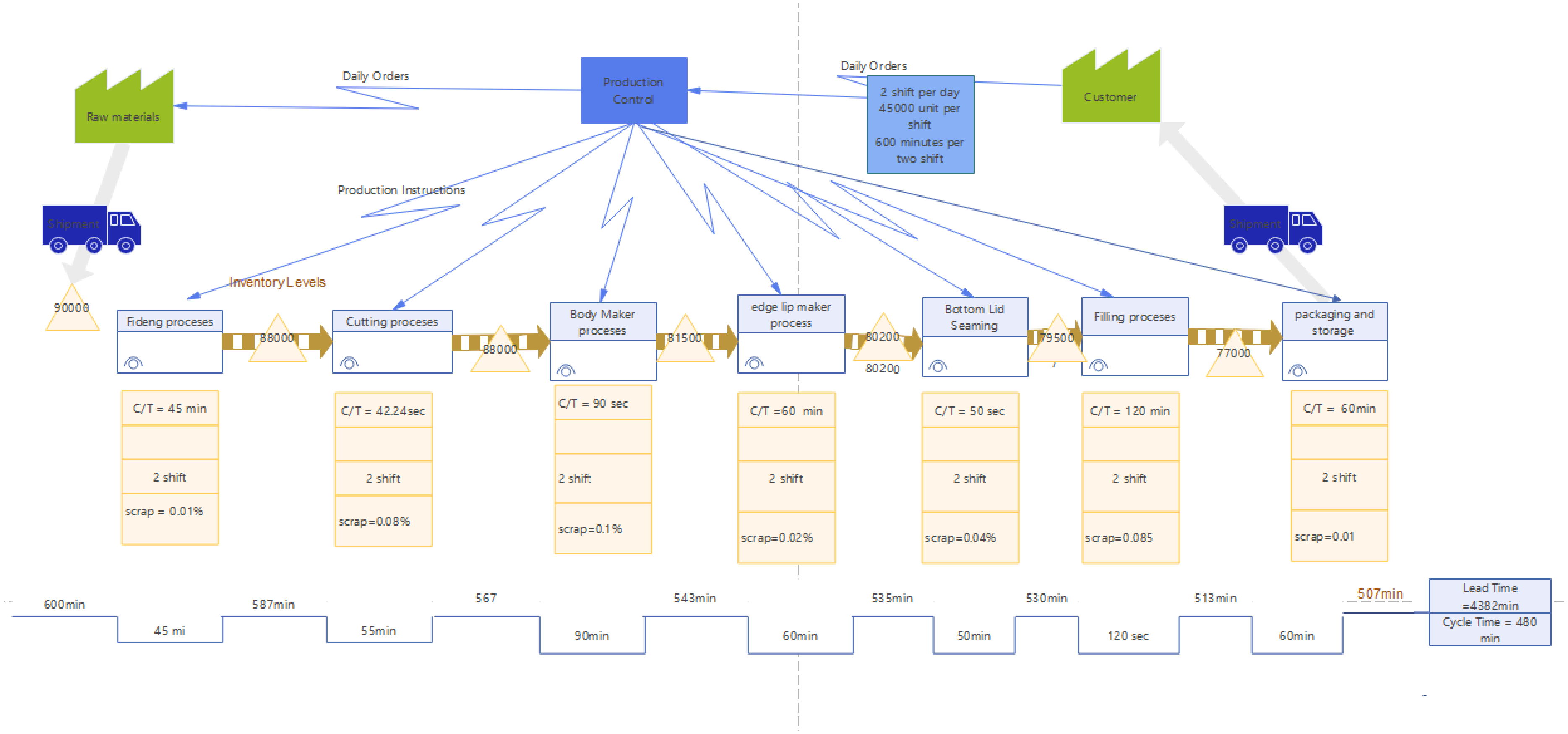


Figure 5.2 VSM for the Processes in plant

5.4.2 Statistical Control Charts

Statistical control charts are used to analyse the production process in conjunction with the process capability (Cpk) to ascertain the quality level of a plant. They are also used to monitor process performance and variance. Control charts come in two varieties: those for variables and those for attributes. Charts of variables give actual measurements as data, whereas attribute charts are often presented as counts or percentages. Consequently, the style of chart used will depend on the data obtained and the size of the subgroup (Saxena 2009). Attribute charts (p-charts) were used in this study based on data collected from the main contractor for the following reasons.

To assess the factory's present performance, decide whether a process is functioning within acceptable bounds, and, if necessary, address a special and common cause, a variable sample size (p-chart) was utilised. Instead of counting the number of flaws per unit, the goal was to count the number of defective items in a group. Forty-one samples of varying sizes were selected over a two-shift period in October and November 2017, when machines were in continuous operation, and the data as shown were used to determine the control chart (Essam Al, 2020).

Statistical Cp and Cpk equations were used for the measurement, and SPC software was used to create the graphical charts. Excel was also used to calculate the current process capacity and the production standard deviation.

(1) The calculation of the proportion of defective items (p_i) for each sample is the first step in the design of a p-chart:

$$p_i = \frac{np_i}{n_i} \qquad \text{Equation 5.1}$$

Where: (np_i) is the number of defective items in delivery, (n_i) is the size of the sample.

(2) The second step is to calculate the average proportion of defective items / centre line ($\overline{P}$):

$$\overline{\mathrm{p}} = \frac{\sum_{\mathrm{i}=1}^{\mathrm{k}} \mathrm{np_i}}{\sum_{\mathrm{i}=1}^{\mathrm{k}} \mathrm{n_i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{Equation 5.2}$$

$\sum_{\mathrm{i}=1}^{\mathrm{k}} \mathrm{np_i}$ is the total number of defective items.

$\sum_{\mathrm{i}=1}^{\mathrm{k}} \mathrm{n_i}$ is the total number of items inspected.

Upper specification limit

$$\mathrm{USL} = \overline{\mathrm{P}} + 3\sqrt{\overline{\mathrm{P}}(1-\overline{\mathrm{P}})/\mathrm{n_i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{Equation 5.3}$$

Lower specification limit

$$\mathrm{LSL} = \overline{\mathrm{P}} - 3\sqrt{\overline{\mathrm{P}}(1-\overline{\mathrm{P}})/\mathrm{n_i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{Equation 5.4}$$

Table 5.3: Production and proportion of defective items (USL and LSL)

Production cans	Wastage cans	LCL %	UCL %
85780	476	0.493	0.647
82888	478	0.492	0.646
66980	378	0.483	0.656
74501	460	0.487	0.652
72040	404	0.486	0.653
78880	482	0.489	0.649
81100	502	0.491	0.648
69326	339	0.484	0.656
69550	370	0.484	0.655
71200	379	0.485	0.654
84800	522	0.493	0.647
79040	464	0.489	0.649
64300	383	0.481	0.658
73880	389	0.487	0.652
73600	449	0.487	0.652
76840	531	0.488	0.651
82960	472	0.492	0.647
83880	456	0.492	0.647
81100	488	0.491	0.648
80010	472	0.493	0.645
81800	407	0.490	0.648
82300	415	0.490	0.648

Due to the varied sample size that was obtained, there are three ways that a control chart can be built and subsequently used, including variable-width control limits, a control limit based on the average sample, and a standardised control chart. Lower specification limit (LSL) and upper specification limit are considered in creating control chart limits (USL). When examining a continuous "sample" size, the p-chart control limits are the same for each sample. In this study, variable-width control limits are used, and the control limits are calculated using the following equation for each sample size:

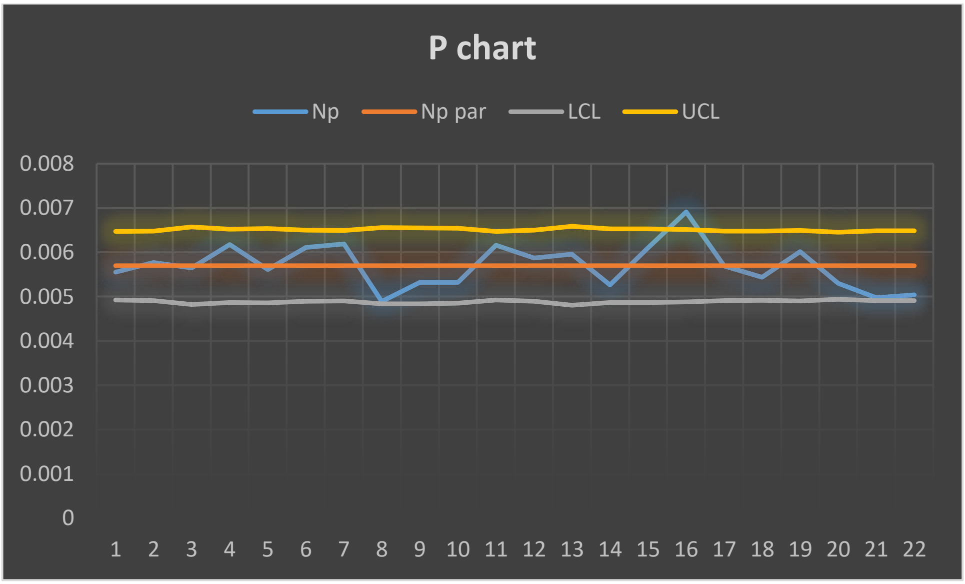


Figure 5.3: Statistical control chart of the process

When points on a control chart exceed the upper or lower control limits, the process is deemed “out of control”. As long as the issues remain inside the control boundaries, the process is considered “under control”. However, what does a process that is out of control indicate? Many feel that damaged components result from a process that is out of control.

In reality, a process that is out of control reveals the existence of non-random variation. Non-random variation is created by assignable causes, which are known particular reasons. These assignable factors render the process statistically unstable or out of control.

More study ought to be encouraged by the occurrence of an unmanageable condition. It is crucial to recognise assignable reasons and act to eliminate them. As soon as assignable reasons are eliminated and only random fluctuation owing to common causes remains, the process will stabilize and return to control.

5.4.3 Process capability index

The process capability index is the primary metric for measuring capability analysis. The process capability index assesses a production process and shows whether it is capable, i.e., able to manufacture items meeting the requirements. Numerous academics have investigated capacity indices, as capability analysis is crucial in several industrial businesses (Besseris 2014).

An indicator of process capacity is derived from specification limitations, often known as tolerances. We assume two-sided specification limits, denoted by the LSL and the USL, which typically imply acceptable quality characteristic ranges. In other words, a product's qualities are deemed acceptable if they fall within the specification interval [LSL, USL]. For instance, the capacity restrictions for cans may be defined as 1 litre or 0.05 litre, indicating that litre and litre units are acceptable. One-sided specification restrictions can also be established. For instance, the capacity of cans may have a minimum specification constraint but no maximum specification limit (Montgomery 2009).

- Process capability calculated
- Process capability indexes Cpk

$$\text{Cpk} = \min\{\frac{USL-\mu}{3\sigma}, \frac{\mu-\text{LSL}}{3\sigma}\} \quad \text{............................... } \textit{Equation 5.5}$$

- USL is the upper specification limit
- LSL is the lower specification limit
- Minimum of these two ratios
- μ equals the process specification target

- Process capability (Cp)
- $Cp = \frac{USL-\text{LSL}}{6\sigma}$
- $Cp = 1 \leftrightarrow [USL - LSL] = 6\sigma$
- USL is the upper specification limit

- LSL is the lower specification limit

$$Cpk = min(Cpu, Cpl) = \min(Cpu = \frac{USL-\bar{c}}{3\sigma}; Cpl = \frac{\bar{c}-LSL}{3\sigma}) \ldots \text{ Equation 5.6}$$

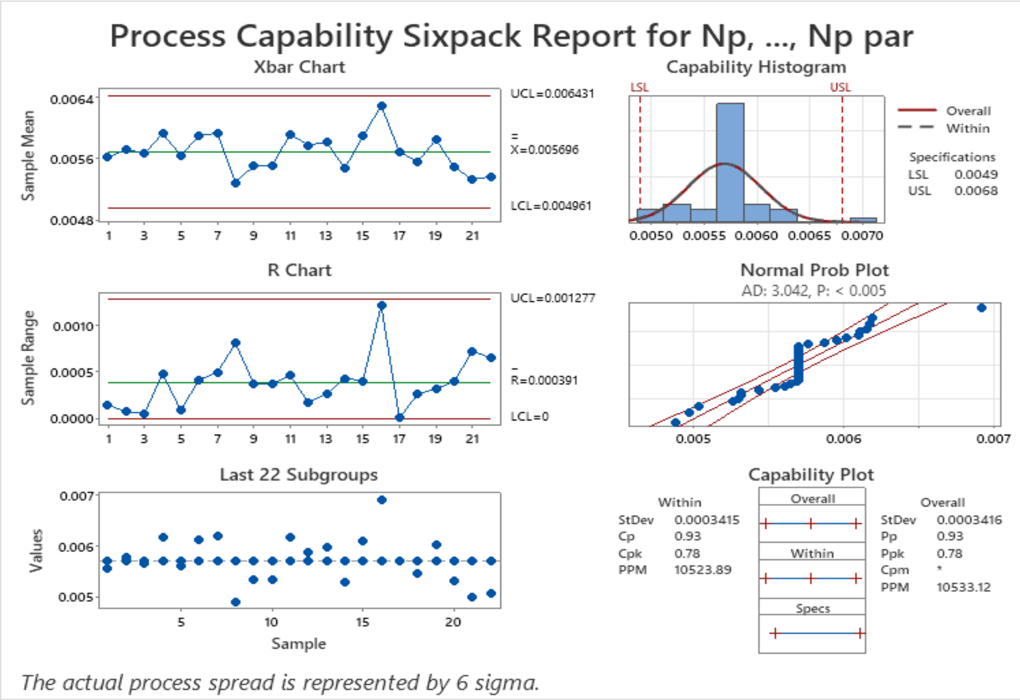


Figure 5.4: Standard deviation and capability of the process

In this step, the data available from the factory included in the production and production losses data were analysed using Excel, and Minitab software was used to obtain Cp and Cpk values.

The following figure(5.4) shows that Cpk is less than what is required because a Cpk of at least +1.33 is ideal; here, 0.78 PPM is rejected, which reaches the sigma level. Hence, it becomes clear that there is a defect in the process, and it is desirable to develop appropriate solutions to address it.

5.5 The analyse phase

After creating, verifying and examining detailed process maps in the previous phases, it is possible to list concerns or pain points within the process. Process perspectives on the problem alone do not give a holistic idea of the causes because although the ‘map’ phase provides information about the process metrics, it is through data analysis that the metrics become more meaningful and useable.

By determining the leading cause of emissions and inefficiencies, this stage aims to identify the primary sources of waste, emissions and flaws in the approved project. Initially, in this phase, value-adding and non-value-adding acts are identified. Following this, the process cycle efficiency is adjusted to compare excellence standards to determine necessary improvement. Concurrently, a project is analysed to identify the bottlenecks and limitations of a chosen project. After investigating the relevant project, it is possible to determine the reasons for emissions, flaws and variances. Here, tools like brainstorming, cause-and-effect diagrams, cause-and-effect matrixes, and Pareto analysis are used. An organic Rankine cycle (ORC) is utilized as one of the tools within the framework to reduce emissions intensity and power generation. Thus, these steps lead to identifying the main reasons for inefficiencies that must be addressed to improve the sustainability measures of the project undertaken.

5.5.1 Identifying waste

Waste is any action or process that increases manufacturing costs without adding customer value. A low degree of generating efficiency leads to more fuel, which increases generation costs without adding value to the end product or benefitting customers. Therefore, increasing efficiency may save substantial energy and cut costs while producing the same goods.

Following the use of a Pareto chart, it is evident that one or two primary issues need to be addressed and analysed further using the “5 Whys”. Once answers are identified, a strategy for their improvement must be formulated. The result of applying the 5 Whys is an improved solution. In addition, future VSM provides ideas for process enhancement.

5.5.2 Cause-and-effect diagram

The current performance must be understood and shown that it is not under an adequate level of quality control by using the aforementioned statistical control approaches and process capacity. There must then be a reduction in variation, and it must be done before comparing process capacities to control the process.

Once the remedies have been put in place, the impacts of such problems also need to be dealt with. According to Munro (2003), this can be improved using a cause-and-effect diagram (also known as a fishbone or Ishikawa diagram); at this point, the method might be viewed or described as a form of systematic brainstorming. The inventiveness of a project group will be of considerable use in this situation. In addition, the analysis phase in the DMAIC approach will be strengthened by this instrument, which will discover the key sources and consequences of the issue. In addition, a summary of all possible reasons can be presented. The whole diagram must have several branches. If this is not achieved, only a superficial understanding of the subject will be reached (Pyzdek 2003). For example, which causes product faults and a lack of quality? The beginning point of the cause-and-effect diagram is to identify six basic causes: measurement, material, people, environment, method, and machine, with each category including one or more secondary causes (Figure 5.5).

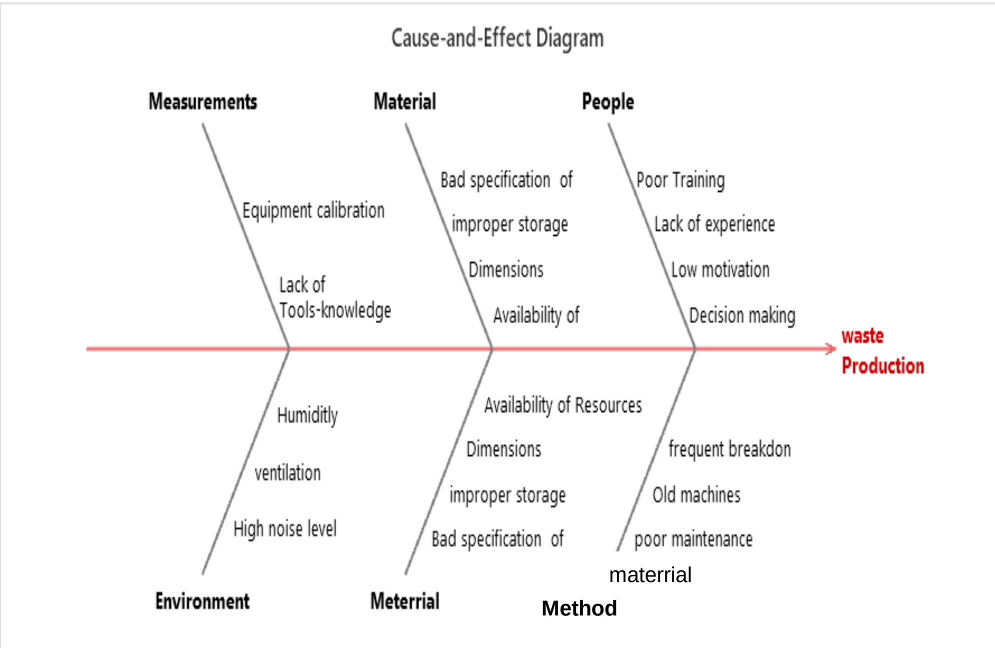


Figure 5.5: Cause-and-effect diagram

5.5.3 Pareto analysis

This phase adheres to the Pareto distribution of defects. This tool aims to highlight the allocation of power amongst the significant reasons discovered in previous study and to identify the most relevant ones for process improvement.

The data obtained were used to create a Pareto chart depicting all reported forms of danger, in decreasing order of frequency from left to right along the horizontal axis. The left vertical axis depicts the occurrence frequency. The right vertical axis indicates the cumulative proportion of total occurrences.

It was established from the data collected from the maintenance team that the main causes of disruption and downtime are as follows: sheet interference, oil leaks, without covering, falling off the conveyer belt, adhesive, and variation in cans.

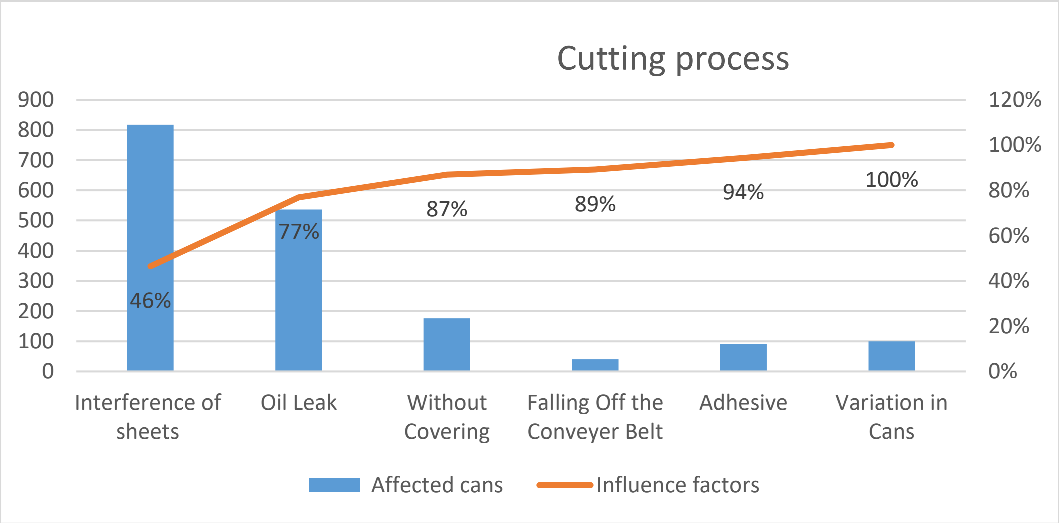


Figure 5.6: Cutting machine effect

Figure 5.6 shows the reasons that led to the delay in receiving and reducing the quality of the production process at the cutting stage.

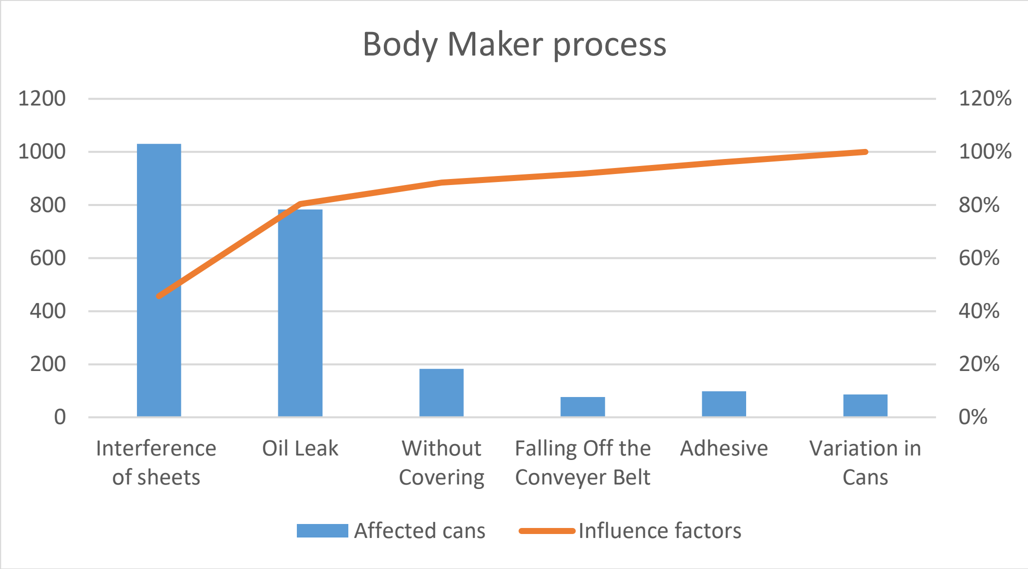


Figure 5.7: Body-making machine effect

Figure 5.7 shows the reasons that resulted in the stoppage of the body-making machine and negatively affected the production process through defective products and an emergency stop.

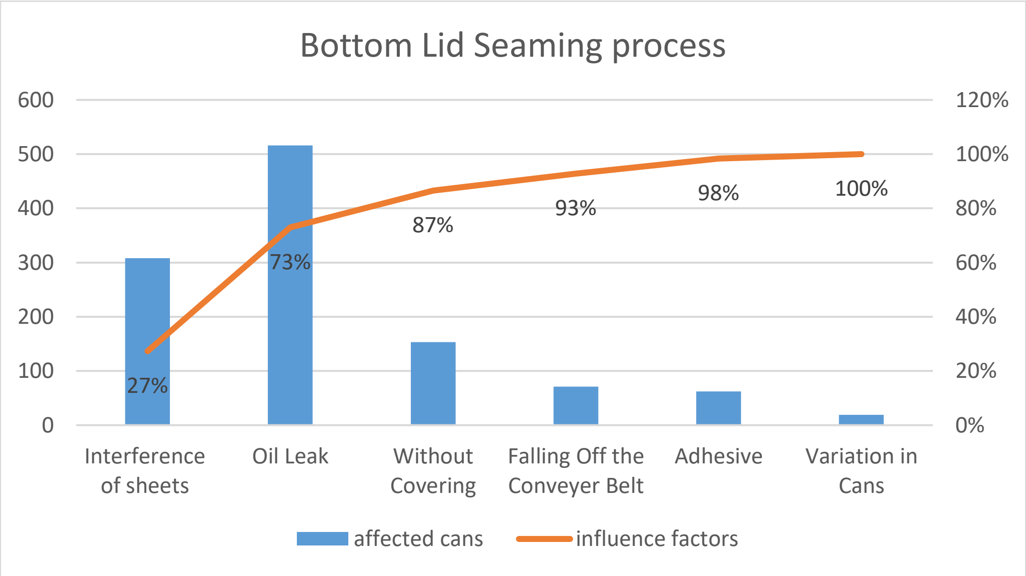


Figure 5.8: Bottom lid seaming effect

Figure 5.8 shows the reasons that caused the machine to stop bottom lid seaming. The main reason was oil spillage, followed by interference of the tin sheet material in the machine.

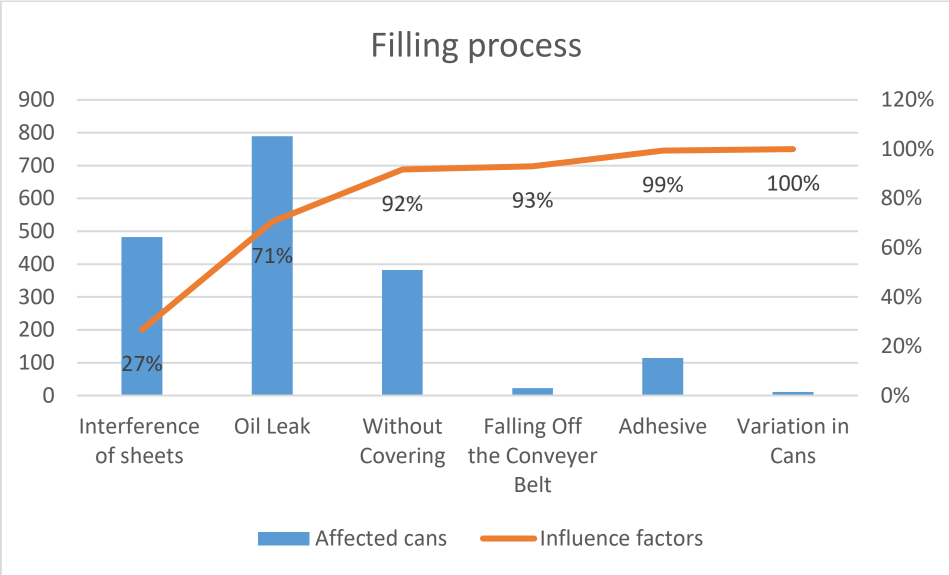


Figure 5.9: Filling machine effect

Figure 5.9 shows the filling machine and the problem that caused a breakdown in the manufacturing process. The main results were oil leakage (71%) and sheet interference (27%); these reasons are the most harmful in the production process.

The data received from the company was analyzed and the reasons and results were as mentioned above, and the reasons that occur within the process that lead to its stop, which results in wastage in the cycle time of the process, and defects in the product, are known., there are three main causes: from the cans, the cumulative effect of which was revealed to be about 80% for each process that caused a delay in the operation. This means that addressing these causes can influence the defect rate significantly, with more effective allocation of efforts and finance for improvements.

5.5.4 Cause and effect matrix

A cause-and-effect matrix lists the causes or emphasises the elements most responsible for a problem. This involves assigning ranks to all of the elements that have been identified as having the potential to be problematic (Kuncar et al. 2013). The cause-and-effect matrix is shown in Table (5.3).

From the data, gained from experience and the employee team who filled in the questionnaire, using the geometric mean approach to calculate the average of the respondents' findings, three failures were identified: sheet interference, oil leakage, and without covering. These failures were allocated and assessed depending on their frequency of occurrence. Then, a grade was given to each possible reason to measure the extent of the failure. The products of the two ratings were then multiplied and the resulting values summed to determine the significance of each cause (Bubshait ,2014) (see Table 5.4 below).

Table 5.4: Cause-and-effect matrix

Rating based on importance to employees		9	6	3	
Problem / (Output) — Input / (Causes)	Rating	Sheet interference	Oil leakage	Without covering	Total
Internal resistance		3	1	1	36
Decision making		3	1	3	42
Availability of resources		1	3	3	36
Changing business focus		1	1	9	42
Lack of corrective action		3	1	3	42
Poor training		9	3	3	117*
Lack of tools-knowledge		3	3	1	48
Lack of calibration of machines		9	9	3	144*
Bad specification of material		3	9	9	108*
Total		34	31	35	

All causes that receive a failure analysis score of greater than 50 will be taken into account after each reason has been rated. Three of the nine reasons, denoted by asterisks in the final column, received scores greater than 50. (Bubshait and Al-Dosary 2014).

And by linking the responses of the respondents to the most important obstacles and challenges facing the company in applying Lean Six Sigma, which can be to increase the level of quality within the factory and reduce waste and the waste production process time. The cause-and-effect matrix tool reveals that the following factors were the most significant contributors to the factory's lack of quality :

- Lack of calibration of machines
- Poor training
- Bad specification of material

5.5.5 The 5 Whys analysis tool

The 5 Whys methodology is a straightforward and efficient method of problem solving. Its major objective is to determine the precise source of an issue by posing a series of "why" inquiries (Table 5.4). The 5 Whys technique lets your team zero in on the underlying reason for any issue.

The purpose of creating a future state map is to address current issues, such as lengthy lead times, disconnected processes, and bottlenecks. The output of a stage is a production flow that is in sync with client needs and produces the correct amount and on time.

This chapter's major goal is to identify the primary causes of production waste and suggest appropriate solutions to address those causes. To accomplish this, the DMAIC methodology and the Lean Six Sigma approach are used to observe and analyse the various underlying causes of production losses and rejection issues, it resulted in a waste of runtime. The following are the main effects on the production process: interference from tin, which forced the machine to stop the process; cans leaving with oil leaks; and cans leaving with loose lids, which increased the amount of rejected goods. Also, the outcome shows that oil leakage and interfering sheets in the machine are significant problems for resource loss, ultimately harming industrial production. Finally, it is suggested that the difficulties be addressed using any potential solutions (Kumar et al., 2019).

Table 5.5: The 5 Whys analysis

Why 1	Why 2	Why 3	Why 4	Why 5	Solution
Lack of calibration of machines	Old machines and old design	Lack of maintenance	100% change is not feasible	Lack of administration	The renovation of machine tools and increasing the number of machines in choke points. Allocate the time required to calibrate the machines before the operation.
Poor Training	Employees' resistance to receiving training.	The absence of rewards and incentives	Workers do not have constant practice	Demand rate is not stable	There is continual training for staff members about LSS.In order to improve the qualification level of the workers, the company can allocate special time for training (20 min every day at the start of the day) and introduce a monthly reward for the best worker. training in waste identification skills, quality improvement skills, and problem-solving techniques.
Bad specification of material	Seller received incomplete data about the material	Changes to the conditions of some operations	The relevant study was based on hypothetical, not actual, conditions	The assigned team did not have enough experience in the practical aspects	Change the type of metal with other minerals of higher quality, such as utilising a member of the stainless steel family known as austenitic or plastic in place of metal.

5.6 The Control and Improvement Phases

The final step in the DMAIC process is control. The control phase aims to maintain ongoing improvements and operational control over the results of applying the lean manufacturing Six Sigma DMAIC methodology. The control phase aids in keeping the organisation committed and prevents a reversion to the old procedures after new routines have been implemented and are being followed by employees. The most comprehensive tool is statistical process control (SPC), which gauges consistency in performance using data acquired from a process's output. (Zapartas, 2012). SPC may tell the operator whether there is a problem if the process is not working consistently, thereby correcting the issue. Due to their complexity, the quality department must provide a “roadmap” to guarantee the appropriate implementation of SPC tools.

In accordance with the LSS implementation paradigm, process improvement consists of a pilot launch, SPC assessment of the performed outcomes, and standardization of solutions by failure modes and effects analysis (FMEA), brainstorming, and 5S in order to calibrate their performance. The next stage is the sponsor assessment of outcomes. If these meet expectations, the method is revised and the corresponding solutions are applied. The final stage outlines the essential activities for the improvement process and recommends a control plan. A collection of quality control tools, such as SPC, balanced scorecard, and Kaizen, provides a business with performance data for controlling processes, evaluating strategic views, and implementing continuous improvement. The evaluation of key performance indicators (KPIs) compares the approach to the organizational goals. Lastly, implementing total productive maintenance (TPM) for process monitoring facilitates analysis of the efficacy of the quality management system.

The application of FMEA identifies and ranks issue causes by risk priority number (RPN) to identify the most important. Using FMEA, 5S, and brainstorming to standardize solutions, the procedure calibrates proposed solutions in order to lessen or remove previously uncovered drawbacks.

Brainstorming methods aid in discovering pertinent solutions, and using 5S in any operation enhances the efficacy of the enhancements.

SPC and Kaizen are used in monitoring the activities and assessing performance. Once solutions have been implemented, the activities must be supervised using an effective control plan. As a general quality control instrument, SPC can analyse process performance. Adopting Kaizen will result in the ongoing improvement of all business processes inside the organization.

Factory management should illustrate how successfully a firm achieves its primary business goals using KPIs, a set of quantitative and qualitative measurements used to evaluate an organization's success relative to its objectives (Marr, 2012). These are split and assigned as goals to departments and people. The accomplishment of these objectives is evaluated at regular intervals. Using "dashboard software" for KPI monitoring allows the whole company to visualize present performance, as it aims to transform raw data into information that can be readily interpreted and utilized to make intelligent decisions (Kerzner, 2011).

Once solutions have been implemented, the activities must be supervised using an effective control plan. As a general quality control instrument, SPC can be used to analyse performance evaluation in contrast with customer happiness, internal business procedures, and the company's learning and growth. Ultimately, adopting Kaizen will result in the ongoing improvement of every business process inside the organization.

To merge green technology, LSS manufacturing, and LSS under the Green (LSS) umbrella, the researcher of this study presented theoretical concepts from the academic literature by facilitating the integration of enablers or success factors, methods, and frameworks to address contemporary manufacturing difficulties. These ideas will make manufacturing sectors more sustainable, and creating a five-step LSS framework, which includes lean manufacturing and Six Sigma technologies, can add to the efficiency of the entire research process.

5.7 Simulation using Arena software

5.7.1. Problem formulation

Title: To simulate the can manufacturing production line and analyse the performance measures, calculate and reduce the down time, along with increasing production.

5.7.2 Aim & Objectives of the simulation study

The main purpose of a simulation study is to check the performance measures of any service or manufacturing system without disturbing the real system and its working. A simulation study imitates a real-world problem and can be performed in parallel alongside the current system's real-time working. Moreover, it points out areas where decisions can be made easily without disturbing the real process flow.

The objectives were as follows:

- To simulate the system
- To measure the resource utilization.
- To calculate the throughput.
- To identify loopholes in the production system.
- To perform post-analysis after closing or improving the loopholes.

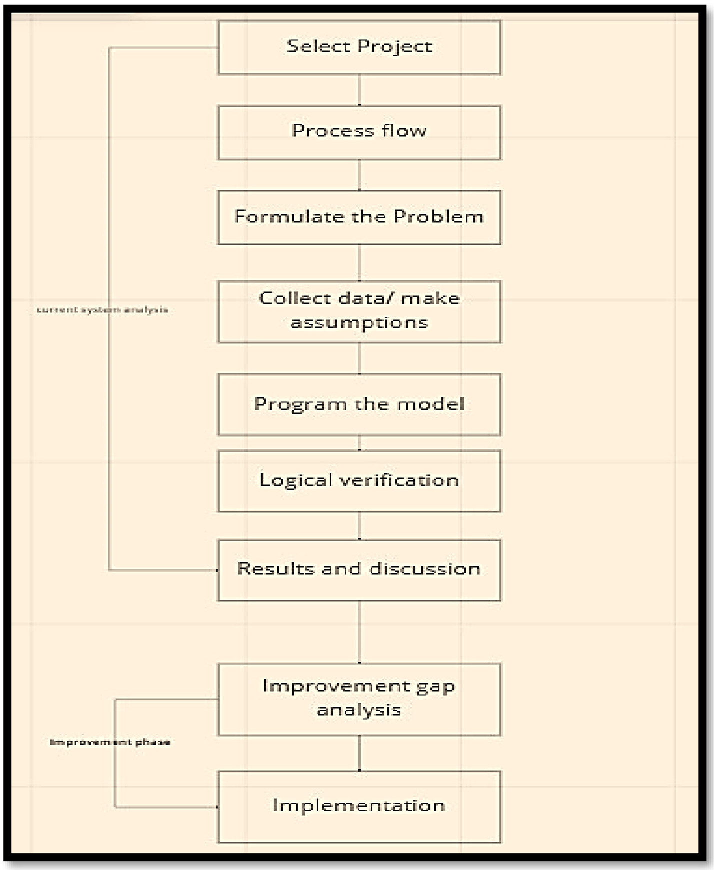
5.7.3 Simulation software

Industrial manufacturing or service simulation is mostly done in order to assess the performance measures using Arena (Rockwell Simulation) software. Arena software has good specifications and is flexible for users to put real system data into a virtual environment. Keeping in mind the established data needed for achieving system flexibility, Arena simulation software was considered appropriate for the whole simulation task and, therefore, it remained validated.

5.7.4 Methodology of simulation

The simulation identifies the system or service flow based on the desired methodology. In the early stages, the project was identified based on an assembly line. (table 5.6).

Table 5.6 simulation flow process



Understanding the fundamental system flow is the first step in any simulation system. Understanding the assembly line mechanism is necessary before data is collected in accordance with the specifications of the software and system functioning circumstances. The project was divided into three stages.

5.7.5 Pre-analysis phase

Arena was used to replicate the system's present operation and calculate the current system performance measures. The production system's present machine layout is depicted in Figure 5.10.

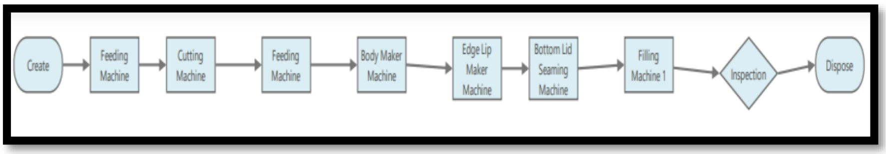


Figure 5.10: Current machine layout

5.7.6 Analysis phase and finding loopholes

In this phase, the system was analysed on the basis of some better alternatives and performance measures, such as efficiency, productivity and resource utilization. The loopholes that needed to be addressed were amended by taking corrective measures. The system processes were simulated again.

5.7.7 Post-analysis phase

The results from the pre-phase were contrasted with the improved system performance metrics. For use in next measures to improve the system's performance, suggestions for ongoing improvement were also given.

5.8 Data collection and distribution

Data collection is the most critical part of a simulation study. The data collection phase is the only one in which a project performer or expert directly connects with the process operation and has the chance to identify improvement gaps on the process floor plan. Thus, in accordance with the assembly line station flow diagram, the data were collected through a direct study method. The data are shown in Table 5.7. The data for items scrapped and the different reasons are shown in Table 5.8.

Table 5.7: Production data table

Production Required of cans	Maintenance Time / minutes	Production Time/ minutes
85780	70	530
82888	95	505
66980	155	445
74501	125	475
72040	135	465
78880	115	485
81100	115	485
69326	130	470
69550	110	490
71200	120	480
84800	75	525
79040	120	480
64300	62	538
73880	143	457
73600	150	450
76840	133	467
82960	110	490
83880	102	498
81100	105	495
80010	90	510
81800	90	510
82300	95	505

Table 5.8: Items scrapped due to different reasons

	Machines					
Reason of deflct cans	Cutting /cans	Body Maker/cans	Bottom Lid Seaming/ cans	Filling/ cans	Total	Percentage
Interference of sheets	818	1030	308	482	2638	38%
Oil Leak	536	783	516	789	2624	38%
Without Covering	176	183	153	382	894	13%
Falling Off the Conveyer	40	77	71	23	211	3%
Adhesive	91	98	62	114	365	5%
Variation in Cans	100	86	19	11	216	3%
				Total Cans	6948	
				Percentage	8%	

5.9 Model formulation and design model description

A logical model was produced using Arena software for the model design, as illustrated in Figure 5.1.

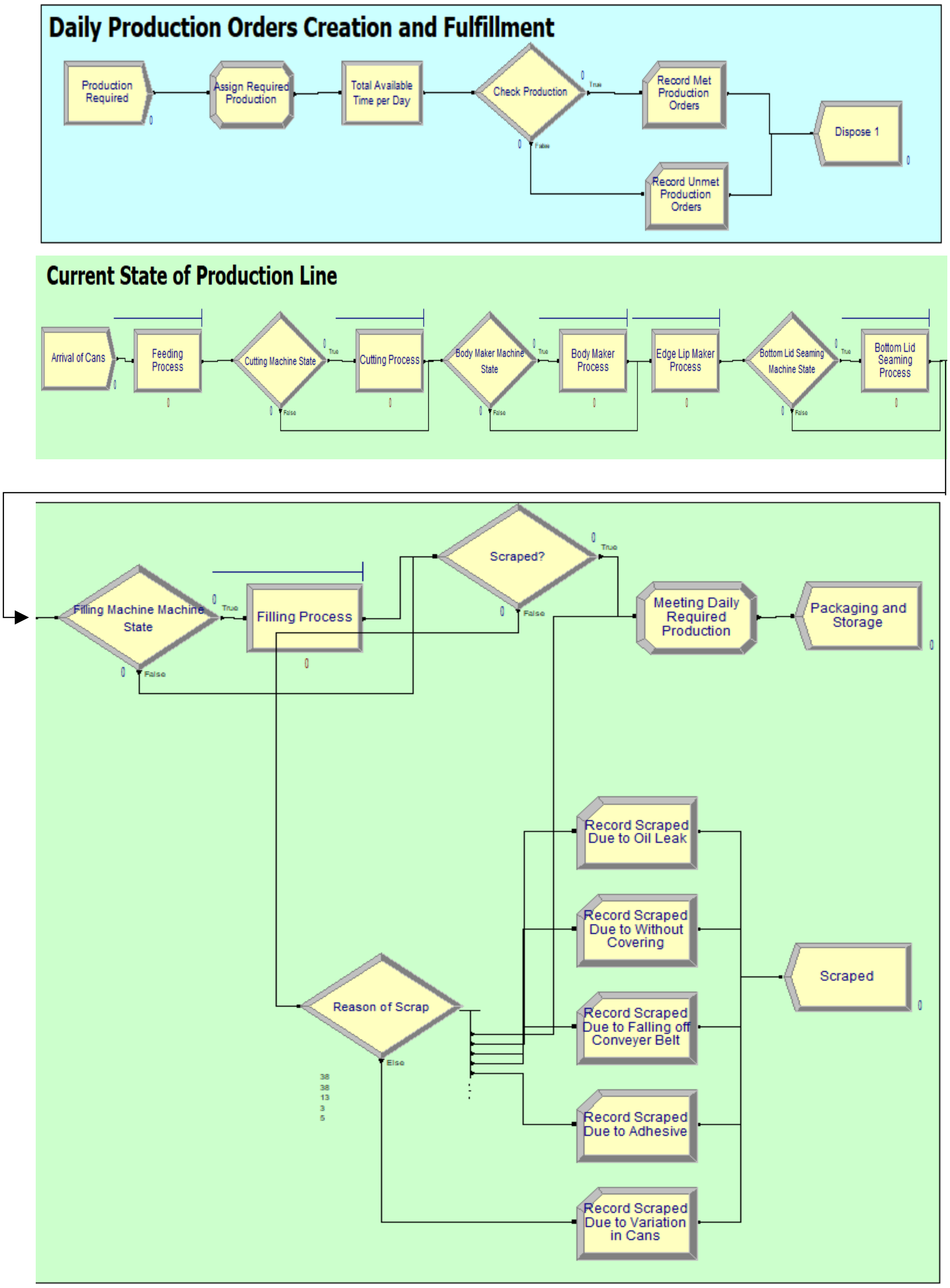


Figure 5.11 Arena module

5.10 The analyse phase

It is necessary to verify and validate the model so that the results can be trusted to solve real-world problems. Therefore, the model was verified and validated before analysing the current model.

5.10.1 Model verification

The production process of the system modelled using the Arena simulation software was discussed with the production general manager (GM), whereby the results represent the true judgement of individuals who were familiar with the system's operations capability. The completed system was agreed as being comprehensive due to the series of processes and steps taken for the emergence of model output. This was run 10 times to ensure randomness and the simulation speed during the process was reduced to a minimum. Single entities were examined, one after another, passing through all the processes to the exit module. The model was considered a replica of the current production system, with no outliers. As the model output arising from the simulation represents the actual scenario intended, the current Arena model could, therefore, be verified.

5.10.2 Model validation

The results obtained from the actual production system were compared with the simulation results. The model validated as the output from the model was very like the actual production output from the real-world production facility. The number of bottles produced in a day, the work in progress (WIP) at the workstations, and the number entering the system were as they are in practice.

5.10.3 Results and discussion

The outcomes for which the full study was carried out to verify the system's overall performance metrics were the results. Table 5.8 displays the information pertaining to time.

Table 5.9. Time-related statistics

Time	Average	Half Width	Minimum Value	Maximum Value
VA Time				
Can	2.1062	0.031943227	0.8000	2.4000
NVA Time				
Can	0.00	0.000000000	0.00	0.00
Wait Time				
Can	3.1050	(Correlated)	0.00	10371.01
Transfer Time				
Can	0.00	0.000000000	0.00	0.00
Other Time				
Can	0.00	0.000000000	0.00	0.00
Total Time				
Can	5.2112	(Correlated)	1.0346	10373.41

From the results, it was possible to assess that the can manufacturing had a total average cycle time of approximately 5.2 s and a value-added time of 2.2 s. The wait time in different queues was 3.1 s, indicating that approximately 60% of the time had been spent waiting due to server business. The wait time statistics and the number of parts waiting at different queues for processing are shown in Table 5.9.

Table 5.10. Wait time and number waiting results

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Body Maker Process.Queue	2.1144	(Correlated)	0.00	10369.73
Bottom Lid Seaming Process.Queue	0.00	0.000000000	0.00	0.00
Cutting Process.Queue	0.00	0.000000000	0.00	0.00
Edge Lip Maker Process.Queue	0.0966	0.030662372	0.00	0.8000
Feeding Process.Queue	0.00	0.000000000	0.00	0.00
Filling Process.Queue	1.5784	(Correlated)	0.00	9528.85

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Body Maker Process.Queue	4.3631	(Correlated)	0.00	8.0000
Bottom Lid Seaming Process.Queue	0.00	(Insufficient)	0.00	0.00
Cutting Process.Queue	0.00	(Insufficient)	0.00	0.00
Edge Lip Maker Process.Queue	0.2415	(Correlated)	0.00	2.0000
Feeding Process.Queue	0.00	(Insufficient)	0.00	1.0000
Filling Process.Queue	3.1741	(Correlated)	0.00	6.0000

From the results, it was seen that the body-maker process and the filling process take more time, as the wait time and number waiting at these stations are high, which limits production and reduces productivity. The server utilizations are shown in the table 5.10.

Table 5.11. Resource utilization

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
Body Maker Machine	0.8201	(Insufficient)	0.00	1.0000
Bottom Lid Seaming Machine	0.8196	(Insufficient)	0.00	1.0000
Cutting Machine	0.8214	(Insufficient)	0.00	1.0000
Edge Lip Maker Machine	1.0000	(Insufficient)	0.00	1.0000
Feeding Machine	1.0000	(Insufficient)	0.00	1.0000
Filling Machine	0.8044	(Insufficient)	0.00	1.0000

The utilization of the edge-lip maker and feeding machine is too high to adjust these machines. However, all other machines have less than 100% utilization. The throughput of the current system is shown in Table 5.11.

The scrap reasons and the respective scrap parts are shown in Figure 5.12.

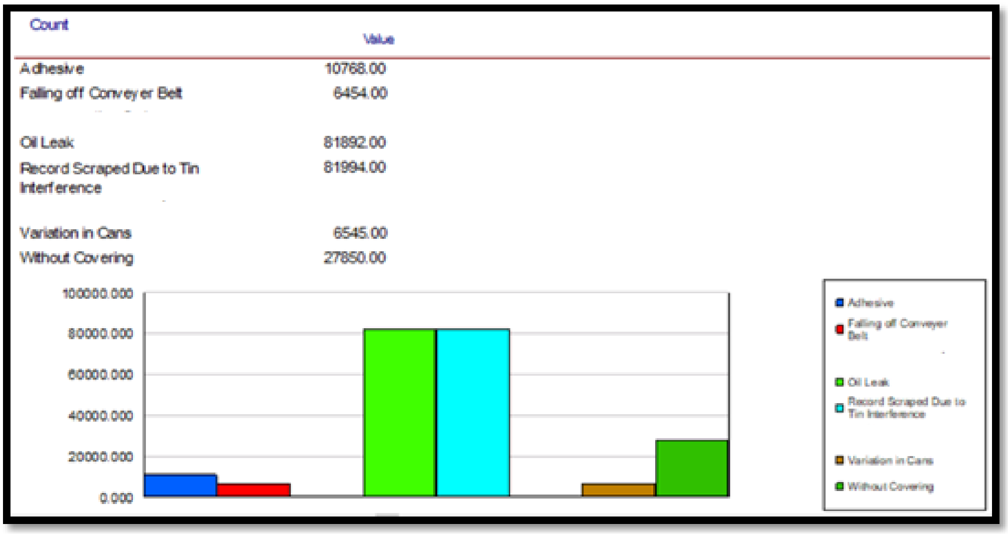


Figure 5.12 Items scrapped scrapped and the different reasons

The results indicate that the high rejection rate of can production is due to tin interference and oil leakage. The rejections must be considered in order to achieve higher rejection control.

5.11 The improve phase

5.11.1 Recommendations and further action

The results analysis indicated that the assembly line was not properly scheduled and balanced due to uneven resource utilization. To close these loopholes, the following are corrective measures that would be beneficial to assembly line performance:

- Enhancing resource capacity is necessary for bottleneck activities.
- It is important to take into account the assembly line's capacity planning domain.
- The process quality could be improved through Six Sigma methodology and the scrap rate reduced to only 2%.
- Scheduling resources is necessary at the resource level.

- ➢ Implementing a LSS manufacturing strategy.
- ➢ Implement a root cause analysis technique.

5.11.2 Post-analysis stage

The post-analysis stage provides ways to apply all suggestions made to improve the performance measures. Therefore, the implementations processes were applied in making the model (Figure 5.10). The machine capacities were set as the new ones and added for the filling and body-maker processes (Figure 5.13).

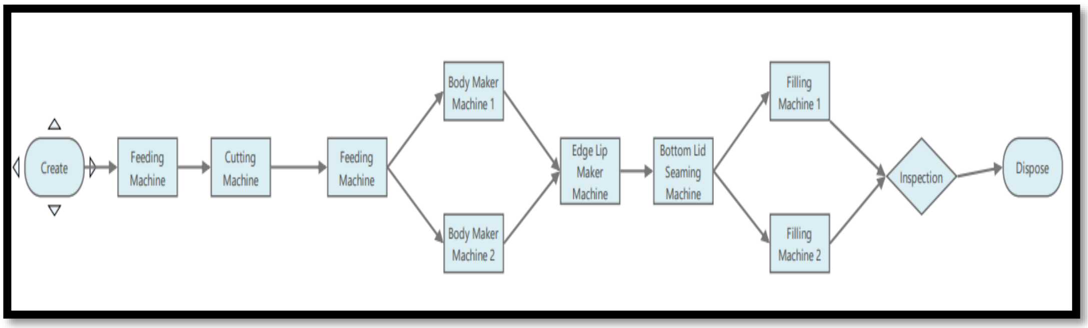


Figure 5.13: Improved machine layout

Table 5.12. Increased mumber of machines for the filling and body-maker processe

	Name	Type	Capacity	Busy / Hour	Idle / Hour	Per Use
1	Feeding Machine	Fixed Capacity	1	0.0	0.0	0.0
2	Cutting Machine	Fixed Capacity	1	0.0	0.0	0.0
3	Body Maker Machine	Fixed Capacity	2	0.0	0.0	0.0
4	Edge Lip Maker Machine	Fixed Capacity	1	0.0	0.0	0.0
5	Bottom Lid Seaming Machine	Fixed Capacity	1	0.0	0.0	0.0
6	Filling Machine	Fixed Capacity	2	0.0	0.0	0.0

5.11.3 Improved results

The throughput of the improved system of production is shown in Figure 5.14.

Number Out	Value
Can	2,699,984

Figure 5.14: Improved production

Table 5.13: *Time statistics*

VA Time	Average	Half Width	Minimum Value	Maximum Value
Can	2.1104	0.035559627	0.8000	2.4000
NVA Time	**Average**	**Half Width**	**Minimum Value**	**Maximum Value**
Can	0.00	0.000000000	0.00	0.00
Wait Time	**Average**	**Half Width**	**Minimum Value**	**Maximum Value**
Can	0.1458	0.020762922	0.00	0.8000
Transfer Time	**Average**	**Half Width**	**Minimum Value**	**Maximum Value**
Can	0.00	0.000000000	0.00	0.00
Other Time	**Average**	**Half Width**	**Minimum Value**	**Maximum Value**
Can	0.00	0.000000000	0.00	0.00
Total Time	**Average**	**Half Width**	**Minimum Value**	**Maximum Value**
Can	2.2562	0.020059222	1.6000	2.4000

The proportions of cans that were rejected are illustrated in Figure 5.15.

Count	Value
Adhesive	2698.00
Falling off Conveyer Belt	1571.00
Oil Leak	20421.00
Record Scraped Due to Tin Interference	20381.00
Variation in Cans	1621.00
Without Covering	7077.00

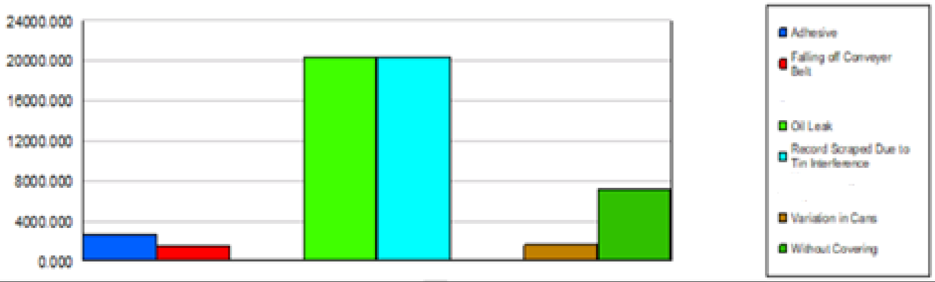


Figure 5.15 Decrease in rejection/scrap rate

5.12 The control phase

5.12.1 Results comparison

Table 5.14 provides a comparison of the findings.

Table 5.14 Comparison of existing and improved scenarios

Statistics	Before improvement	After improvement
Run length	30 days	30 days
Total production	2566485 per shift	2699406 per shift
WIP	13 on average	5 on average
Avg. cycle time	5.21 s	2.26 s

The production's output results are shown in Table 5.14, which also shows an increase in production length. The cycle time was decreased from 5.21 seconds to 2.26 seconds, and WIP was dramatically reduced from 13 to 5. The cycle time reduction = 2.26 / 5.21 = 43.38%.

5.12.2 Rejection analysis

The number of cans scrapped before and after improvements were introduced is shown in Table 5.15.

Table 5.15 Scrap reduction after improvement

Scrap type	Before improvement	After improvement	Scrap reduced
Sheets Interference	91994	20381	71613
Adhesive	10767	2698	8069
Falling off Conveyor Belt	6554	1571	4983
Oil Leakage	81885	20421	61434
Variation	6544	1621	4923
Without Cover	27853	7077	20776

Total scrap reduction = 171,798 cans

5.13 Summary

The research was completed within the framework of time and according to the stages. The current system and data analysis was carried out according to the system process flow and data and the performance measures were analysed using a simulation study. Some potential results were measured and compared with regard to the improved process of simulation results. The cycle time of parts was reduced by almost 44%, 171,798 fewer cans were scrapped, and the same number was added to production. There are also managerial skills that can be applied to make the system more effective and efficient.

The production system designed an LSS implementation framework for Az-Zawiya manufacturing process, which was accomplished in order to enhance process performance and decrease the defect rate. The application of the LSS model yields goals for future improvement, problem-solving suggestions, and a future state map for the crucial route.

Planning and organization related to strategic parts of LSS implementation and contained a collection of LSS tools for defining current issues and establishing improvement targets. The primary outputs of this phase are a flowchart illustrating the production process in detail and a capacity analysis identifying SPC issues.

The augmentation and activation phase continues as a means of investigating process flaws using VSM. Existing VSM statements on current waste can be expanded with a comprehensive view of the manufacturing process.

Issues were analysed in the assessment and activation phase, and their causes sought to develop improved solutions. This phase features a fishbone diagram, Pareto chart, and 5 Whys root cause analysis. The research concludes with suggestions to dedicate specific time for training on the work floor and to implement a material requirements planning (MRP) system for planning and management. Pull rather than push is proposed as the new method of operation for Az-Zawiya. Just in time (JIT) manufacturing contains a suite of tools, including Kanban, SMED (i.e., single minute exchange dies), 5S, and Supermarket. All modifications result in a substantial decrease in non-value-adding time from 5.21 s and of value-added time of 2.26 s for each production cycle.

The last phase is improvement and verification and specifies the implementation sequence for improvement solutions and offers a control strategy. The improvement comprises a pilot launch, SPC assessment of solutions, FMEA and 5S standardization. Within Az-Zawiya, the control plan suggests the use of Kaizen for mentorship, KPI evaluation for verification, and overall equipment effectiveness (OEE) evaluation.

Chapter 6: Assessing the potential of reducing Libyan oil refinery emissions by using the ORC system

6.1 Introduction to the Assessment of Potentials

Waste heat is a significant energy source for many manufacturing industries. Collecting this waste heat to conserve energy and lessen the industry's environmental impact is becoming increasingly crucial. Numerous production processes produce industrial waste heat that is hot enough to run a power cycle and provide electricity for on- or off-site were used by the companies that refine the oil to produce cement, glass, and steel in huge industrial plants that consume a lot of energy and generate a lot of waste heat. Over 50% of the energy used in manufacturing is lost to the atmosphere (Jouhara, Khordehgah et al. 2018). Recapturing waste heat in particular circumstances, such as industrial furnaces, can boost energy efficiency by 10% to 50%. According to estimates, waste heat recovery in a medium-sized cement mill can increase energy efficiency by 20% and decrease CO_2 emissions by up to 10,000 tonnes yearly, enhancing our quality of life and sustainability (Jouhara, Khordehgah et al. 2018). Several factors, such as pressure, pressure drop, chemical composition, permitted temperature, temperature levels, and flow rate, might impact the viability of waste heat recovery systems. Several factors, such as flow velocity, waste temperature, enthalpy, and the specific heat of the waste heat stream, affect the amount of available waste energy in waste heat sources. The ability of heat recovery exchangers to transfer power is influenced by fluid phase, flow rate, and temperature. The chemical composition of the waste heat stream may limit the possible selection of heat exchanger materials and cause fouling problems. The dew point temperature in exhaust gas streams frequently establishes the lowest permissible temperature because the liquid phase might cause heat exchanger corrosion. The solubility of wax, lipids, and dissolved minerals in liquid waste heat streams determines lower temperature limits. (Chowdhury, Hu et al. 2018 and Jouhara, Khordehgah et al. 2018).

According to the US Department of Energy, the industrial manufacturing sector in the US consumed 30% of all energy in 2009, with roughly a third of that energy being emitted as waste heat. Industrial waste heat includes steam at temperatures between 100 and 250 °C and process gas vapours between 80 and up to 500 °C, flue gases between 150 and up to 800 °C, liquid streams between 50 and 150 °C, and vapour streams between 50 and 150 °C. Under 230 °C, almost 60% of the waste heat was at low temperatures. (Jouhara, Khordehgah et al. 2018). The enormous volume of low-temperature waste heat makes up for its less thermal energy than high-temperature waste heat. However, the potential waste heat at a more desirable temperature over 250 °C has been calculated to represent an electric generating capacity in the 6000-8000 MW range using current technology (Llera, Vigil et al. 2022).

6.2 The emissions sources from crude oil refinery in Libya

Libya has five domestic refineries, with a combined capacity of approximately 380,000 bbl/d (51,351 tons/day), significantly higher than the volume of domestic oil consumption (227,000 bbl/d; the rest is exported). Libya's refineries include:

• Ras Lanuf export refinery, completed in 1984 and located on the Gulf of Sirte, with a crude oil refining capacity of 220,000 bbl/d.

• Az Zawiya refinery, completed in 1974 and located in north-western Libya, with a crude oil processing capacity of 120,000 bbl/d.

• Tobruk refinery, with a crude capacity of 20,000 bbl/d.

• Brega, the oldest refinery in Libya, is located near Tobruk with a crude oil capacity of 10,000 bbl/d.

• Sarir, a topping facility with 10,000 bbl/d of capacity.

The plants are unsophisticated and consume a lot of energy. They cannot produce products that correspond to the specifications required by the consuming countries, such as unleaded petrol, reformulated gasoline and low Sulphur gas oil (Table 6.1). The refineries suffered very badly from the technological and equipment limitations imposed by sanctions. Refineries are a potential source of atmospheric emissions of carbon dioxide (CO2), carbon monoxide (CO), methane (CH4), Volatile Organic Compounds (VOCs), including hazardous substances such as benzene and 1,3-butadiene, Sulphur, reduced Sulphur compounds and oxides of Sulphur, ammonia, oxides of nitrogen, toxic organic micropollutants (dioxins, PAHs), heavy metals, particulates and odour(Samer Y, Yasser F. 2018)

Catalytic or thermal cracking units, catalytic reformer units, sulphur recovery plants, storage vessels, fluid coking units, wastewater streams, cooling towers, equipment leaks, blow-down systems, vacuum distillation units, steam boilers, process furnaces, process heaters, compressor engines, barge or ship loading, and gasoline loading racks located at petroleum refineries are the most significant sources of air emissions (Table 6.1). It lists the air contaminants from these air emissions sources and presents the US EPA publication AP-42 estimates of these oil refinery air emissions sources' uncontrolled emissions. The refineries suffered very badly from the technological and equipment limitations imposed by sanctions. Refineries are a potential source of atmospheric emissions of carbon dioxide (CO2), carbon monoxide (CO), methane (CH4), Volatile Organic Compounds (VOCs) including hazardous substances such as benzene and 1,3-butadiene, Sulphur, reduced Sulphur compounds and oxides of Sulphur, ammonia, oxides of nitrogen, toxic organic micro pollutants (dioxins, PAHs), heavy metals, particulates and odour.

Table 6. 1 Emission factors and the air emissions from crude oil refinery industry in Libya (Samer Y, Yasser F. 2018)

Pollutants	Emission factor kg/1,000 bbl crude oil	Gas Emissions ton/year
Carbon dioxide	8,057	1,117,400
Methane	15.59	2,163
Nitrous oxide	0.2543	35.3
Particulates	347	48,129
Carbon Monoxide	6215	862,020
Sulfur Dioxide	224	31,069
Nitrogen Oxides	33	4,577
Hydrocarbons	398	55,203
Aldehydes	8.7	1,207
Ammonia	24.5	3,398
Inorganic Chlorine	4,450	617,220
VOC	2.12	294
	Total emissions (ton/year)	2,742,715
	Total emissions of eCO_2 (ton/year)	1,182,000

6.3 Effluents and Emissions

It is important to know that regarding the nature and quantities of refining pollutants, the macro-scale composition of crude oils differs even to some degree. For the more, refineries are still restricted to a relatively narrow variety of diets on crude oil. Normally, wide differences in refinery emissions are not anticipated when transitioning from one crude oil to another within that range. Consequently, the form and amount of refining emission to the atmosphere during normal operations are well known. However, Occasionally, the refining of crude oils previously unknown to the refinery can have unintended consequences on the efficiency of refinery processes and contribute to a rise in emissions Goodland, R. (2013); This is particularly likely to affect aquatic emissions and to a lesser extent, air emissions. Table 6.1 shows a simplified example of what a refinery consumes and emits.

6.4 Emissions to the Atmosphere

The environment's major pollution causes of carbon monoxide and ammonia, nitrogen oxides (NOx), particulates, and sulphur oxides (SOx) are boilers, heaters, and catalytic cracks. Refinery operations need a lot of electricity; more than 60 per cent of refinery air pollution is usually correlated with energy generation for specific processes. Sulphur recovery units and flares also contribute to those emissions. Catalyst changeovers and cokers release particulates. The storage unit causes the emission of volatile organic compounds from pipes, seals, drains and the handling facilities; oil/water separation systems are also affected by fugitive pollutants. Many atmospheric pollutants include particulate components and metals and H2S, NH3, BTX, CS2, COS, and HF.

The greenhouse gas most frequently discussed in the debate over climate change is carbon dioxide (CO_2). The processing of fuel primarily causes pollution from CO2. A frequent intermediate byproduct of the combustion processes is carbon monoxide (CO). However, compared to CO_2, the significance of CO_2 leaks from refineries is not very significant.

When nitrogen oxides (NOx) are discharged into the environment, they can combine with air and become a component of "acid rain." Sunlight, volatile organic compounds, and NOx all help to produce ground-level ozone. The combustion process, which mostly results from the combustion air itself and is turned into a combination of NO2 and NO during the combustion, is the primary contributor of NOx. Important factors in this include the conditions for combustion. As a significant greenhouse gas, N_2O contributes to the destruction of stratospheric ozone. Sulfur oxides (SO_x), when released into the atmosphere, combine with air to form an "acid rain" part. Energy production is the main contributor to SO_x; gasoline's sulphur is transformed into a combination of S02 and SO during combustion. The sulphur recovery unit is another source. The feed sulphur has a clear connexion to a combustion process and the sulphur oxides of the flue gas. Smoke gas. In general, the sulphur content of the refinery fuel pool is a delicate balance between the energy needed, the form of crude refined, and the pollution limits.

As previously described, volatile organic carbons (VOC) can react with NO_x in sunlight to create low-level ambient ozone. In addition, VOC emissions can cause odour problems, leading to complaints from nearby residents. The cause of VOC pollution during storage and delivery is the evaporation and leakage of hydrocarbon fractions. Hydrocarbons can often be released under non-optimal combustion conditions, although these only add a limited volume.

6.5 Air Quality Results Around Az-Zawiya Refinery

Includes readings from seven monitoring stations five stations surrounding the site and two stations inside the industrial area. The measured values were recorded on the average bases of three hours of measurement per location (station).

The pollutant gases measured were Hydrogen Sulfide (H_2S), Volatile Organic Compound (VOC), Carbon Monoxide (CO), Nitrogen Oxide(NO), Nitrogen Dioxide(NO_2), NO_x (NO_2 + NO), Ozone (O_3) and Sulfur Dioxide (SO_2). The results of the average concentration detected are presented in table 6.2 and Figures 6.1 represent the average concentrations compared with standard (as per appendix 2) limits for H_2S, VOC, O_3, NOX, NO and NO_2 respectively at each station(Appendix 3) presents a complete tabular data of the analyzer output for all stations).

Table 6. 2 Summary of the Air-Quality Analysis Average Results For the Seven Stations (Arc.com.ly. 2019).

No	(station)	H_2S (PPb)	VOC (ppm)	CO (ppb)	NO_x (PPb)	NO (PPb)	NO_2 (PPb)	O_3 (PPb)	SO_2 (PPb)
1	Station 1	0.95	3.57	0.04	3.23	0.86	2.37	45.45	1.48
2	Station 2	1.13	3.37	0.60	12.44	5.45	6.99	47.80	2.42
3	Station 3	1.79	6.30	0.14	19.23	12.54	6.67	43.89	5.35
4	Station 4	0.93	4.70	0.06	6.03	1.29	4.74	43.18	3.02
5	Station 5	1.38	5.58	0.30	10.05	4.72	5.33	60.70	2.38
6	Station 6	1.11	5.63	0.07	4.72	1.89	2.83	49.16	1.57
7	Station 7	2.00	6.13	0.28	12.68	6.56	6.12	35.67	2.59
	Maximum Average(≈3hrs) reading	2.00 ppb	6.30ppm	0.60ppb	19.23ppb	12.54ppb	6.99ppd	60.70ppb	5.35ppb

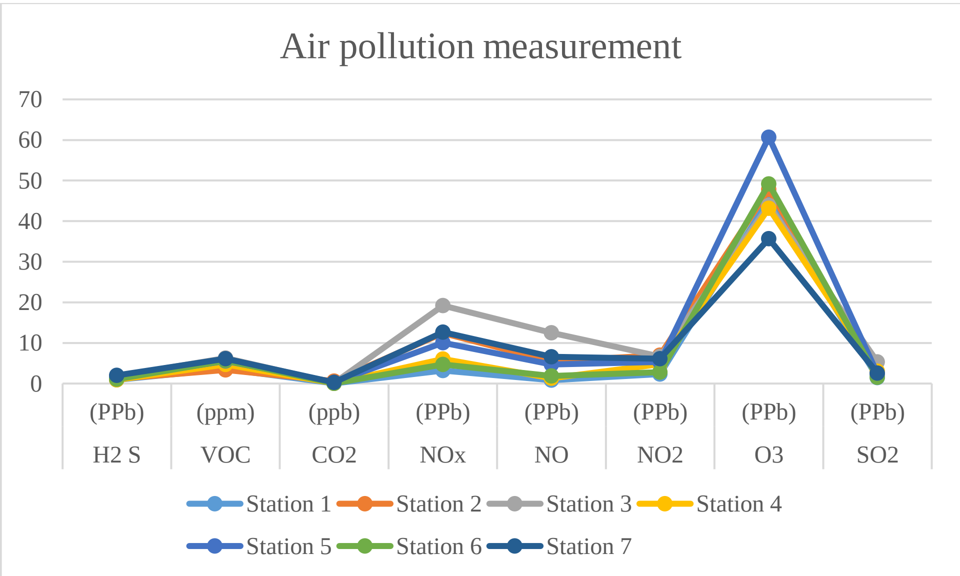


Figure 6. 1 shows the volatile gases from the refinery.

This figure shows, the harmful rate of volatile gases from the refinery chimneys, which is the air in and around the refinery, as a result of the glowing heat from the refinery nozzle, which helps these fumes to spread to a further extent. This heat can be used to reduce emissions and conserve energy by using the Organic Rankine Cycle.

6.6 Stage 1 of DMAIC: Define

6.6.1 Problem Statement

Due to several reasons, the environmental impact study has criticised the detrimental effects of the processes involved in the discovery and extraction of crude oil: The process of fuel extraction has been considered hazardous when humans come in contact with the oil product that releases hazardous/toxic gasses and affluents during production. This phenomenon also affects many animals in habitats when a spillage occurs, and the environment is affected during fuel production, where many refineries plant releases an unquantifiable amount of CO_2 and toxic gases into the atmosphere this resulting in aggravating the consequences of climate change (Gawedar and Ramakumar 2016).

Oil refineries bring on air pollution and smog. They pollute at levels that are unhealthy and unacceptable. In addition, oil refineries release various pollutants, including benzene, hydrogen fluoride, nitrogen oxide, carbon dioxide, carbon monoxide, methane, and dioxins. First, to use an ORC to recover "waste" heat, evaluate if there is enough available waste heat to support creating an ORC and if the waste heat is actually "waste." If the process already exists, the "waste" heat could be produced at the expense of using more high-quality hot utilities elsewhere. Therefore, one should first examine whether waste heat can be eliminated by changing the heat exchanger network of the current operation to decrease hot utilities. If enough waste heat is left over after this step to warrant recovery, an ORC can be considered. However, because the waste heat temperature can affect the ORC system's power production, adjusting the heat exchanger network to prioritise higher-grade heat could be preferable. Two factors are considered when synthesising a heat exchanger network to conserve hot utility and improve waste heat. The environmental impact of Az Zawiya Oil

Refining Company is a significant issue. Air emissions all affect the atmosphere. To reduce emissions from Az Zawiya Oil Refining Company, exploration and production activities must consider these factors. The main effects of atmospheric impacts, categorised as flaring and venting, fossil fuel exhausts from diesel engines and gas turbines, losses from process equipment, tankage, and loading activities, are climate change and ozone layer depletion. GHGs, among other things, are part of these emissions (Gawedar and Ramakumar 2016).

Since the gas is burned in the air without benefit, much energy is wasted daily, about (43,800 tons/year). Sometimes the burner blew out the flame, causing leakage of large amounts in the air with an unpleasant smell. The problem was raised when the company's manufacturing and petroleum refining officials wanted to find an alternative solution to eliminating the waste gas. Therefore, we have been cooperating to discover a resolution to this problem. Proposals have focused on the following:

Consider benefiting from the outside exhaust from burning to run the electric power station.

Another problem facing Az Zawiya Oil Refining Company is the shutdown of electricity sources during operation time, which lades to stopping and starting up machines again in the company.

6.6.2 Motivation

Each waste heat source's energy potential must be considered while determining the ORC cycle's operating parameters to generate more power with reduced areas. Most studies for waste heat recovery system energy generation through residual heat recovery rely on using exhaust gas heat from the gas turbines already set up on the platforms, which provide medium and high-temperature heat sources. The most effective solution for this plant power support is heat recovery from exhaust gas from a gas turbine on a refinery platform. (Reis and Gallo, 2018).

This chapter outlines a fresh analysis to estimate the refinery's potential benefit from various waste heat recovery options. The analysis showed that a sizable portion of the heat thrown off the chimney comes from low-grade sources, allowing for the evaluation of ORC's potential for low-temperature waste heat recovery from the combustion process. The goal was to generate more electricity, make the combustion process more efficient, and reduce greenhouse gas emissions. The major goal was to create a computational calculation tool to optimise ORC cycles and a mathematical model to assess the ORC cycle's thermodynamic efficiency and estimate the heat exchanger's design. This information will indicate the ORC cycle's potential for use on a Libyan refinery chimney proposed. (Mansouri et al., 2020).

Due to their physical space constraints, weight restrictions, and security measures, refineries provide a significant challenge for power generation in terms of meeting the demand for this input. Given its small size and notable economic performance due to its straightforward design, the ORC cycle is a technology with much potential for this application. Each platform should have a different physical footprint to better suit the needs of the fields where it will be put. As a result, a set of optimal solutions that will be offered from the optimised ORC operation can be limited using the calculating tool that has been built. This study may determine the ideal arrangement for the various platforms' available spaces.

However, the effectiveness of a Rankine cycle employing water as the working fluid to convert thermal energy to power For boiler temperatures below 350°C, the thermal energy-to-power conversion efficiency of a Rankine cycle utilising water as the working fluid becomes uneconomically low. (Ibrahim, 2018). The organic Rankine cycle (ORC) system outperforms the conventional Rankine cycle at low temperatures and temperatures, and the organic Rankine cycle (ORC) system outperforms the conventional Rankine cycle, particularly when waste heat is present. The sole difference between the organic and traditional Rankine cycles is the absence of water in favour of volatile organic liquids like pentane, benzene, and isobutene or refrigerants such as R-22, R134a, and R-123. Because the organic working fluids of ORC systems have lower boiling points than steam or water, they can function in low-temperature waste heat sources. Water had the lowest potential for generating electricity when tested at low heat source temperatures between 100 °C and 225 °C in comparison to isopentane, propane, ammonia, n-heptane, benzene, and water (Quoilin, Van Den Broek et al. 2013).

Many studies are paying close attention to carrying out and assessing how the different working fluid types affect the system's ORC performance and output power due to its successful ORC running and significant role. A working fluid is chosen based on various factors, including affordability, environmental effect, good availability, thermodynamics, non-corrosiveness, non-fouling, thermal stability, physical properties, non-flammability, non-toxicity, and material compatibility. The system's thermal efficiency seldom changes when fluids are used at their critical temperatures. Compared to R245ca and R245fa, they do less well when dealing with R141b, R123, R11, and R113, but they exhibit good preferences for environmental impacts. (Liu, Chien et al. 2004). Other research has concentrated on the study of pure fluids, and it has been advised to employ zeotropic fluid blends to improve cycle performance and modify heat exchanger design to stop fluid fractionation during phase transition in practical applications, with the help of waste heat emitted from the cooling system of the oil and gas production platforms, a propane and ethane mixture was expected to perform better in a transcritical cycle than CO_2. Geothermal power generation has successfully been used to power ORC systems larger than 5 MW. Low-temperature ORCs and their usage on a smaller scale are of significant interest, although there have only been a few known demonstration projects. Two ORC systems were installed successfully to generate a net power of up to 200 kW, utilising a combination of landfill flare and reciprocating engine exhaust. With the ORC power system, water at a temperature of 76 °C in oil field waste could create electricity. ORC system plants are already functioning with spring water at a temperature as low as 74 °C to create 200 kW (Quoilin et al., 2013).

Biomass and wood ORC systems have not been widely used as alternatives to gas, coal, and oil to deliver heat for industrial-scale processing in renewable energy sources like solar thermal energy. Compared to renewable energy advancements, using industrial waste heat to power ORC systems has various advantages:

- It has a higher potential utilisation factor compared to solar or wind energy,
- It does not call for any novel materials or complex technology.
- Since waste heat power generation may be used immediately and is not dependent on a grid connection or supporting generation like wind, it can be used immediately.
- It does not require large space or land.
- It can be established and run in a safe setting.

The largest obstacle to utilising more industrial waste heat for power generation is a lack of experience in plant discovery, design, and operation in sectors with significant resources. More development and application research is required to establish a standard procedure for analysing potential resources, creating the concept design for the heat extraction unit and the ORC cycle, selecting the components and fluid, modelling and simulating the components and system, and determining the technical and financial viability. The rate of return on standardisation is positive due to experience and economies of scale. These successes are crucial to the government's incentive programmes for green energy and attracting money from the private sector.

6.6.3 Potential for Waste Heat Power Conversion at the Al-Zawiyah Petroleum Refinery

In this section, the background of the Az-Zawiyah oil refinery will be presented in detail, and the characterization of the waste heat sources in this refinery will be discussed in more information. Figure 6.2 shows some photos of the Oil refinery in Az Zawiyah company.

Figure 6. 2 Photos of Az Zawiyah Oil refinery.

The characterisation of the gas flame stream is covered in the following sections, including determining its pressure, flow rate, and temperatures. In addition to investigating boundary conditions, working fluids, operating conditions, and system performance, the modelling of the ORC system is detailed. The presentation shows how the temperature of the gas flame at the heat exchanger exit affects the net electrical power output. Sensitivity analysis and economic study of the ORC unit building have been conducted.

6.7 Stage 2 of DMAIC: Measure

6.7.1 Characterization of Waste Heat Resources and Data Gathering

Crude oil is typically distilled at a predetermined higher temperature in an atmospheric distillation column at a refinery to avoid thermal cracking. Distillation produces the remaining oil, which boils over 215 °C, and collects it at the bottom of the column. The leftover oil is then treated to further distillation in a temperature-controlled vacuum distillation column. Table 6.3 shows characteristics of waste gas flow I.N.C. (2020).

Table 6. 3 Features of Waste Gas Movement.

Variable (Unit)	**Mixed values**
Temperature (°C)	175-215
Pressure (bar gauge)	7.2–7.6
Rate of flow (kg/s)	3
Number of Chimney	2
Density (kg/m^3)	815–830

All the data such as temperature, pressure and density of the gas flame have been selected from the recording data in the department of operation in the company. These data are recorded by sensors which are installed in the different places in the refinery. Figure below shows some photos that have been taken when we selected the data collection in the operation department. Figure 6. 3 shows some photos of the control room and data record room in the oil refinery at Az Zawiyah company.

Figure 6. 3 Photos of the control room and data record room in the oil refinery.

After the data input, inside the Simulink\Simscape software to run and simulated the ORC a proposed system is made in order to get the power output and also how can the ORC system reduces the waste heat to the atmosphere.

6.8 Stage 3 of DMAIC: Analysis

6.8.1 Modelling of the ORC System

A thermodynamic model of the organic Rankine system has been developed in this section. The model was designed to accept source and sink heat stream parameters as inputs. Possible ORCs were then calculated bounded by the heat source and sink conditions. The ORC cycle parameters of turbine inlet pressure, working fluid mass flow rate, degree of superheat and working fluid are all variables that can be changed. This model was written in Simscap\Simulink using fluid thermodynamic and transport properties databases to calculate fluid properties as required. Standard thermodynamic relations are used to calculate the ORC cycle. Research on gas flame waste heat recovery has been conducted using the simple ORC technique depicted in Figure 6.4 (a). Figure 6.4 (pressure-enthalpy)'s (P-h) diagram shows the working fluid's thermodynamic processes in a cycle. For each steam in the cycle, the point numbers represent the state points of the working fluid. An ORC system is fitted in a bypass pipe constructed between the cooler and the pump to give the evaporator a slipstream of the waste flame chimney. Before the current air coolers, the slipstream returns a portion of the flame flow from the main chimney line stream to the mainstream. A control valve installed at the evaporator's input can change the waste heat flow rate necessary for the ORC unit.

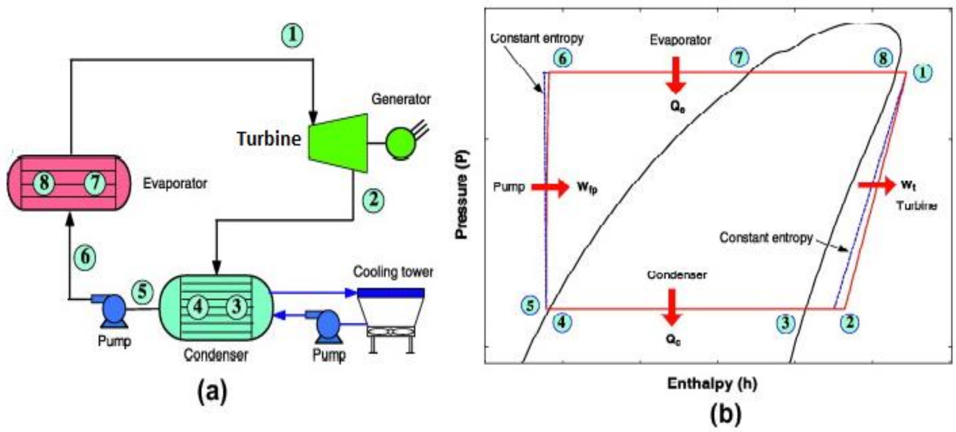


Figure 6. 4 Diagrams representing the system's pressure-enthalpy relationship and the ORC system in a simplified manner.

The ORC unit is installed in a bypass line constructed between the pump and chimney to provide the evaporator with a slipstream of gas flame waste, illustrated in (Figure 6.4). A portion of the gas flame flow from the main pipe of the chimney is intercepted by the slipstream before it enters the environment. A control valve positioned at the evaporator's input can alter the gas flame flow rate necessary for the ORC unit. Direct thermal energy transfer occurs as the working fluid passes through the heat exchanger, the evaporator, and the gas flame waste. The working fluid is preheated from its subcooled liquid state at State-6 to a saturated liquid at State-7, where it eventually evaporates via processes 7-8. At State-1, the generator is powered by the superheated vapour expanding through the turbine under reasonably high pressure. The vapour from the turbine output at State 2 is de-superheated to become a saturated vapour at State 3 and condensed into a saturated liquid at State 4 as it moves through the condenser. The sub-cooled liquid at State-5 is moved to the pump and delivered into the evaporator to finish the cycle. Since cooling water is easily accessible at the study site, a wet cooling system is considered(Zhang et al., 2021) . The ORC system is assumed to operate in a single-day condition while modelling it. Furthermore, it is anticipated that relatively little heat will be lost from the system's parts to the environment. The thermal energy obtained by the working fluid (Q_evap) in the evaporator and the thermal energy transferred from the gas flame waste heat stream (Q_waste) are stated as follows, respectively:

$$Q_{waste} = \dot{m}_{waste} \, . (h_{in} - h_{out}) \tag{6.1}$$

$$Q_{evap} = \dot{m}_{ORC} \, . (h_1 - h_6) \tag{6.2}$$

Where $\dot{m}_{waste}$ and $\dot{m}_{ORC}$ is the flow rates of the gas flow waste heat and ORC working fluid in kg/s, whereas h is the fluid's enthalpy (in kJ/kg) at the given condition. The working fluid phases are denoted by numbered subscripts in Figure 1, and the subscripts I and o stand for the evaporator's input and output (in kJ/kg) (Fergani et al., 2016). The working fluid flow rate needed for the power cycle for a particular mass flow rate of gas flame waste, m ORC, is defined by the energy balance and Q waste = Q evap.

Consequently, the turbine's power output can be determined as follows:

$$\dot{W}_{Turbine} = \dot{m}_{ORC} \, . (h_1 - h_2) \tag{6.3}$$

Where h2 is computed as, and h1 and h2 are the enthalpies at the intake and outflow of the turbine, respectively.

$$h_2 = h_1 - \eta_{Turbine} . (h_1 - h_{2is}) \tag{6.4}$$

Where $\eta_{Turbine}$ is the isentropic turbine efficiency which assumed to be 0.85 in this study, and h_{2is} is the fluid's isentropic enthalpy. .

The heat energy rejected from the ORC working fluid (Q condenser) to the cooling water in the condenser is represented by the following equation:

$$Q_{condenser} = \dot{m}_{ORC} . (h_2 - h_5) \tag{6.5}$$

The working fluid feed pump's power requirements (in W pump) are as follows:

$$\dot{W}_{pump} = \dot{m}_{ORC} . (h_6 - h_5) \tag{6.6}$$

Where h6 is the enthalpy of the pump's exit.

As a result, the cycle performance (η cycle) and net cycle power (W net) can each be calculated as follows:

$$\dot{W}_{net} = \dot{W}_{Turbine} - \dot{W}_{pump} \tag{6.7}$$

$$\eta_{cycle} = \frac{\dot{W}_{net}}{Q_{evap}} \tag{6.8}$$

The pinch point analysis is used to calculate the ideal temperatures for evaporation (T evaporator) and condensation (T condenser) in the heat exchangers. The pinch point, also known as the pinch point temperature difference (ΔT pp), is the location in a heat exchanger where the temperature difference between two fluid streams is at its smallest. To find the internal pinch point (T pp), which is brought on by the phase shift in the evaporation and condensation processes, one plots the temperatures of fluids as a function of the heat transfer rate, also known as a T-Q diagram. The ΔT pp can be calculated as follows when the evaporator's State 7 contains the pinch point:

$$\Delta T_{pp} = \frac{T_{waste,in} - T_{waste,out}}{Q_{waste}} Q_{6,7} - T_{evaporator} \qquad (6.9)$$

Where $T_{waste,in}$ and $T_{waste,out}$ are the temperatures at which waste heat enters and exits, respectively, and Q6,7 is the rate of heat transfer during the pre-heating process. Similar methods can be used to calculate T pp in the condenser or at various pinch points. The operating condition violates the second rule of thermodynamics when T pp is negative. The zero T pp indicates that the system requires an infinitely big heat exchanger (Quoilin, Van Den Broek et al. 2013). The size of the heat exchangers can be decreased by raising T pp in the system design, but at the cost of reduced heat transfer efficiency (Fergani et al., 2016).

6.8.2 Considerations for Working Fluids

The ORC can use a variety of fluid types as working fluids, including hydrocarbons (like pentane), hydrofluorocarbons (like R134a), hydrochlorofluorocarbons (like R22), ammonia, carbon dioxide, and mixes. For the eight working fluids under consideration, P Temperature-entropy (T-s) graphs are shown in Figure 6.5. Based on the slopes of the gradients of their vapour saturation curves on a temperature-entropy (T-s) diagram, the fluids can be loosely divided into three groups: dry, isentropic, and moist fluid. Dry fluids have a positive gradient, and wet fluids have a negative slope. The gradients of the isentropic fluid are almost vertical. The isentropic fluids (such as pentane and R134a, respectively) must be superheated to ensure a superheated condition at the turbine output, even if appropriate for the subcritical cycle. Moisturizing fluids (such as water, ammonia, and ethanol) are recommended for the transcritical cycle to avoid liquid droplets generated during the expansion process at the two-phase region from corroding the turbine blades. (Tchanche, Petrissans et al. 2013).

In this study, the examination is carried out on a mole basis using working fluid, such as pure fluids of R134a. Pure fluids were chosen because they are some of the most often used fluids in ORC plant manufacturers, and their performance is compared to that of the mixtures.

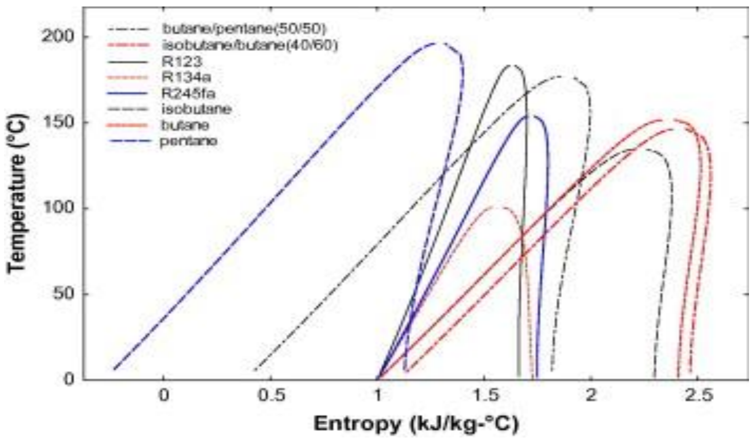


Figure 6. 5 Diagrams of temperature-entropy (T-s) for the eight working fluids being studied (Rayegan, 2011).

6.8.3 Validation of the System

The most important concern in numerical modelling is the model's accuracy in predicting the physical behaviour of the real system. This section validates the developed Simscape MATLAB simulation model against data available in the open literature. The comparison between the current model results and published theoretical and experimental data was carried out regarding different operating parameters and performance indicators of the ORC system. It includes operating cycle temperatures, mass flow rates, heat transfer rate, pump power, turbine power, net output power and system efficiency. The developed Simscape model results are validated in this section against the real Chena geothermal power plant data. The validation was done by comparing the developed model results with the real plant data at the nominal design point, as shown in Table 6.4 (Aneke et al., 2011). Table 6.5 shows that the results obtained from the developed model are in very good agreement with the real plant data. The maximum deviation between the developed model results and real plant data is less than 1%, demonstrating that the developed model accurately describes the processes taking place in the real ORC plant and its overall system performance.

Table 6. 4 Chena power plant operating conditions used in the simulation model.

Parameters	Value
Working fluid	R 134a
Geothermal water mass flow rate kg/s	33.39
Geothermal water source temperature ^{o} C	73.33
Turbine inlet pressure bar	16
Turbine outlet pressure bar	4.39
Turbine efficiency %	80
Molar Mass kg/kmol	102.03
Critical pressure MPa	4.06
Critical temperature ^{o} C	101.06

Table 6. 5 Comparison of the simulation model results with real data of Chena power plant.

Parameters	Chena plant	This model	DEV %
Geothermal water outlet temperature ^{o} C	54.4	54.7	0.8
Working fluid mass flow rate, kg/s	12.17	12.23	0.57
Turbine gross electric power, kW	250	250.1	0.01
Thermal efficiency, %	8.14	8.20	0.75
Turbine inlet pressure bar	16	16.5	0.5
Turbine outlet pressure bar	4.39	4.39	0

6.9 Stage 2 of DMAIC: Improvement

6.9.1 The Findings and Discussion

The ORC concept design's technological viability was assessed, and the effects of the working fluids on system performance were looked into to transform waste heat from refineries into power. The R134a refrigerant is the study's working fluid. The system's power production is directly impacted by the temperature and flow rate of the refinery's exhaust gas flame. In MATLAB, Figure 6.6 depicts the ORC connected to the chimney in an oil refinery, while the yellow parts represent the chimney, and the ORC system is denoted by the blue lines and blocks. The model was run for one day using actual business operation data.

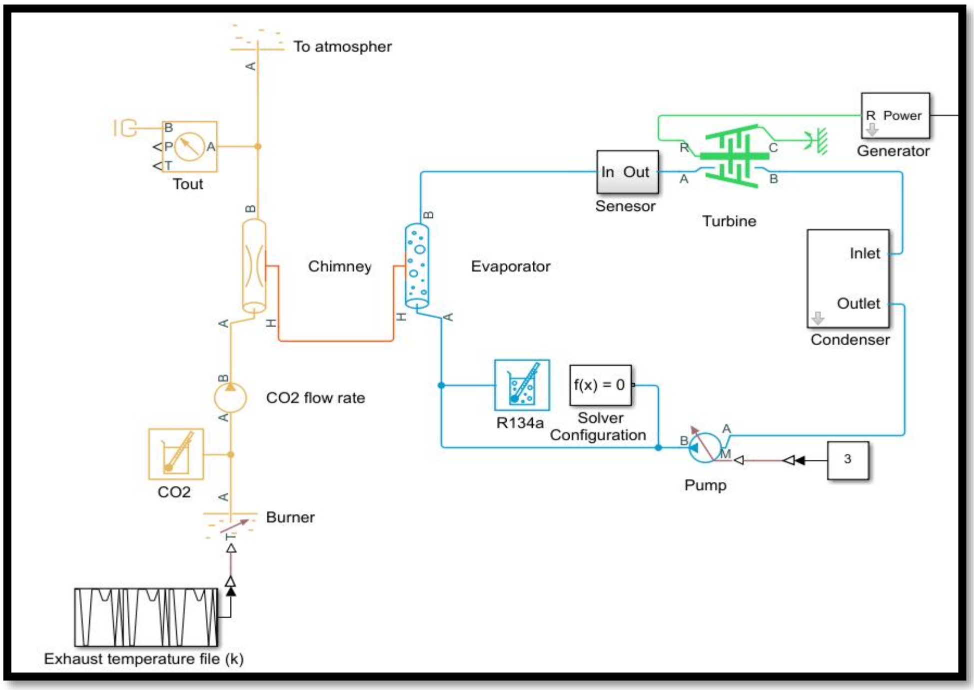


Figure 6.6 schematic diagram of ORC system in MATLAB

Variation of exhaust gas flow waste temperature of the oil refirenry chimney is shown in the figure 6.7 below. It is clear that there are variation of exhaust gas flow waste temperature during the one operation day.

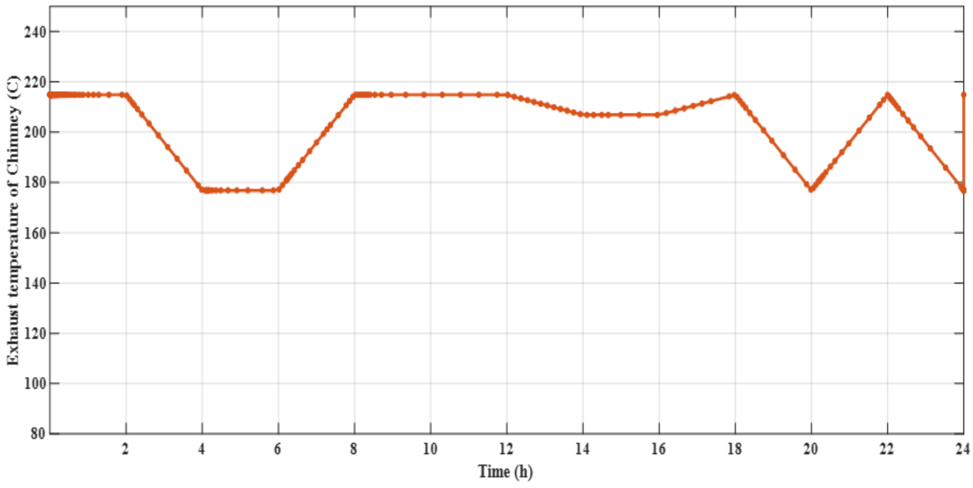


Figure 6. 7 Variation of exhaust gas flow waste temperature

Variation of the working fluid mass flow rate of CO2 and other from the chimney is shown in figure 6.8 below.

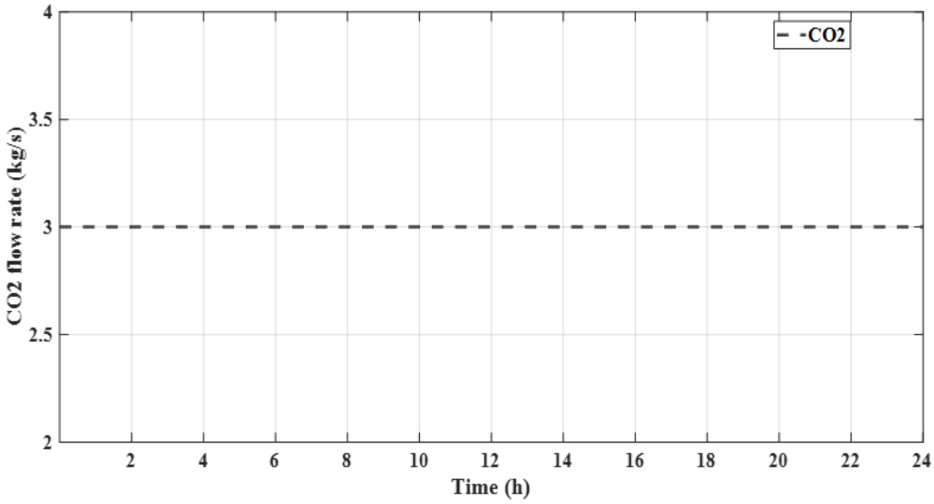


Figure 6.8 Variation of the working fluid mass flow rate of exhaust

This figure shows the flow rate of the exhaust mass, and through the flow rate is 3 kg again, which is a semi-stable rate. There are some simple changes, so the average was chosen for the flow rate.

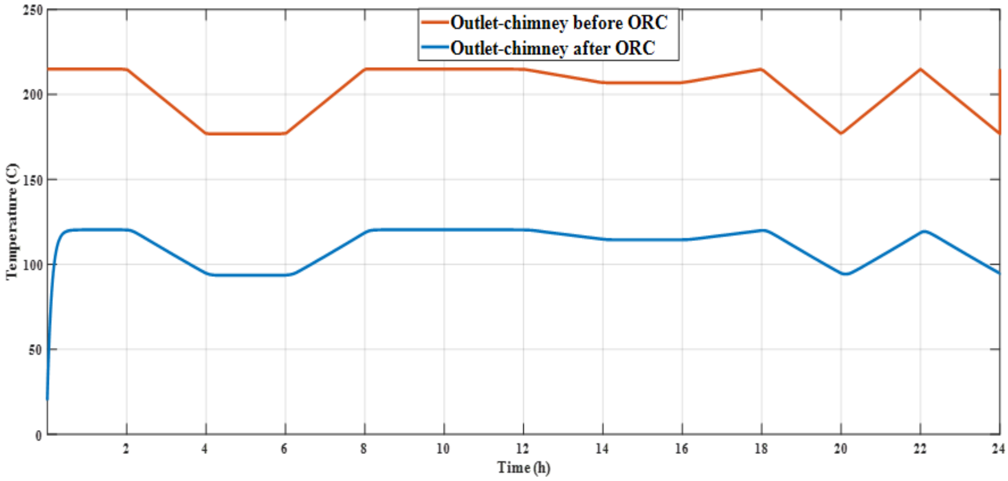


Figure 6. 9 Variation of exhaust temperature before ORC and after ORC.

Figure 6.9 displays the temperature changes during the day in the chimney. The red line shows the temperature leaving the chimney before ORC, producing more than 210 degrees Celsius, while the blue line shows the exhaust temperature after installing ORC. From the figure, the temperature has decreased from 210 to 112, with a difference of approximately 100 degrees Celsius, leading to reducing harmful emissions and global warming. This function has proven to be used in petrochemical plants and other industries. Hence, it is recommended to use it in Libyan refineries.

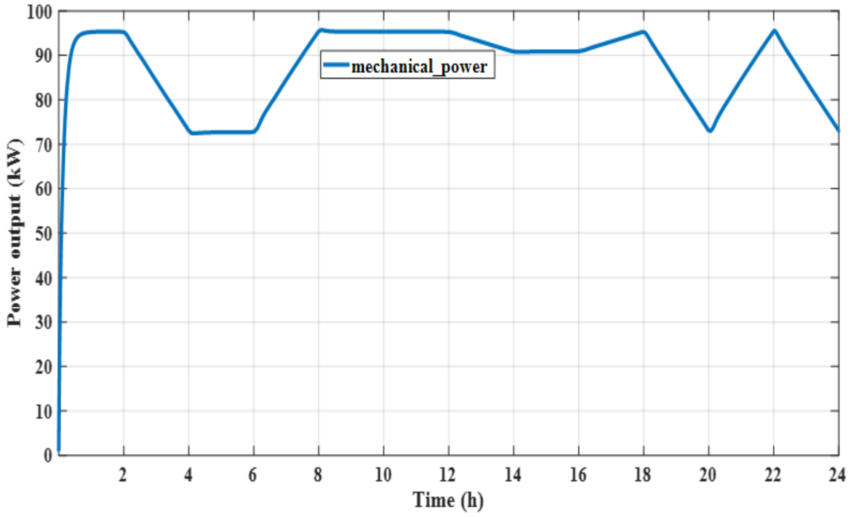


Figure 6.10 ORC output during the day.

The result of the simulation presented in figure 6.10 shows that the waste heat from the oil refinery plant can be used to produce up to 95.40 kW of electricity at an efficiency of 65% while operating at the plant nominal design point. This value is equal daily average electricity usage by some building blocks in the company which currently stands at about 95 kW. In a real system, there is always a deviation in the nominal design point during the day-to-day operation of the plant. This may arise due to variations in the ambient weather conditions or other disturbances in the system such as variations in the waste heat source temperature and mass flow rate.

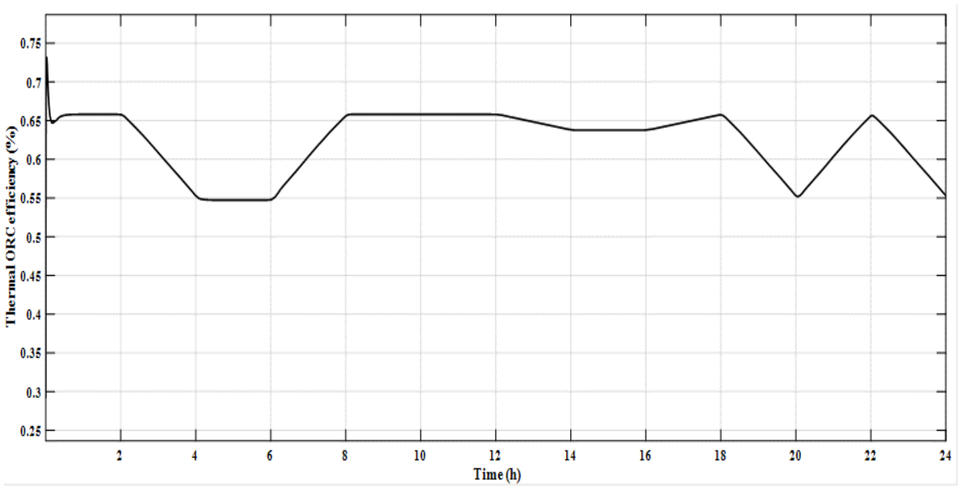


Figure 6. 11 thermal efficiency of the system.

Figure 6.11 shows the packed staple during the whole day's operation, where the rate of the packed density is 0.65. A decrease in the rate can be observed at four in the morning until six in the morning, and that is due to the fluctuation in the temperature of the chimney because the density depends mainly on the temperatures entering the system

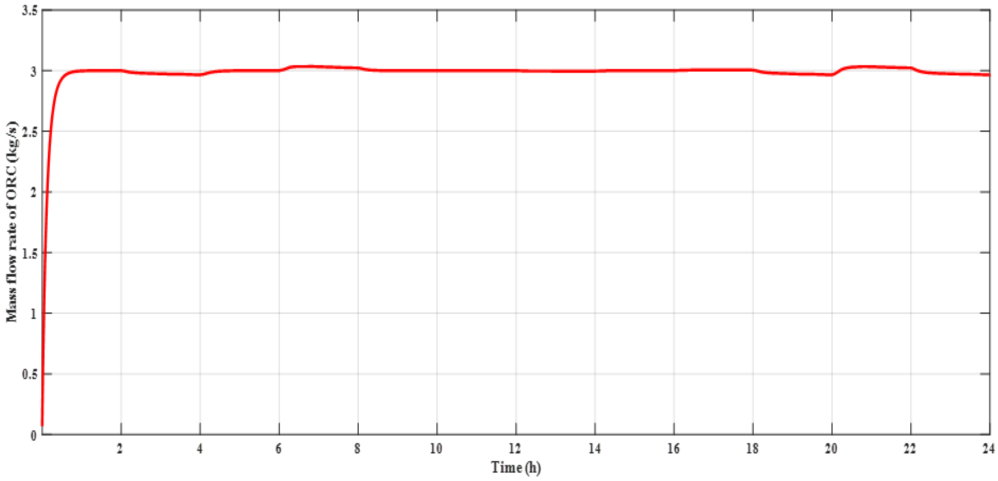


Figure 6. 12 Variations of mass flow rate of ORC.

Figure 6.12 shows the mass flow of ORC system. During the day, there is a slight fluctuation in the rate of mass flow due to the system's response to temperature.

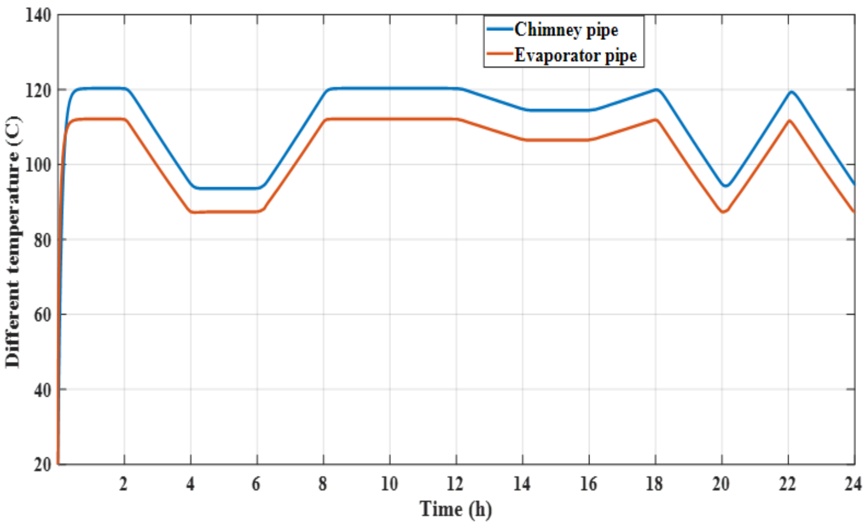


Figure 6. 13 The evaporator pinch point temperature difference.

Figure 6.13 shows the difference in temperature, which is called a difference is a result of the temperature in the chimney, as well as the temperature in the heat exchanger. Whereas, the temperature difference is equal to 10 degrees Celsius, according to previous literature.

6.10 Financial Analysis

This section provides a description of the ORC unit construction project that was conceptualised in the economic feasibility analysis of the previous section. First, a study of the operating and maintenance costs for the ORC plant as well as the installation costs, which were provided based on previous experience. The exact financial data required for the economic study is introduced in the next section. The investment's profitability in the plant installation is then evaluated using economic indicators including the net present value (NPV), the annual system cash flow (CF), the levelized cost of electricity (LCOE), and the payback period (PP). Finally, the sensitivity of the economic feasibility to important variables like the precise installation cost and the price of electricity is investigated. In the table 6.6 below, data are offered for financial analysis.

The systems investment cost is calculated as:

$$\text{Total capital cost} = K_{HX,pipe} * A_{HX,pipe} + K_{ORC} + P_{el} * kWh_{ORC} \qquad (6.10)$$

The systems yearly cash flow (CF) can be written as:

$$CF = E_{el} * K_{el} - K_{O\&M} \qquad (6.11)$$

The operation and maintenance cost (KO&M) is estimated as 1% of the capital cost:

$$K_{O\&M} = 0.01 * Total\ capital\ cost \quad (6.12)$$

The net present value (NPV) of the investment is calculated as:

$$NPV = -Total\ capital\ cost + R * CF \quad (6.13)$$

Where the equivalent project life (R) is expressed as:

$$R = \frac{(1+r)^N - 1}{r * (1+r)^N} \quad (6.14)$$

The simple payback period (SPP) is defined as:

$$SPP = \frac{Total\ capital\ cost}{Time * CF} \quad (6.15)$$

The payback period (PP) is calculated as:

$$PP = \frac{In\left[\frac{CF}{CF - Total\ capital\ cost * r}\right]}{In(1+r)} \quad (6.16)$$

The levelized cost of electricity (LCOE) can be calculated as below:

$$LCOE = \frac{Total\ capital\ cost + N * K_{O\&M}}{N * E_{el}} \quad (6.17)$$

Table 6. 6 Data for financial analysi.

Parameters	Symbols	Values
Electricity cost	(Kel)	0.04 $ kWhel−1
Heat exchanger pipe specific cost	$(K_{HX,pipe})$	325 $ m^2
ORC specific cost	(Korc)	3250 $ kWel−1
Project life	Years **R**	(25)
Discount factor	(r)	3%
Operation and maintenance cost	(KO&M)	1% of the capital cost
Length of the heat exchanger	m	100

So, after the financial data and parameters of ORC system are inputed, the financial results can be obtained from this section of the study as shown in the table 6.7.

The annual income from electricity generation is $33,288. The annual operating and maintenance costs are $3,412.50, resulting in an annual cash flow of $29,875.50.The Net Present Value (NPV) of the project, after 25 years at a discount rate of 3%, is approximately $178,976.49. This suggests that the project is financially viable, as the NPV is positive.

Table 6. 7 Data for financial analysis results.

Parameters	Symbols	Values
Total capital cost	$	341,250.00
Net present value	$	178,976.49.
Payback time	years	11.43 years

Indeed, the costs are highly stable and not subject to variation, the necessity for a sensitivity analysis might seem reduced. Sensitivity analysis is primarily employed according to (Ding and Weele, 2016). for the understanding of how changes in specific variables that affects outcomes or results. Accordingly, if costs are exceptionally stable and variation is unlikely, the need for sensitivity analysis is not relevant for cost-related factors.

There are several reasons why sensitivity analysis might not be directly necessary, these include:

- Stable Costs: This implies when the costs are fixed and not subject to variations, costs such as electricity prices staying constant over an extended period of up to 20 years, there might be no instant need to conduct sensitivity analysis I.N.C. (2020).
- Low Risk Exposure: When the business or project level of exposure to external factors that could cause variations in costs or revenues only, the sensitivity analysis might not be a priority. If the business is not sensitive to changes in market conditions, there might be less urgency to perform sensitivity analysis.
- Limited Impact: In some cases, the potential impact of variations in the variable are analysed might not significantly affect the overall outcome or decision-making process. If changes in electricity prices, for instance, would not drastically affect the business operations or financial performance, conducting sensitivity analysis will not provide substantial insights according to (Ding and Weele, 2016).

- Knowing a Stable Environment: When the market or industry conditions are well unchanging and documented over an extended period or time, the need for sensitivity analysis is reduced, at least in the short-term run. This was the highlighted in the research.
- Time and Resource Allocation: Conducting a sensitivity analysis can be resource-intensive in terms of time, effort, and potentially monetary resources. If the current circumstances did not warrant the need for this analysis and resources are better applied elsewhere, it is regarded not a priority at that instance, hence this instance in the research informed the decision to making the analysis remained not obligatory.

6.11 Summary

New and improved heat conversion technologies must be created in order to benefit from the necessary increase in the supply of renewable energy. Because it can recover low-grade heat and can be used in decentralised, smaller-capacity power plants, the Organic Rankine Cycle is a good fit for these applications.

A numerical model of the typical ORC system and a financial model were developed in order to evaluate the technical and financial feasibility of installing an ORC to convert low-grade industrial waste heat from gas flame waste heat into electricity in a petroleum refinery. Source of emissions throughout the whole oil and gas refinery. Meanwhile, exhaust from the blast burner leaves the chimney. Due to its simple construction and great efficiency, ORC technology has been shown to be a viable option for recycling plentiful low-grade heat from hot stove flue gases.ORC is utilised to provide power for CO2 compression and heat for solvent regeneration in order to decrease energy costs associated with CO2 collection. In this chapter, the project aims to identify a sustainable method for enhancing energy efficiency and CO2 recovery. Several implementation options for CO2 collection in ORC from a chimney are analysed. The performance study compares the proposed system to the baseline in terms of CO2 reduction and energy balances.

Chapter 7 Conclusion

7.1 Research Achievement

7.1.1 Literature Review

A complete literature study was conducted to develop the information needed to fulfil the research goals outlined in Chapter Two. Lean and Six Sigma manufacturing were the primary methodologies discussed in Chapter Two. In addition, an integrated approach to quality management was examined to determine which approaches are frequently incorporated and combined. The purpose of this chapter was to address two main goals; how waste could be addressed by merging the two techniques and identifying the drivers required for combining LSS methodologies in order to develop an LSS model.

7.1.2 Research methodologies

This chapter explains the methodologies used in this research, which follows the quantitative and qualitative approaches, which involve several approaches, such as the questionnaire, the company's internal reports, and previous literature studies in this field. In spite of this, the analysis was carried out using scientific research methods, and the data was examined utilising trustworthy procedures and data analysis software such as Excel, Minitab, SPSS and Arena software.

7.1.3 The proposed integrated LSS framework

The primary focus of chapter four was the creation of an integrated quality management system for the oil and gas industries. The study illustrated how the framework was created and how the framework's approaches interact to create synergy The framework's primary components and its implementation strategies are thoroughly described. By creating the framework, the research showed how combining lean manufacturing with Six Sigma manufacturing creates a platform for managing the quality strategy and vision as well as putting in place an operational mechanism to achieve exceptional performance.

The validation and implementation methods for the framework are also explained in Chapter 4. The DMAIC improvement strategy was one of the methods used to uncover possibilities for quality improvement during the model's development and to aid in the implementation phase. DMAIC integrates a number of sequentially organised LSS technologies and methodologies to speed up the implementation process and improve performance. The model is divided into five DMAIC-based phases and contains two main parts: strategic aspects and execution elements. It was realised that the model may explain the management strategies and vision to which managers must be dedicated in order to improve the processes, decrease variance and waste, and meet or exceed customer expectations. (more details were presented in Chapter Four).

This thesis makes a substantial contribution to both the academic community and the business world with the structure it suggests. The design and execution of the questionnaire study were also covered, demonstrating the three portions of the questionnaire: the initial gathers background information from respondents; second offers assess to the framework; and the third describes how the framework should be implemented. The evaluation of CSFs and barriers to framework implementation are covered in the questionnaire's final section. The methods for confirming the CSFs were provided based on the results of the data analysis, which was done using statistical analysis. According to the study's findings, the proposed framework is relevant to manufacturing organisations and, if implemented or used effectively, can help those organisations gain a competitive edge while also offering advice on how to execute it successfully.

This action completely met the fourth study goal, which was to develop and validate the suggested LSS model. To build and validate the suggested model, the model was created and then connected to the questionnaire survey that was completed. 50 questionnaires were given to quality experts, and 43 of them were promptly returned. The major findings of the poll showed that oil and gas businesses are using the model successfully as long as it is combined with enduring strategic rational. It was also found that LSS execution is still in its early stages. Nevertheless, the majority of survey respondents possess the necessary culture for implementing LSS, and nearly all of them are familiar with the standard LSS tools and procedures.

7.1.4 LSS framework implementation

In this section of the research, the numerical data for production and downtime for maintenance times were analysed using LSS procedures and applied to the oil mixing plant in the Az Zawiya Company. The way in which these methodologies contribute to reducing waste and operational cycle times was also considered.

In the first step, the processes inside the factory were clarified, which is referred to as the define stage in the DMAIC diagram. Then the bottlenecks within the process and the most important reasons leading to them were clarified. The researcher then analysed the root causes of the problem using scientific methods based on LSS tools. As highlighted in the fifth chapter, solutions of waste elimination in terms of time and materials were also proposed to help the company's decision-making centre.

The proposed solutions were analysed using the Arena program, and the results of the analysis were shown. The solutions resulted in a substantial decrease in non-value-adding time from 5.21 s and of value-added time of 2.26 s for each production cycle, and total scrap was reduced by 171,798 cans.

7.1.5 Heat recovery

In the current research, heat recovery is also included within the Lean Six Sigma framework. To address heat waste, a portion of the heat generated by the refinery chimney was converted to electricity using an ORC. Although the ORC has a lower efficiency than a conventional Rankine cycle, its ability to operate at lower pressure and temperature levels makes it a popular and fascinating alternative for the production of electricity from low-quality waste heat sources.

A MATLAB simulation was presented on the basis of the temperatures that come out of the refinery stacks. The results showed that 90 kW/h of the electrical energy can be saved. It is possible to use this energy, which was originally wasted, to light some of the refinery facilities or for heating, as needed.

7.2 Contributions of the Research

This study widens the limited quantity of research presently available on oil and gas industry-related topics. It also adds to the limited quantity of empirical evidence determining the influence of lean and Six Sigma methodologies on oil and gas industry performance. Consequently, this study contributes to academic work that seeks to develop a conceptual model that supports valuing the environment and effective quality management methods for performance in projects connected to the oil and gas sector and that contribute to reducing waste. There have been few attempts to analyse the link between lean and Six Sigma methods and performance in oil and gas industry-related projects and establish conceptual frameworks for evaluating performance in the oil and gas sector.

This study contributes by developing a framework for activating lean and Six Sigma methods in the oil and gas industry and using the findings of semi-structured interviews with a diverse variety of stakeholders. A survey of the literature should also contribute to a larger and more thorough examination and understanding of the many lean and Six Sigma approaches that could have an impact upon and enhance oil and gas industry performance.

The development of an environmental management framework for sustainability in Libya's oil and gas industry produced results that were presented, analysed, and applied to the study. For this stage of the study, both qualitative and quantitative results were employed, and survey respondents were enlisted to examine the final findings. The data and the survey respondents were analysed in order to highlight and confirm the influence of lean and Six Sigma practices on performance and waste reduction in the aspects of the production of waste and heat waste in projects related to the oil and gas industry.

7.3 Limitations of the Study

The goal of the study was to better understand how Lean Six Sigma techniques were used in Libyan projects pertaining to the oil & gas production. This thesis has a amount of constraints, much like any other research work, the most of them are related to the size of the subject under investigation. Due to the fact that the second half of this study involved empirical research, there were additional limitations in terms of time, informational accessibility, generalizability, and other resources. This makes it crucial to take into account several restrictions, which are elaborated on in the following sections.

- The data gathered and used to validate the models and framework came from a single industrial sector due to a lack of relevant resources and references. Nonetheless, the relatively large samples of data acquired from a credible target group offer reliable data for confirming the study.
- While there have been some publications regarding Lean Six Sigma and waste production, few have been published specifically about oil and gas industry-related initiatives. Little information is available on this subject.
- The scope of the research was restricted to one refinery in the oil and gas sector due to the availability of connections inside the firm that allowed the distribution and collection of survey questionnaires.
- The upstream portion also employs waste management to attain its objectives. When considering that the characteristics of the oil and gas segment are completely distinct from those of the downstream, further study is necessary.

7.4 Recommendations for Future Studies

The research improved the quality performance of an oil and gas company by using an integrated approach to quality management. Even if the framework and models now have a lot of novel features and methods, the following important recommendations for further research are still within the purview of this thesis:

- Further enhancements could be added to the framework functions and phases, notably in terms of regulating and maintaining the potential gains.The industrial character of this industry necessitates additional study to examine how Lean Six Sigma practises affect all quality performance-related disciplines.
- By utilizing the framework and the integrated models in oil and gas industry practice, more research could be undertaken to evaluate its performance efficacy.

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Appendix:

1: ***Questionnaire***

Section 1 of 5

Evaluating the Framework of Environmental Impact on waste management in Oil and Gas industry

PARTICIPANT INFORMATION

I am a researcher at the University of Nottingham and currently conducting a survey on Novel Environmental Management Framework towards Sustainability in the Oil and Gas industry in Libya. This research examines ways of reducing the environmental impact of wastes and emissions from the oil & gas industry by waste managment Inside refineries.

It will take you approximately 15 minutes to complete the questionnaire. This is an important part of my work, and I would be very grateful if you could help. All information that you provide will remain confidential and no information will be shared with the employer, and other participants or individuals from the sector will not be informed that any individual participant has participated in or has not participated in the survey.

A. IMFORMED CONCENT: Do you consent to take the survey with you? *

- ◯ I agree
- ◯ I disagree

B. ATTESTATION: Imformation you provided will form part of the PhD research work, will be edited and and used for website presentation, it will be used for academic purposes, publications of comferences and journals, and for statistical analysis. The data collected will be stored in secured location in accordance with the university of Nottingham General Data Protection Regulation (GDPR) guideline. (https://www.nottingham.ac.uk/utilities/privacy:information-for-students-and-applicants.aspx). *

- Yes
- No

C. DECLARATION: I declair that the information provided is my views and not the views of other persons *

- I agree
- I disagree

Section 2 of 5

Main questions

This section of the survey is to present a clear picture of the respondent's background and understanding the level of LSS awareness or another quality program. This part of the survey seeks to provide an understanding of your involvement in Six-Sigma and Lean tools and techniques that have been used in your company or used by you and how useful these tools to business for Oil and Gas industry .

What is your position within your company?

- Operational Manager
- Technical manager
- Quality Manager
- Project Lead

What is your company's existing quality management system?C

- ISO Series
- Lean
- Six sigma
- Lean Six sigma
- TQM

How long have you been using the Lean and/or Six-Sigma approaches?

- ◯ 6 months or less
- ◯ 1-2 years
- ◯ 2-5 years
- ◯ 5-10 years+
- ◯ Option 6
- ◯ Never used Lean and/or Six-Sigma
- ◯ Other...

Do you utilise any of these Lean Six Sigma Management tools?(Tick as you consider appropriate)

	not used	Used only once	Used rarely	used frequently	commonly used
Pareto Analysis					
Value Stream ...					
5S methods					
Total Productiv...					
Design of Expe...					
Brainstorming					
Kanban					
Cause-and-effe...					
Poka-yoke					
Kaizen events					
Failure mode e...					
Process capab...					
SIPOC (supplie...					
PERT chart (pr...					
Cause and Effe...					
Statistical Proc...					
PDCA (plan, do...					
ANOVA					
Process flowch...					
Key Performan...					

Which of these Lean and/or Six Sigma tools are beneficial to your company?

	Not useful	Less useful	Moderate	Useful	Very Useful
Pareto Analysis	○	○	○	○	○
Value Stream ...	○	○	○	○	○
5S methods	○	○	○	○	○
Total Productiv...	○	○	○	○	○
Design off Exp...	○	○	○	○	○
Brainstorming	○	○	○	○	○
Kanban	○	○	○	○	○
Cause-and-effe...	○	○	○	○	○
Poka-yoke	○	○	○	○	○
Kaizen	○	○	○	○	○
FMEA Failure ...	○	○	○	○	○
Process capab...	○	○	○	○	○
SIPOC (supplie...	○	○	○	○	○
PERT chart ((pr...	○	○	○	○	○
Cause and Effe...	○	○	○	○	○
Statistical Proc...	○	○	○	○	○
PDCA (plan, do...	○	○	○	○	○
ANOVA	○	○	○	○	○
Process flowch...	○	○	○	○	○
Key Performan...	○	○	○	○	○

What is the perceived benefits that your company can reap from implementing an integrated Lean-Six Sigma framework? Please rank from the lowest benefit to the highest benefit from 1 to 5 (1 – Very Low 2 – Low 3 – Moderate 4 – High 5- Very High)

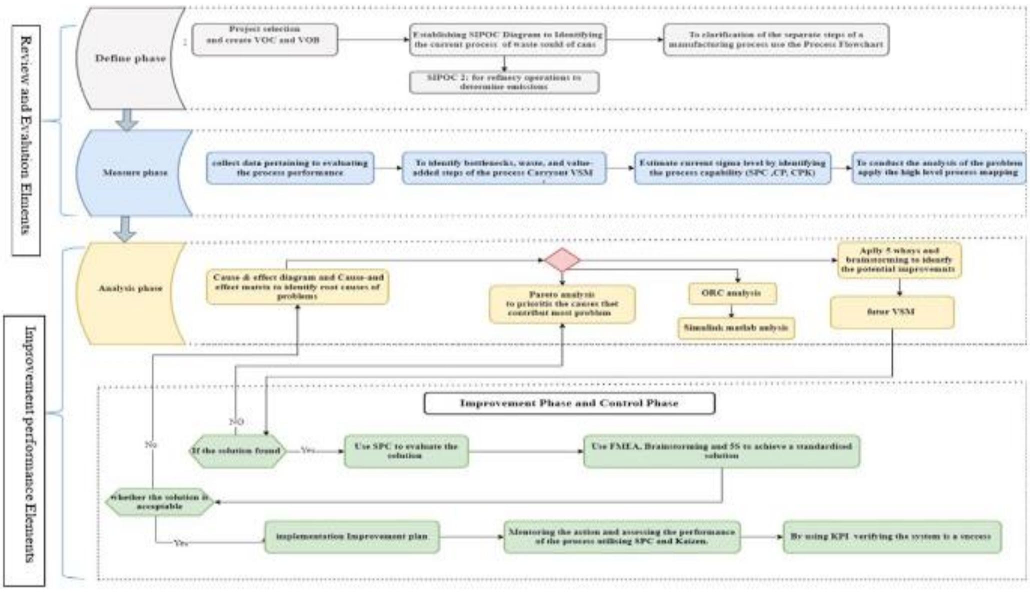
	1	2	3	4	5
Customers satisfaction	○	○	○	○	○
Reducing quality problems (defects and	○	○	○	○	○
Cultivate the quality concepts and awareness	○	○	○	○	○
Improved productivity	○	○	○	○	○
Emphasising on continuous	○	○	○	○	○
Increasing profits and reducing the cost of	○	○	○	○	○
Organised working environment	○	○	○	○	○
waste reduction	○	○	○	○	○
Enhancing the organisation's	○	○	○	○	○

Section 3 of 5

Give your comments on the Lean- Six Sigma framework to evaluate the proposed framework for your company.

This section of the survey seeks to evaluate the proposed Lean-Six Sigma framework for Oil&Gas companies by giving comments on the questions. It aims to provide an understanding of basic Lean-Six Sigma tools and implementation procedures that are suitable for Oil and Gas Company and identify possible difficulties in implementing the proposed framework.

Lean Six Sigma Framework-DAMIC cycle



Do you agree with the precedence In the use of tools (structure)?(Tick as you consider appropriate)

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

Is it easy to understand this proposed framework?

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

What is the degree to which you agree this proposed framework is relevant to appropriate for your company?

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

Do you anticipate any challenges in implementing Lean-Six Sigma in your company using the suggested framework?

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

Do you have any suggestions for improvement?

Short answer text

Critical Success factors for Lean-Six Sigma

The purpose of this section of the survey is to get an awareness of the important critical factors that are required for the effective implementation of Lean-Six Sigma in Oil and Gas companies as well as the possible hurdles that may hamper the process of adoption.

Please rank the relevance of these important critical success factors in implementing Lean-Six Sigma to wards sustainability success in your company.

	Not important	Slightly import...	Quite Important	important	very important
Education and training					
Good Communication on all Levels					
Linking LSS to organisation's business strategy					
Monitoring and evaluation of performance					
Understanding of processes					
Clear Vision of Business plan					
Clearly definde goals					
financial capability					

Please indicate to what extent these factors will impede the implementation of Lean-Six Sigma and to achieve sustainable benefits.

	Very Low	Low	Moderate	High	Very High
Internal resistance	◯	◯	◯	◯	◯
Decision making	◯	◯	◯	◯	◯
Availability of Resources	◯	◯	◯	◯	◯
Changing business focus	◯	◯	◯	◯	◯
Lack of corrective action	◯	◯	◯	◯	◯
Poor training	◯	◯	◯	◯	◯
Lack of Tools-knowledge	◯	◯	◯	◯	◯
Lack of calibration of machines	◯	◯	◯	◯	◯
Bad specification of material	◯	◯	◯	◯	◯

Section 5 of 5

Thank you for Participation

Please do not hesitate to contact the research team if you have any questions regarding this questionnaire or would want additional information about the study.
Yours Sincerely

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