FACTORS CONTRIBUTING TO DISASTER RISKS REDUCTION IN TRANSPORTATION OF PETROLEUM PRODUCTS IN KENYA

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A research thesis submitted in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Disaster Management and Sustainable Development of Masinde Muliro University of Science and Technology

May, 2024

DECLARATION AND CERTIFICATION

Declaration by the Candidate:

I hereby declare that this thesis is my original work and that, to the best of my knowledge, nobody else has ever presented similar work in any other institution for a degree or any other award.

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The undersigned certify that they have read and hereby recommend for acceptance of Masinde Muliro University of Science and Technology a thesis entitled "**Factors Contributing to Disaster Risks Reduction in Transportation of Petroleum Products in Kenya**"

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DEDICATION

This thesis is dedicated to my wife, Dorcas Mojisola Oguntoyinbo, and my late supervisor, Professor John Obiri, who continued to support me up till his last, even when I almost quit the study several times. He contributed immensely to the completion of this research. I also dedicate it to Professor Samuel China, who encouraged me to continue, in honour of the memory of his late colleague.

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God bless you.

ABSTRACT

Over the past decades, there has been enormous increase in the number of disasters in the global petroleum industry. At a continental level, Africa has experienced many disasters in the downstream sector of the industry. Kenya has had its share of disasters in the petroleum industry, with a number of these occurring during transport of petroleum products. These disasters resulted in several fatalities, injuries, suffering to families, loss of assets and damage to the environment. It is of concern that the underlying causes of some of these disasters may not have been fully established, and this has resulted in recurrence of similar disasters. In some countries in Africa, disasters during transportation of petroleum products by road tankers have become a regular phenomenon. The overall objective of this research is to examine factors that contribute to disaster risks reduction (DRR) in the transportation of petroleum products in Kenya, with the aim of designing most effective ways of preventing disasters. The specific objectives include identification of factors influencing disaster risks during transportation of petroleum products in the study area, analysis of root causes of the disasters, and evaluation of strategic options for sustainable management of the industry. Research designs adopted included: descriptive survey for identification of factors influencing disaster risks during transportation; correlation for analysis of the root causes of the disasters, and evaluative design in the analysis of strategic options for sustainable management. The analysis of the root causes of the disasters was anchored on the Tripod Beta methodology, which is an investigation tool that identifies human causal elements of accidents in a structured way, with the aim of improving the working environment, and thereby minimize human errors that lead to disasters. A survey was carried out via questionnaires, using simple random sampling, with a sample size of 391 tanker drivers. Interviews were held with tanker drivers, managers of transporters, staff of petroleum marketing companies, and industry regulators. Analysis of the questionnaires revealed that, whilst tanker drivers play a critical role in prevention of disasters during transport, due consideration was not being given to their suitability prior to employment, as some of them lack experience and understanding of rules associated with industry operations. The drivers have inadequate awareness that disasters can be prevented through compliance with rules. The study revealed that tanker drivers in the 30 – 40 years age group stood out as causing least accidents, lowest oil spills and lowest injury rate. In addition, drivers with experience between 6 to 10 years had the least accident rate, as well as drivers that had secondary education level. This research therefore recommends that minimum age of tanker drivers should be set at 30 years, with minimum driving experience of 6 years, and educational level of secondary school certificate. The transporters need to focus more on competence improvement of their managers, to be able to provide support to drivers to imbibe the mindset that all accidents can be prevented. Managers can contribute to improving the work environment, which will motivate the drivers towards compliance naturally, when they believe it is for their good. It is recommended that an "Adopt-A-School" scheme for tanker drivers be established, enabling the drivers to disseminate awareness about dangers of petroleum products in the society. A public awareness program by government at all levels is also recommended, through use of print and electronic media, to enlighten society about the risks.

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LIST OF ABBREVIATIONS/ACRONYMS

BRFs	Basic Risk Factors
BRV	Bulk Road Vehicle
CNA	Clean Nigeria Association
DM	Disaster Management
DMC	Disaster Management Committee
DPR	Department of Petroleum Resources (Nigeria)
DRR	Disaster Risk Reduction
EPRA	Energy and Petroleum Regulatory Authority
ETSC	European Transport Safety Council
FPSO	Floating Production Storage and Offloading
GFTs	General Failure Types
HFA	Hyogo Framework for Action
HSSE	Health, Safety, Security and Environment
ICAM	Incident Causation Analysis Model
IDNDR	International Decade for Natural Disaster Reduction
ISDR	International Strategy for Disaster Reduction
IVMS	In-cabin Vehicle Monitoring System
KPC	Kenya Pipeline Company
LOT	Large-sized Oil Transporters (haulage companies with over 50 road tankers)
MOT	Medium-sized Oil Transporters (haulage companies with 10 – 49 road tankers)
NACOSTI	National Commission for Science, Technology and Innovation
NEMA	National Environmental Management Agency (Kenya)

NGOs	Non-Governmental Organizations
NTSA	National Transport Safety Authority
OBC	On-board Computer (used in vehicles/trucks)
OFTs	Organisational Factor Types
PAR	Pressure and Release (PAR) Model
PIEA	Petroleum Institute of East Africa
SNEPCO	Shell Nigeria Exploration & Production Company
SOT	Small-sized Oil Transporters (haulage companies with 1 – 9 road tankers)
TM	Tripod Methodology
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNISDR	United Nations International Strategy for Disaster Reduction

OPERATIONAL DEFINITION OF TERMS

Bowtie Technique: a risk evaluation method that can be used to analyse and demonstrate causal relationships in high-risk scenarios. It identifies hazards, risks and controls to prevent disasters

Bulk Road Vehicle (BRV): a heavy goods motor vehicle designed to transport petroleum products in bulk, including gases (LPG).

Disaster Risks Reduction: reducing risks to as low as reasonably practicable

Downstream: include activities after production phase of petroleum oil and gas, starting from refinery process, through storage of products, transport and delivery to consumers at petrol stations or oil/gas processing plants.

Hazard: anything that has the potential to cause injury to person, negative impact on health, damage to environment or asset

Road Tanker: a vehicle designed to transport petroleum products, including gases. The road tanker, also referred to as Bulk Road Vehicle (BRV), comprises a truck cabin and a tank trailer that carries bulk liquid freight. The tank incorporates compartments, each with a manhole designed to resist opening in the event of a rollover. The compartments help with stability of the vehicle during its journey, to minimize heavy movement of liquids across the tanker. At the point of product loading, the process can be either top-loading or bottom-loading. For bottom loading, the tanker must have over-fill protection to prevent spill over. Each tanker must have an over-pressure protection, through use of pressure relief valves, to prevent pressure build-up during transportation, due to changes in temperature.

Safety Case: a document produced by the operator of a facility, documenting hazards, risks and controls required to prevent serious accidents/disasters

Sustainable Development: Meeting the needs of the present, without compromising the ability of future generations to meet their own needs

Upstream: oil/gas production is conducted by companies who identify, explore, extract, and produce crude petroleum oil and gas. The activities are often called Exploration and Production.

Well blowout: uncontrolled release of hydrocarbon from a wellhead during drilling or operations of the facility

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

The petroleum industry carries significant hazards that must be managed to protect lives, health, the environment, assets and reputation of the industry. By the chemical nature of the products and by-products of the industry, explosive atmospheres occur wherever products are released. Uncontrolled release of the products has led to disasters in the past, not least being products inadvertently released during transportation. Through investigations into causes of disasters, lessons can be learnt to prevent recurrence. Innovative investigation tools exist in the industry, and they can be applied in a proactive manner to significantly reduce the risk of disaster recurrence, with the overall goal of elimination.

The last 60 years have witnessed a dramatic increase in both the frequency and severity of natural disasters, a significant percentage of which have been due to climatic change and global warming (Kunreuther & Michel-Kerjan, 2011). During the same period, there has been concurrent increase in the frequency of industrial and other man-made disasters within the petroleum industry (Park, 2012). These disasters resulted in high numbers of casualties, deaths, environmental damage and severe economic losses. In 1988, the Piper Alfa platform explosion in the North Sea, which resulted in death of 167 persons, and loss exceeding $3 billion, is considered one of the worst disasters in the petroleum industry worldwide (Pate-Cornell, 1993). In Africa, there has been almost an annual incidence of disasters in the petroleum industry, resulting in several fatalities, including damage to assets and the environment. It has been observed that a high number of these disasters in the African petroleum industry occurred during road transport of petroleum products. In August 2019, a petrol tanker carrying products exploded in the Morogoro region of Tanzania, killing more than 60 people in the neighbourhood (DW news, 2019)

In Kenya, the Sachangwan road tanker explosion disaster of 2009 is considered one of the worst in the country (Omuterema, et al., 2009). Other incidents have occurred during transportation of petroleum products in the country, with lesser consequences. More recently, 13^{th} February 2022, an explosion occurred near Mutarakwa Shopping Centre on the Mai Mahiu – Nairobi highway, when an LPG tanker was involved in a road accident, subsequently leading to release of petroleum gas and explosions (Kenya.co.ke news, 2022). Fortunately, there was no fatality from this disaster, though several vehicles were destroyed, and the environment severely impacted. Therefore, it is of concern that the root causes of these disasters may not have been fully understood, given the frequent recurrence.

Researchers have suggested that it is crucial to anticipate the next possible disaster, and not merely seek to avoid repeating the most recent one. Such an approach would differ from the current path of reactive reform, to a proactive one. Lessons learnt from past disasters can be applied proactively, through review of standards, procedures and guidelines, to avert future disasters. Legislative reform, and industry standards reviews, in the wake of disaster, inevitably and appropriately must begin from the contours of the immediate problem. It is hard enough to determine how to prevent identical mistakes from happening in future, and virtually impossible to predict the precise contours of the next tragedy that may occur (Flournoy, 2011). This emphasises the importance for investigation tools that would not only identify root causes, but also

DRR opportunities that could anticipate and prevent the next disaster. Afterall, the focus of disaster management should be on prevention, rather than reactional response.

Several tools are available for incident investigations, some of which are reviewed in the literature survey of this study. The tools include Root Cause Analysis, Fishbone diagram, Tripod Beta Methodology, etc. Whilst the tools aim to identify root causes of accidents, the acceptance of inevitability of human errors in accidents and disasters must be appreciated (De Landre et al., 2006). Therefore, addressing human causal elements of disasters should become a key aspect of DRR in the petroleum industry. Social scientists who study human-caused disasters emphasize that disasters cannot be understood purely in technical terms. Rather, disasters arise from an interaction between technological and organizational system failings. There is much to learn about preventing disasters from the work of social scientists who study the causes of disaster and how organizations can learn from disasters (Flournoy, 2011).

This study was initiated as a result of concern that past disasters that occurred in the petroleum industry may not have thoroughly investigated to reveal root causes, and appropriate recommendations may not have been put in place to prevent recurrence. When considered against the backdrop of the frequency of disasters that have occurred across the continent during road transportation of petroleum products, there seems to be inadequate research about initiatives to minimize associated risks. This study is expected to contribute towards developing initiatives that will prevent future disasters

1.2 Statement of the Problem

The frequency and severity of disasters in the petroleum industry in Africa have increased in recent times, leading to unimaginable losses, human suffering and negative impact on industry reputation. The disasters resulted in several fatalities, enormous impact on the health of victims, damage to the environment and assets. Of particular concern were disasters that occurred during road transport of petroleum products, and led to preventable loss of lives, sometimes exceeding hundred fatalities. This research was initiated based on the frequency of the disasters, and the fact that root causes of some of the disasters that occurred in Kenya may not have been properly understood, as there are very few empirical studies done on petroleum-based disasters (Mutugi, *et al.*, 2011). Most reports of petroleum disasters are media-based or government-led investigations, and have not adequately identified root causes of the disasters, nor the human causal elements. Hence, measures to prevent recurrence of disasters have not been fully addressed. This research investigated events and contributory factors that led to some disasters in the petroleum industry, and analyzed them in order to identify opportunities for risk reduction and sustainable management of the industry. Studies have shown that reckless driving and inexperience have contributed to road traffic accidents in the country (Shileche, 2012). For road transport of petroleum products, tanker drivers are critical stakeholders, who can contribute to, or prevent, accidents that lead to disasters. These drivers and their management were the focus of the study. This research was anchored on the Tripod Beta Methodology, which is an investigation tool that addresses human causal elements of accidents and disasters.

1.3 Research Objectives

The overall objective of the research was to examine factors that contribute to DRR in the transportation of petroleum products in Kenya, with a view of designing most effective ways of mitigating petroleum related disasters in the industry.

1.3.1 Specific Objectives

The study pursued the following specific objectives:

i) To identify factors contributing to disaster risks during the transportation of petroleum products in Kenya

ii) To examine the root causes of disasters during the transportation of petroleum products in Kenya

iii) To evaluate the strategic options for sustainable management of the transportation of petroleum products in Kenya.

1.4 Research Questions

i) What are the factors contributing to disaster risks during the transportation of products in the Kenya ?

ii) What are the root causes of disasters during the transportation of petroleum products in the Kenya ?

iii) What are the strategic options for sustainable management of transportation of petroleum products in Kenya ?

1.5 Significance of the Research

The petroleum industry contains hazards that need to be managed to avoid disasters, loss of lives, damage to assets and the environment. In the past, the industry has experienced disasters that have had catastrophic impact on host societies. With the adoption of the Sendai Framework for DRR (UN SF 2015-2030), and its predecessor, the Hyogo Framework for Action (UNISDR, 2004), the need to identify DRR opportunities that will prevent disasters has become more pressing. The petroleum industry and its regulators can learn from past incidents and disasters, with the aim of making the industry and society safer.

This study reviewed past disasters that occurred in the petroleum industry in order to identify practical ways of reducing risks. The aim is to help both operators and regulators establish policy, guidelines and procedures for disaster prevention. This study will contribute to academic research regarding application of incident investigation tools in a proactive manner to prevent disasters, including alignment and congruence with existing tools in disaster management. It also provides opportunities for further research on DRR in the petroleum industry. The results of the study will provide opportunities for better understanding of underlying causes of disasters, and how appropriate DRR strategies could be mainstreamed into guidelines for transportation of petroleum products in Kenya and other countries.

Key stakeholders that would benefit from the study include petroleum products marketing companies, haulage contractors involved in transportation of petroleum products, tanker drivers, the road transport industry, industry regulators and civil societies, in addition to contributing to scholarship. It will also contribute to reduction in the vulnerability of society, as well as making the industry more sustainable.

1.6 Scope of the Research

The research reviewed disasters that occurred in the Kenya petroleum industry between 2007 and 2022, and examined three disaster case studies, their impact and opportunities to eliminate future occurrence. Sites and facilities where the three disasters occurred were visited, to enable assessment of the spatial extent and environment. Parties interviewed during the research included officials of government and industry regulatory agencies, staff of companies within the petroleum industry, including contractors, associated government agencies, emergency response teams, appropriate members of the civil societies/NGOs, and families of victims of past disasters. Investigation reports of the disasters and other research materials from industry and educational institutions were reviewed to identify generic issues. Findings and recommendations from the study will be applicable across the continent of Africa and globally.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This section presents the literature review in three main areas. The first part reviews disasters that have occurred in the petroleum industry on a global and regional context, before reviewing those that happened in the Kenyan petroleum industry during the study period. The second part reviews current tools available for carrying out incident investigations, with the main objective of preventing recurrence of disasters. The third section highlights the key aspects of the incident investigation tool that was applied in identification of factors that contribute to disaster risk reduction and determination of root causes of accidents and disasters.

The increase in the frequency and severity of disasters are evidence of lack of resilience and sustainability of the current human environmental and industrial adaptations. Disasters occur at the interface of Society, Technology and Environment, and are basically the outcome of the interactions of these features (Oliver-Smith, 1996). When disasters occur, there is always wide coverage in the media, both print and electronic. Multiple causes that led to the disaster are presented in the media and opinion formed on the basis of news coverage and second-hand information. Sometimes, government initiates an investigation into the disaster with the aim of finding out lessons, but there has been a shortage of published reports of the investigation. Over time, society forgets about the disaster, until the next one. In the petroleum industry, there have been very few industry-led investigations into disasters. This highlights the need for research into past disasters by academia, and effective collaboration with the industry to develop robust DRR initiatives that will prevent future disasters and make society more resilient.

2.2 Disasters in the Petroleum Industry

The petroleum industry is a relatively high-risk industry, with attendant risks of explosion, fire, environmental devastation, severe health impact, etc. Petroleum products are usually highly explosive, and have long-term health and environmental impacts. Therefore, the exploration, production and transport of petroleum crude oil, including refinery, storage and handling of petroleum products are hazardous activities, which have to be managed in a safe manner to prevent disasters. Within the petroleum industry, health, safety and environment (HSE) is a critical area that demands top management attention, to set strategic directions that would mitigate risks in the business. Unfortunately, there has been a long history of disasters in the industry, and it has continued to this day, with high number of fatalities, injuries, damage to health, environment and assets, not to mention impact on the reputation of the industry.

2.2.1 Overview of Global Petroleum Industry Disasters

During a heavy storm on 27th March 1980, one of the bracings attached to the Alexander L. Kielland, a Norwegian semi-submersible platform, failed whilst drilling in the North Sea, resulting it to capsize, with 123 fatalities, out of the 212 workers on board. It was Norway's worst disaster since World War II (France, 2019). Indirectly related to the petroleum industry, the Bhopal Union Carbide chemical plant disaster that occurred in India in 1984 resulted in over 3,000 deaths, over 350,000 injured, an estimated $900 million loss of stock, and over $470 million to settle litigations (Tattum, 2012). As a result of this disaster, the international Union Carbide company incurred enormous loss of economic value, and was subsequently sold out. The Piper Alfa platform disaster that occurred in 1988 also in the North Sea (UK) is considered one of the worst disasters in the petroleum industry, with 167 fatalities and an estimated asset loss that exceeded $3 billion (Pate-Cornell, 1992).

In addition to these safety-related disasters, several marine oil spills have taken place over the years, with severe environmental impact. The *Torrey Canyon* super-tanker crude oil spill that occurred in March 1967 off the coast of Cornwall England, was considered one of the worst marine spills at that time, with a loss of over 31 million gallons of crude oil, causing a slick that covered over 270 square miles (Causley, 2013). On 16th March 1978, the *Amoco Cadiz* tanker spill occurred off the coast of France, spilling more than 67 million gallons of crude oil, and resulting in an ecological disaster (Science News, 1978). A well blowout occurred on an exploratory well, Ixtoc-1, at the Bay of Campeche, off Ciudad del Carmen, Mexico in June 1979. Though no initial reports of deaths or injuries, all efforts to cap the well and stop the spill failed for several months, and two new wells were subsequently drilled to divert the flow of oil into tanker ships. By the time the well was brought under control in 1980, an estimated 140 million gallons of oil had spilled into the bay (Congress Digest, 2010). The tanker *Exxon Valdez* oil spill that occurred in Alaska in 1989, with between 11 and 32 million gallons of crude oil spilt, cost over $2.5 billion in clean-up costs alone (Haycox, 2012).

Just one month after Mexico's Ixtoc-1 disaster, two super-tankers, Atlantic Empress and the Aegean Captain, collided off the coast of Tobago in Caribbean, resulting in a spill of over 90 million gallons into the sea. A thunderstorm had thrown the Atlantic Empress of course, into the path of the Aegean Captain. Both tankers were carrying crude oil, and multiple explosions were heard immediately after. The number of fatalities from the incident stood at 26 crewmembers from the Atlantic Empress, and one from the Aegean Captain (Gillis, 2011)

On 2nd March 1992, a massive oil spill occurred in the Mingbulak oil field in Fergana Valley in Uzbekistan. It is still the largest inland oil spill in history, with over 88 million gallons spill. The spill resulted from a well blowout in the field, and the oil coming out of the well later ignited, which burnt for another two months until the oil well became dry (Squillace, 2001).

Apart from the foregoing spills, there have been a number of explosion incidents, fire disasters and well blowout in the industry. An explosion occurred on 23rd July 1984 at the Union Oil Company Refinery in Romeoville, Illinois-USA, resulting in the death of 17 employees, 10 members of the fire brigade, and an estimated asset damage exceeding $500 million. On 19th November 1984, explosions occurred in a Liquefied Petroleum Gas (LPG) tank farm in San Juanico Mexico, resulting in between 500 – 600 deaths, and estimated 5,000 - 7,000 people suffered severe burns. The incident caused devastation in the city of San Juanico, and it is recorded as one of the deadliest disasters in the world. It is also recognised as the worst LPG disaster in history (Arturson, 1987). On 23rd March 2005, 15 workers were killed and 180 injured in a series of explosions and fires during start up at the BP Refinery in Texas City, USA. And in 2010, the Deep-Water Horizon rig in the Gulf of Mexico suffered a blowout and 11 people were killed, with the incident unleashing an oil slick of up to 4.9 million barrels over an area of 68,000 square miles (Park, 2010). The three companies involved in the disaster, BP, Transocean and Halliburton, have agreed to pay huge sums of money in settlement. BP agreed to pay a settlement cost of $18.7 billion (Cason, 2015). The petroleum industry is still reeling from the fallout of these disasters.

The1988 Piper Alpha disaster was investigated by a panel led by Lord Cullen, and one of its recommendations led to the legislation requiring the preparation of a Safety Case at all petroleum facilities (Pate-Cornell, 1993). This legislation meant that operators have to run a safe operation, rather than simply meeting their legal obligations, as the Safety Case is meant to demonstrate that the operation is safe. The Safety Case has since become an integral part of petroleum companies' documentation to demonstrate that their facilities are safe for operations by their staff. In addition, it demonstrates that contractors, third parties and the host communities would not be exposed to undue risks from the operations of the companies.

2.2.2 Overview of Petroleum Industry Disasters in Africa

Whilst the African continent has been lucky not to suffer as many disasters in the petroleum industry, it has not been completely spared. On 28th May 1991, the ABT Summer tanker exploded in Angola, and leaked between 260,000 Tonnes of oil into the sea. In addition to the leak, five crewmembers died from the incident (ITOPF, 1991). The oil industry in Nigeria has been beset by several oil spill incidents, which have contributed to an ecological disaster in the Niger Delta area of the country. However, these spills cannot be attributed to the operations of the oil industry alone, as the 1967-1970 Biafra war also resulted in the damage of some oil/gas facilities, for which the clean-up activities for polluted groundwater aquifers are still ongoing several decades later. In 1993, a well blowout occurred in Orogo in Delta State, Nigeria, resulting in loss of well control and release of more than 10 million gallons of oil to the environment (Obi, 2012). Late December 2011, there was an oil spill from the Shell Nigeria

Exploration and Production Company (SNEPCo) Bonga's Floating Production Storage and Offloading (FPSO), resulting in a spill of just less than 40,000 barrels (1.7 million gallons) of crude oil (Offshore Energy, 2019).

In addition to environmental devastation caused by oil spills on the African continent, there have been several pipeline explosion/fire incidents that resulted in loss of lives. For example, in May 2006, there was a petroleum pipeline explosion in Ilado, Lagos-Nigeria, resulting in the death of 200 people (Arab News, 2022).

On 1st June 2015, a road tanker transporting Premium Motor Spirit (PMS), popularly called petrol, crashed into a busy bus station in Onitsha, resulting in the death of over 60 persons, injuries to many more people in the locality, and damage to assets and the environment (BBC News, 2015). There was another road tanker disaster in Onitsha-Nigeria on 16th January 2019, resulting in the death of a mother and her child, with several buildings and shops engulfed by the inferno hundreds of meters away (Premium Times, 2019). Again, on 28th January 2022, another road tanker rolled over in Onitsha-Nigeria, spilling PMS that caught fire and razed over 40 shops in the area (Guardian News, 2022). It has been observed that incidences of road tanker explosion have become a regular occurrence in Nigeria, and some other African countries.

On 10th August 2019, a petrol tanker carrying products exploded in the Morogoro region of Tanzania, killing more than 60 people. It occurred when the driver of the tanker was travelling on the main road near the Msamvu bus station, and was trying to avoid a motorcyclist. In the process, the tanker driver lost control and the tanker rolled over. The crash attracted a large crowd to the scene, and when they noticed the product leaking from the tanker, some of them rushed to get buckets and containers to pilfer the fuel. Whilst doing this, there was a large explosion with several fatalities and injuries (DW, 2019).

2.2.3 Petroleum Industry Disasters in Kenya

The Kenyan petroleum industry has also experienced a number of disasters. In 2009, a petroleum tanker that was transporting petrol rolled over whilst travelling to Southern Sudan. The rollover was followed by pilferage of petrol by members of the community where the accident occurred. The pilferage subsequently led to product spill and a gas cloud, followed by an explosion that resulted in over 120 fatalities. In June 2011, there was also an explosion in a Nairobi petrol station, resulting in four fatalities and injuries to over 60 persons in the surrounding vicinity of the station. In September 2011, the Sinai petroleum disaster occurred, resulting in over 75 fatalities and destruction of houses and assets along the banks of Nairobi River in the Industrial Area in Nairobi, Kenya. There have been other disasters in the industry. There was a road tanker explosion on 18th July 2021 in Siaya-Kenya, after a motor accident involving the tanker which rolled over, and inhabitants started to pilfer fuel from the leaking road tanker. Initial reports indicate there were 13 deaths, with another 24 victims in hospital from injuries sustained from the explosion and resulting fire (BBC News, 2021). There have been other petroleum industry related disasters in Kenya.

More recently, on 13th February 2022, an LPG road tanker, involved in an accident along Nairobi-Limuru highway, exploded and fire subsequently engulfed three other trucks and six cars (Standard News, 2022). This research is aimed at identifying opportunities for reduction of associated risks and prevention of recurrence.

Table 2.1 presents a list of some of the petroleum industry disasters that have occurred in Kenya in the last fifteen years.

Table 2.1: Disasters in the Petroleum Industry in Kenya

Year	Disaster
2007	Tanker accident along Salgaa Road, followed by explosion/fire, with 7 deaths
2009	Tanker transporting fuel rolled over near Sachangwan, pilferage of products, resulting in over 130 fatalities
2011	Oil spill in Nairobi Sinai area, leading to massive fire during siphoning of product, with at least 75 people killed and over 112 badly burned
2011	Explosion occurred at a Nairobi petrol station, with over 6 deaths and several injured
2013	An explosion occurred in an illegal LPG filling plant in Nakuru; one person died
2016	Tanker accident at Karai on the Nairobi – Naivasha highway, with 30 fatalities
2021	An explosion occurred after a road tanker involved in an accident in Gem, Siaya County, rolled over, exploded caught fire. 13 fatalities were reported.
2022	An LPG tanker travelling on Nairobi – Limuru highway was involved in an accident, followed by explosion, and fire engulfing other vehicles in the area.

Source: PIEA (2022)

2.3 Downstream Petroleum Sector

The petroleum industry can be classified into two broad sectors: upstream and downstream sectors. The upstream Sector covers exploration, drilling, and production of crude petroleum oil or hydrocarbon gas. In general, upstream companies discover deposits of crude oil. Upstream activities are followed by transportation of crude oil/gas through several options, which include pipelines, sea-going vessels, rail or road tankers (Investopedia, 2022). The downstream sector starts from the receipt of crude oil at the refinery, through processing of crude and purifying of raw natural gas, as well as marketing and distribution of products derived from the crude oil and natural gas. It includes transport of petroleum products to storage facilities, distribution of the products and eventual receipt by the end-users. The transport of petroleum products could be through pipelines, road tankers or sea-going vessels and water barges. Given the hazardous nature of the petroleum products, risks exist of fire, explosion, spills, damage to the environment and health of people during operations of the facilities. Ewbank et al (2019) revealed 94% of global deaths from road tanker accidents occurred in low- and low-middle-income countries (LMIC), which may largely be due to scooping or pilferage of products. Hence, a high proportion of the disasters occur in Africa. This study considered three key sub-sectors of the downstream petroleum industry, i.e., bulk oil storage and distribution terminals; oil transportation via bulk road vehicles; and oil storage/sale points at petrol stations.

2.3.1 Bulk Oil Storage and Distribution Terminals

On refinery of crude oil, petroleum products are stored in terminals, from where they are distributed to other facilities in the supply chain. The products can be distributed through pipelines to other depots or transported by road tankers, called Bulk Road Vehicles (BRV). A BRV can transport a minimum of four thousand and five hundred litres of petroleum products (Law Insider, 2022). In areas where there are marine facilities, the petroleum products may be transported by sea-going vessels, to depots for storage and further distribution down the supply chain. The volume of products stored in bulk storage & distribution terminals can vary from hundreds of thousand litres to millions of litres, resulting in a high volume of product that must be managed to avoid exposure to sources of ignition or environmental damage arising from spills.

2.3.2 Oil Product Transportation via Bulk Road Vehicles

Transportation of oil products by BRV is a critical part of the distribution chain to end-users. Road transport forms the major linkage between the depots and the bulk consumers and retails outlets. The cost per unit of transporting the products by road depends both on the road distance and BRV in use (Obasanjo & Nwakwo, 2014). The volume of product BRV can transport can vary from about 4,500 to 33,000 litres, depending on the size of the trailer, tank and the number of compartments per tank (Law Insider, 2022). The BRV needs to meet minimum technical specifications that would ensure the product is not released to the environment, nor constitute risks to other road users and the community, in the event of a road traffic accident. The technical devices/specs required to achieve these goals include spill-proof manholes, non-leak valves, spark arresters, pressure relief valves, number of tank compartments to guarantee stability of truck, etc.

2.3.3 Oil Product Storage & Sales at Petrol Stations

The key interface facility through which the public procures oil products, for energy, transport, commercial or domestic means, is the petrol station. It is the place where refined petroleum product is dispensed to consumers (Law Insider, 2022). The BRV delivers oil products to the petrol station, where it is stored in underground storage tanks and subsequently sold to the public via the pump bays. Significant quantities of oil products are stored at the station prior to sale, leading to risks of exposures to both the environment and the public at large.

2.4 Incident Investigation Tools

Technology plays an important role in the prevention of disasters, including those from natural hazards. Monitoring and early-warning devices will continue to play critical roles in the prevention, and minimization of the impact, of disasters. The environment is always impacted whenever there is a disaster, both from natural and industrial hazards. Among social sciences, two major paradigms have emerged about disasters (Gaillard *et al*., 2012). On the one side is the hazard paradigm, which asserts that people affected by disasters are those who fail to adjust because their perception of the risks associated with the hazards is insufficient. On the other side is the vulnerability paradigm, the more recent one, which asserts that disasters primarily affect those who are marginalised in everyday life and lack access to resources and means of protection that are available to others, who have access to power and resources. Both paradigms emphasize the need for DRR as an effective means for disaster management, rather than the traditional focus on post-disaster response. Academia has a duty to bridge the two paradigms by contributing to improvement in hazard awareness by society, and providing guidance towards formulation of legislation and policies that will minimize disasters and improve the resilience of society at large. Incident and disaster investigation can help towards that goal.

Whenever accidents and disasters occur in the petroleum industry, incident investigations are carried out to identify immediate and remote causes. In the past, attempts were made to reduce the frequency of disasters through correction of deficiencies that were identified. When a disaster occurs, the tendency is to identify the immediate causes of the event, without necessarily arriving at the root causes that would prevent recurrence. It is no surprise such shallow investigation technique has proven ineffective in the prevention of disasters. Instead of accident prevention programmes, the industry has been groping with "accident correction", by focusing largely on the correction of the immediate causes of the accident. The future trend is to use incident investigation tools to identify weaknesses in the safety culture of the organisation and vulnerability of the community, and use these to prevent future occurrence of disasters (De Landre *et al*. 2006). This is coherent with the DRR framework, whose goal is to prevent disasters. There are a number of tools available within the petroleum industry to investigate incidents and disasters, with the main objective of identifying the root causes of the incidents in order to prevent recurrence. Some of these tools are reviewed in this study.

2.4.1 Root Cause Analysis

Root Cause Analysis (RCA) is a systematic process that is used to address problems or identify the source of the problem. It identifies the root cause of the failure of the process, which when resolved will prevent recurrence of the problem (Connelly, 2012). An important aspect of RCA is the use of a structured approach to examine errors, and remove the focus on individuals when analysing the situations. It is not about looking for whom to blame, but rather focus on the underlying cause of the failure. This does not imply that people will not be held accountable for their actions, but the tool assumes that people are fallible, and can make mistakes, hence the focus will be on how to prevent errors. A systems approach is adopted in RCA, by examining how a particular system failed to produce the desired result, and how it led to the error, that is, accident or disaster.

There are two levels of problem causes, the physical (or direct) cause and the system (or latent) cause (Okes, 2008). The tendency is to stop the incident investigation at a level when the physical cause has been identified and corrected. Whilst this might suffice for minor incidents, if the consequence of the problem is high, it will be more appropriate to take the investigation to the system level. The system cause is the root cause of the problem or failure. It is the system cause (or latent cause) that actually allows the physical cause to occur (see Figure 2.1)

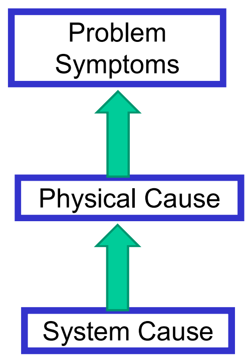

Figure 2.1: Levels of Causes of Failures

Source: Okes, 2008

RCA seeks to find causes that need to be addressed in order to prevent recurrence. The RCA has three major components:

1) Clear and complete problem definition that includes what the problem is, where and when it occurs and its magnitude
2) Identifying possible causes
3) Collecting and analysing data

2.4.2 Fishbone Diagram

The Fishbone diagram is another tool used in the analysis of direct and indirect factors involved in accident prevention. It provides a systematic way of understanding effects and their causes, with the aim of identifying root causes of accidents or failures (Kenkere *et al*., 2013). The design of the diagram looks like the skeleton of a fish; hence it is referred to as the Fishbone diagram. It is a graphical tool used to identify many possible causes for an effect, and explore all the potential or real causes that result in a single accident or disaster. The various causes are grouped into categories, and the causes cascaded from the main categories, flowing towards the effect (Li, *et al.* 2011). The generic cause categories of People, Method, Machine, Material and Environment can be used, as in the diagram (Figure 2.2).

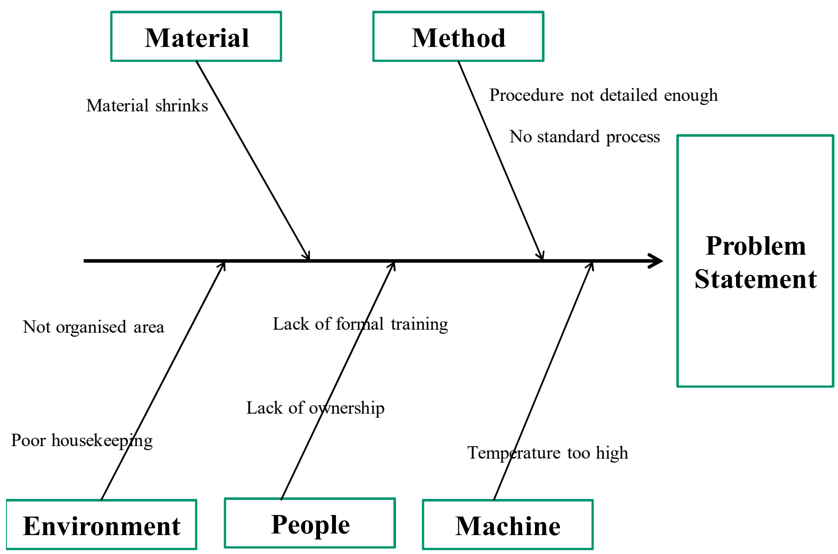

Figure 2.2: Fishbone Diagram

Source: Li *et al.,* 2011

2.4.3 Incident Cause Analysis Method

The principles of the Incident Cause Analysis Method (ICAM) were derived from the work of James Reason, an organisational psychologist and human error expert. During his tenure as Professor of Psychology at the University of Manchester, he studied on topics such as error and absent-mindedness, safety and error management in various industries, as well as cultural and organizational issues (Peltomaa, 2012). He developed a conceptual and theoretical approach to safety in large and complex organisations, with the acceptance of human error as being inevitable to accident causation, but it can be linked to the culture of the organisation. ICAM was initially developed by the international mining company, BHP, with assistance of James Reason, the Australian Transport Safety Bureau (ATSB) and in consultation with safety representatives from various industries (HSE International Group, 2020).

ICAM is a holistic systemic safety investigation analysis tool that aims to identify both local factors and failures within the broader organisation and productive system. It ensures that investigations are not limited to only errors and violations of personnel, but linked back to pre-conditions in the organisation and its culture that allowed the failures to happen. It identifies the local factors that contributed to the accident, and the latent hazards within the system and organisation (De Landre *et al.*, 2006). ICAM sorts out the findings of an investigation into a structured framework that allows the underlying issues to be identified in order to prevent recurrence. ICAM has the ability to identify root causes of the accident, and make recommendations on the prevention of recurrence. The ICAM Model of Accident Causation is shown in Figure 2.3.

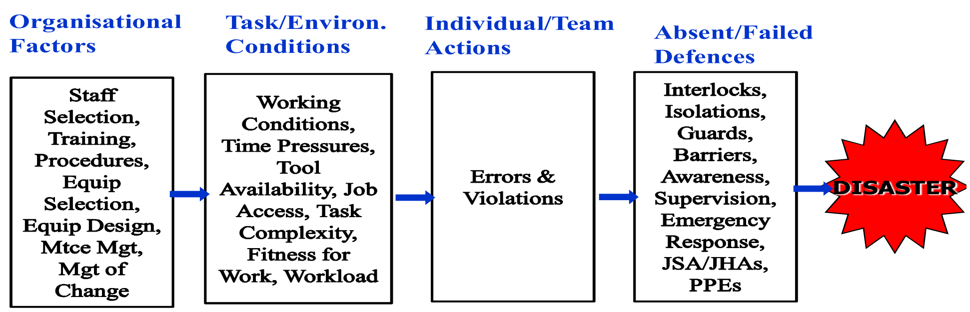

Figure 2.3: ICAM Model of Accident Causation

Source: De Landre et al., 2006

From Figure 2.3, it was observed the ICAM comprises 4 elements, which are briefly explained as follows:

1) **Absent/Failed Defences**: contributing factors from absent or inadequate defences that failed to protect the system against human and technical failures

2) **Individual/Team Actions**: Errors or violations that led directly to the incident

3) **Task/Environmental Conditions**: These are conditions that existed immediately before, or at the time of, the incident that directly influence human and equipment performance at the workplace

4) **Organisational Factors**: These are underlying organisational factors that produce conditions that affect performance at the workplace.

The ICAM classifies these factors into 14 Organisational Factor Types (OFTs) shown in Table 2.2.

Table 2.2: Organisational Factor Types

#	**Organizational Factor Type (OFT)**
1	Hardware (HW)
2	Training (TR)
3	Organisation (OR)
4	Communication (CO)
5	Incompatible Goals (IG)
6	Procedures (PR)
7	Maintenance Management (MM)
8	Design (DE)
9	Risk Management (RM)
10	Management of Change (MC)
11	Contractor Management (CM)
12	Organisational Culture (OC)
13	Regulatory Influence (RI)
14	Organisational Learning (OL)

Source: De Landre et *al.* (2006)

2.4.4 Tripod Incident Management Methodology

The Tripod Incident Management Methodology (TM) is based on further development of the ICAM. It uses both the "Swiss Cheese" model and human behaviour model to analyse the reasons for failure of a barrier that would have prevented the accident or disaster. In the "Swiss Cheese" model, an organisation's defences against failure are presented as a series of barriers, represented as slices of the cheese. The holes in the cheese slices represent individual weaknesses in individual parts of the system, and are continually varying in size and position in all slices until the holes line up and cause an accident, loss or disaster. TM recognises there are no perfect individuals or organisations, and weaknesses, represented by holes, will occur. The Swiss-Cheese model of accident causation describes how the various holes can line up and eventually cause an accident or disaster (Ren *et al.*, 2008). This implies that various types of failures in controls may have existed a long time prior to the disaster itself, but finally occurred when all the "holes" line up. The focus of TM is to prevent the holes (failures) from existing, instead of creating more barriers. The Swiss cheese model is presented diagrammatically in Figure 2.4.

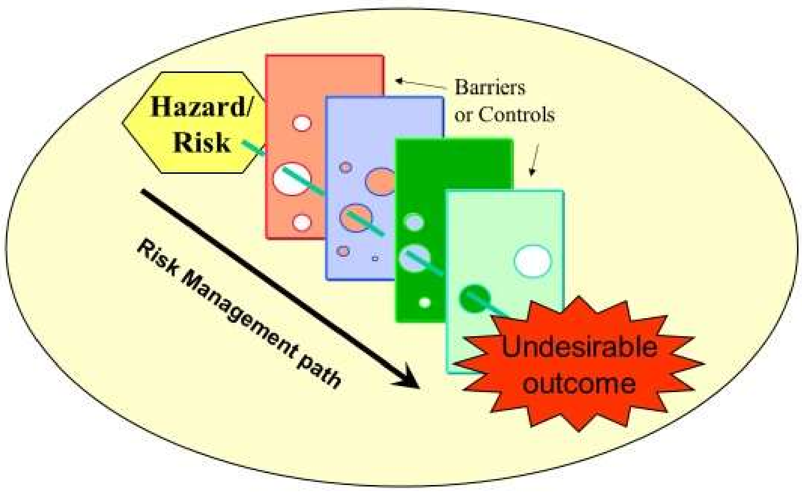

Figure 2.4: Swiss cheese Model for Incident Causation

Source: Energy Institute, 2015

Therefore, the TM theory of incident causation uses the Swiss cheese model to highlight failed barriers, in both organisations and individuals, which should have been in place to prevent the disaster or accident. However, rather than blame the individual who made the error, TM concentrates on logical analysis of the "error-inducing" systemic influences. It believes that minimizing human errors can be more effectively achieved by controlling the working environment (Energy Institute, 2015). In this manner, TM is perceived as being a more robust and practical tool than the ICAM. TM presents an accident or disaster as the intersection of a Hazard and an Object, and aims at preventing the intersection, i.e., the accident, from taking place. Through this technique, TM is more visual and easier to appreciate than other tools. It realises that human error is an important contributory cause in most accidents and disasters. Therefore, in highlighting barriers held in place by individuals on the paths of both Hazard and Object, to prevent their intersection, DRR is better appreciated. The elimination of human errors is a promising target to prevent disasters, and it can be achieved through the work environment. Research has shown that the prevention of human errors can be achieved through focus on the organisation and the working or living environment (Hudson *et al*., 1994). In disaster management, the hazard could be a natural hazard like flood, whilst the object could be the exposed community or the environment, for example, land, houses, roads, etc. In the petroleum industry, the hazards would include hydrocarbon gas or liquid, whilst the object could be people, equipment or the environment. It is the coincidence or intersection of the hazard and the object that results in disaster.

Most incident investigation tools deal with the chain of events and the barriers that failed, leading to the incident. However, TM deals with the analysis of the reasons for the failures in a structured manner that is both logical and visual, coming up with recommendations to prevent recurrence. As 90% of incidents have human causal elements, TM looks closely at the human nature, not with a view to change it, but to change the organisational environment or culture, and thereby influence the human nature. Figure 2.5 presents that accident/disaster causation path in the context of TM.

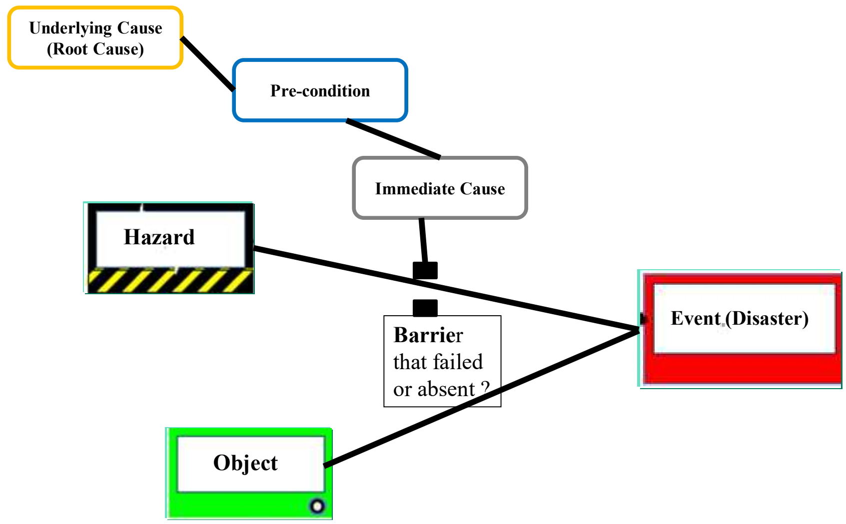

Figure 2.5: The Incident Causation Path in the context of Tripod

Source: Energy Institute, 2015

TM investigates the barrier that failed, or an absent barrier, that led to the accident. If an absent barrier, it investigates the immediate cause of the failed barrier, and human causal elements. Then it investigates the pre-condition within that organisation that contributed to the immediate cause, before arriving at the root cause or underlying cause, which is often the responsibility of management to address.

TM has re-classified the 14 Organizational Factor Types (OFTs) of ICAM into 11 General Failure Types (GFTs), which reflect the human causal elements of failures in organisations. TM was developed jointly by the Universities of Leiden and Manchester, and its key objective is to identify underlying causes, or root causes, that allow active failures to take place in an organisation, leading to disasters. The view taken by TM is that it is more effective to concentrate on the conditions defined by the GFT's rather than to attempt to stop unsafe acts that lead to accidents within an organisation. The GFT's behind the large numbers of unsafe acts and accident-triggering events form a natural and more limited set of targets for improvement to prevent disasters (Hudson *et al.,* 1994).

The GFTs used in TM, which are also called Basic Risk Factors (BRFs) are shown in Table 2.3. Whenever an accident investigation is carried out, all the identified root causes are classified into one or more of the 11 BRFs, These BRFs were well described by Akerboom & Maes (2006).

Table 2.3: Description of General Failure Types /Basic Risk Factors

No	General Failure Type (GFT) or Basic Risk Factors (BRFs)	Description
1	Design (DE)	Design of workplace, equipment, ergonomics
2	Hardware (HW)	Condition, suitability or availability of materials
3	Maintenance Management (MM)	Performance of maintenance, tasks and repairs
4	Housekeeping (HK)	Orderliness of working/storage area/location
5	Error Enforcing Conditions (EC)	Quality of physical work conditions, climate, physical and psychological conditions
6	Procedures (PR)	Usefulness and availability of procedures and instructions
7	Training (TR)	Quality of job-related training, competence or experience among team/group/workers
8	Communication (CO)	Quality and effectiveness of communications between individuals/team/group/company
9	Incompatible Goals (IG)	The way safety is managed against a variety of other goals
10	Organisation (OR)	Effectiveness of organisation's structure and processes
11	Defence (DF)	Quality of safety equipment/controls and contingency planning and procedures

Source: Akerboom & Maes (2006)

It has been shown that organisational conditions can contribute to human errors that lead to disasters (Ren *et al.,* 2008). Through its survey, this research investigated both human errors occasioned by tanker drivers, and organisational issues associated with transporters. In Chapter-4 of this study, human factors and organisational issues associated with tanker drivers were investigated and presented. Chapter-5 presents organisational issues associated with transporters and hauliers, the employers of the tanker drivers. Managers and supervisors have a key role to play in improvement of tanker drivers' performance and the belief that goal-zero, that is ability to drive without accident, injury or spill, is achievable. In Chapter-6, strategic options for sustainable management of the downstream petroleum industry are reviewed and evaluated, with focus on road transportation of petroleum products. The aim is to influence policy and trigger industry initiatives that will prevent future disasters in the industry.

2.5 Vulnerability within the context of the petroleum industry

With the introduction of the Sendai Framework for Disaster Risk Reduction (UN SF 2015-2030), which specifies that every country has the primary responsibility to prevent and reduce disaster risk, including through international, regional, and sub-regional cooperation, the concept of DRR becomes more critical. Each country is therefore expected to establish both local and national priorities towards the reduction of vulnerability as a key ingredient of building resilience. The main product of the petroleum industry is hydrocarbon, which is highly explosive and flammable upon release to the atmosphere. With increasing global demand for energy, and the petroleum industry currently contributing over 70% of the world energy demand, host communities have benefited significantly from the activities in terms of employment opportunities and economic growth through the development of associated industry. However, the communities have also become exposed to the hazards of the petroleum industry, which include environmental degradation, health risks and industrial disasters. Therefore, communities have faced increased vulnerabilities from the activities of the petroleum industry.

The study investigated gaps in DRR and the vulnerability of communities and workers, which contributed to past disasters. TM was considered an effective tool for incident investigations, and was used to identify the root causes of the petroleum industry disasters in Kenya and how to enhance DRR and sustainable management of the industry.

2.5.1 Vulnerability Concept

Vulnerability comprises the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of a community, workers or third parties to the impact of hazards (UNISDR, Hyogo Framework for Action, 2005-2015). Therefore, environmental vulnerability occurs when environmental factors increase the susceptibility of a community to the impact of hazards. The first step in any DRR scheme is hazard assessment, which identifies potential hazards the target community is exposed to and its vulnerabilities. Vulnerability assessments are an indispensable component to hazard assessment exercise. The DRR should analyse physical, social, economic and environmental vulnerability to hazards at the local level, with recommended actions to improve the resilience of the community to the identified hazards/threats. Vulnerability is hazard specific. Capacities are strengths and resources that are available within communities, which allow them to cope with, prevent, mitigate or quickly recover from disasters. Therefore, Vulnerability equals Hazard divided by Capacity. The higher the capacity of the community, the less vulnerable it is to a specific hazard.

2.5.2 Social Vulnerability

Political and economic issues often determine the social vulnerability of a society. For example, population growth, distribution and composition are some of the most important factors that have increased vulnerability of communities to disasters (Donner *et al.*, 2008). These demographic changes have exposed greater number of people to natural and industrial hazards. As a result of the activities of the petroleum industry, the social fabric of the host communities is always often impacted. Whilst on the one hand, the industry generates employment, the environmental, health and safety hazards necessitate that the vulnerability of the community is evaluated, and clear controls put in place to minimize their risks. The social benefits of employment, income generation and economic growth need to be balanced with other social hazards, which may include rural-urban migration, over-population, and increase in criminality.

2.5.3 Environmental Vulnerability

The environment and disasters are linked, as environmental degradation affects natural processes, changes the resource base of the community and increases its vulnerability (UNLWR, 2004). Within the petroleum industry, almost all aspects of the environment of the host communities are affected. These include soil and groundwater risks from spills and loss of containment of petroleum products, air pollution through emission of hydrocarbon, as well as contamination of effluent and surface water through spills. Environmental vulnerability of host communities should therefore be given due consideration by both the industry and its regulators.

2.5.4 Physical Vulnerability

Perhaps, one of the most visible impacts of the petroleum industry is the physical vulnerability of the communities within its areas of operations (Sizemore, 2017). Starting from simple facilities like petrol stations, the vulnerability includes exposure to explosion and fire incidents that could arise from operations of the industry. In the case of the San Juanico LPG (Mexico) explosion, some people who lived over 1Km from the incident site suffered serious injuries from burns (Arturson, 1987). Whilst the petroleum industry endeavours to locate its facilities within a safe zone, and obtain regulatory permits for the design and installation of safety equipment to prevent such disasters, communities have often expanded to within the proximity of the petroleum industry, in order to maximise social and economic gains from the location of the facility. This is likely to have been one of the key issues that contributed to the Sinai petroleum disaster in Kenya, where a densely populated community had arisen, and thrived, within the neighbourhood of petroleum oil terminals.

On 3rd June 2015, a fire incident occurred in a GOIL petrol station in Accra Ghana, resulting in over 150 deaths (Ghana Web, 2019). The incident occurred during a heavy rainfall, and most of the people killed had taken shelter at the petrol station as the area had become flooded from the train. Somehow, there had been a spillage of petrol, which the flood carried to surrounding area. Open flame, likely from one of the nearby buildings, or from a smoker's cigarette, must have ignited the flood of petrol, which instantly transferred back to the petrol station causing a huge flame that quickly engulfed the station, killing most of the people who had taken shelter there, and in nearby buildings. The physical proximity of buildings and people at the petrol station must have had an impact on the number of fatalities from the incident.

2.6 The Pressure and Release Model

The Pressure and Release (PAR) model (Blaikie *et al*., 1994) presents disaster as the intersection of two opposing forces, hazard and vulnerability. The basis of the PAR model, which is also called the Crunch model, is that disaster will occur when hazard meets vulnerability. The Crunch model therefore explains why disasters occur. According to the model, vulnerability can be understood within three progressive levels: namely, unsafe conditions, dynamic pressures and underlying (root) causes. The root causes are closely linked to the aspect of governance, emphasizing the lack of access by vulnerable groups to political power, economic power and resources (St. Cyr, 2015). The diagram of the Crunch model of PAR is shown in Figure 2.6.

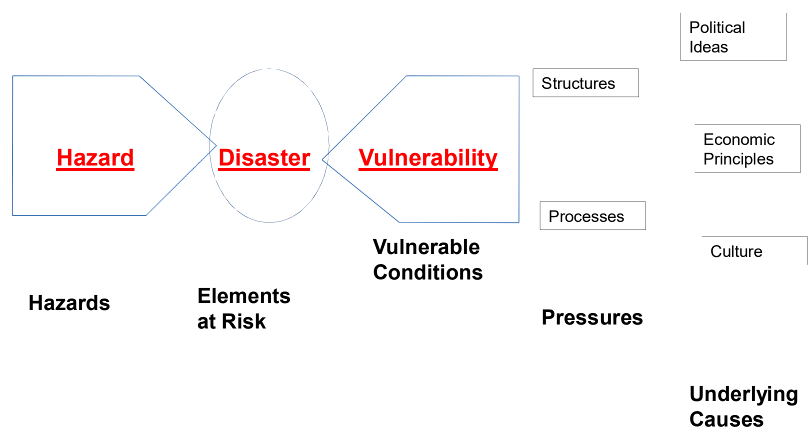

Figure 2.6: The Crunch Model of Disaster Management

Source: Blaikie, 1994

Underlying causes imply dynamic pressures that lead to unsafe conditions (vulnerable conditions), which in turn are specific forms in which human vulnerability is revealed and expressed. Unsafe conditions cover living in dangerous locations, or having livelihoods that are at risk, or the absence of local institutions in governance, or having entitlements that are prone to rapid and severe disruption. The lack of disaster preparedness and appropriate risk reduction measures is itself considered as an unsafe condition (Wisner *et al.*, 2004). Within the petroleum industry, the unsafe conditions are exemplified by the choice of people to live close to petroleum industry facilities, with the associated risks, as was seen in the Sinai petroleum disaster.

The PAR model concentrates on exploring opportunities for reduction of Vulnerability, such that when the Hazard intersects with it, the consequences can be minimised. The equation for Vulnerability is:

$$V = H/C$$

Where V is Vulnerability, H is Hazard and C is Capacity

The higher the Capacity, the lower the Vulnerability. Therefore, DRR opportunities include exploring means of increasing the capacity of society to cope, in order to reduce its vulnerability. Through increase of capacity to cope, impact of disasters on a society can be mitigated, and subsequent recovery mechanism effective.

The PAR model has however been criticised (Anderskov, 2004) as being situational-focused, not being able to predict the consequences of hazards, and lacking in scale of magnitude to facilitate comparison of one disaster with another. This study highlights how the application of TM can address the weaknesses of the PAR model in the identification of root causes of disasters and estimation of consequences. TM is a tool that is used after the occurrence of a disaster to identify root causes, and the barriers and controls that will prevent a recurrence. The identified barriers and controls are allocated to key stakeholders, who are responsible for ensuring they are in place to prevent the reoccurrence of the disaster. TM gives a further advantage of facilitating integration of local experience and established scientific knowledge in disaster risk reduction schemes, through the allocation of these barriers and controls. This significant advantage of TM has been demonstrated through the process for identification of the root causes of disasters in the petroleum industry. Whilst the immediate cause of the disaster can be addressed almost immediately, the root causes require multi-stakeholder involvement to prevent recurrence. Therefore, TM presents opportunities for engagement of stakeholders, including the local communities, in the prevention of disasters.

2.7 The Theoretical Framework for Disaster Risks Reduction

The main objective of DRR is the identification of hazards that could lead to disasters, and placement of controls to reduce the risks and prevent occurrence. The disaster causation path, which is the framework for TM in incident investigation, has been adopted in the research and has been used proactively within the DRR framework to eliminate disasters. The similarity between the PAR and TM models have been explored in the study. The research reviewed the integration of the Disaster Causation Path into the DRR framework, to facilitate a more exhaustive analysis for disaster management in the industry.

There are always two sides to every accident/disaster, the technical side and the behavioural side (Park, 2012). Whilst it is usually relatively easy to solve the technical problems, the history of disasters has shown that the behavioural problems that permit the exposure to hazards, or affect the vulnerability of the target communities, are more difficult to address. The solution to behavioural problems usually requires changes in mind-set, cultural challenges, working environment, and collaboration between stakeholders. The research therefore investigated human causal issues, which permitted the pre-conditions to the failures that eventually led to the disasters. There will always be human causal elements of disasters, and some of these have been addressed in the study.

When the barriers (or controls) to prevent a disaster are put in place within a community, location or industry, they require appropriate stakeholders' representatives (e.g., government, industry standards, civil societies and management) to ensure the barriers continue to be maintained. Unfortunately, barriers sometimes fail. This is an area where TM is effective in the identification of underlying causes of the barriers that failed, leading to the disasters. Identification of such underlying causes will provide opportunities to address recommendations that will prevent recurrence.

2.7.1 Disaster Prevention

Within the petroleum industry, one of the effective ways in disaster prevention is through placement of controls or barriers that will eliminate the release of the hazards within the facility. For example, safety devices could be installed that would not only prevent the release of hydrocarbon into the environment, but also divert the product into well-designed vessels during operations process upset or emergencies. Unlike the PAR where the barriers are mainly directed at reducing the vulnerability, the TM provides opportunity to place barriers in the path of the Hazard, in order to prevent its coinciding with vulnerability (Object) in time and space. This principle is considered appropriate for man-made disasters, where the hazards can be controlled or eliminated. In the PAR model, which largely focuses on natural hazards, it is assumed that little or nothing can be done to prevent the Hazard. In this research, TM was used to demonstrate its effectiveness in prevention of release of the Hazard, as well as exposure (vulnerability) of the community.

2.8 Conceptual Framework

The study was guided by the conceptual framework in Figure 2.7.

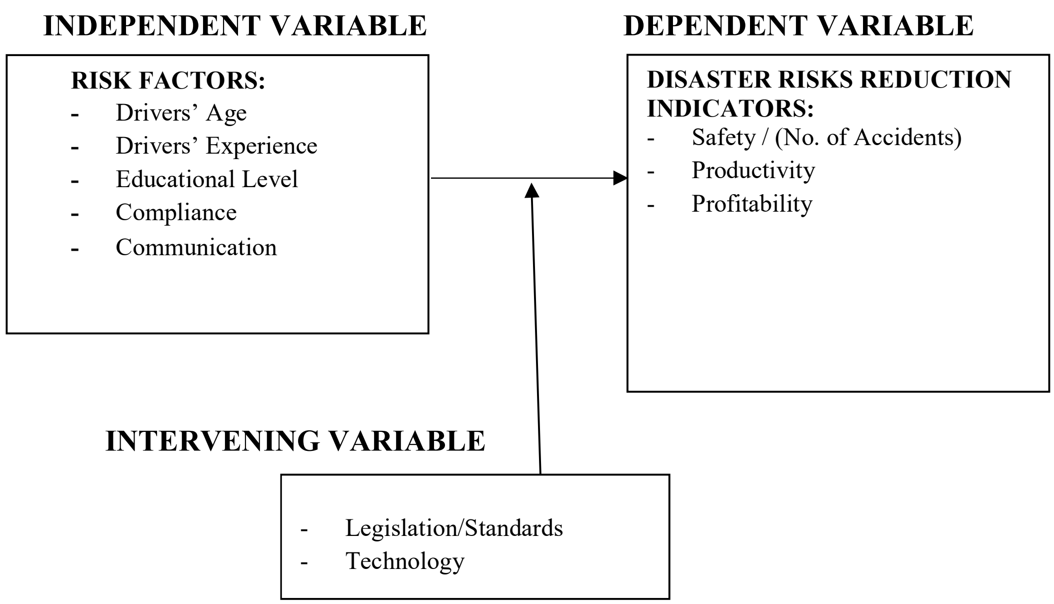

Figure 2.7: Conceptual Framework showing relationship between dependent and independent variable

Source: Author, 2022

The independent variables were identified through application of TM analysis. The 11 Basic Risk Factors (BRFs) of TM were reviewed for appropriateness to findings of investigations into the disaster case studies considered by the study. Not all the BRFs will be applicable in each disaster. The top three BRFs, which were common to the three disaster case studies, were used to applied to review their appropriateness to DRR indicators, the dependent variables. These performance indicators include number of accidents involving road tanker drivers, injuries to drivers, product spills, productivity and profitability. Application of technical standards and technology were found to have a moderating effect on disaster risk reduction, and hence sustainable management of the industry.

2.9 Gaps in knowledge

This study has identified a close relationship between the Pressure and Release model and the Tripod Beta Methodology. However, there are gaps in ways both models manage hazards and identification of DRR opportunities. The need for alignment between the two models can be the subject of future research.

There seems to be a lack of framework of recognised tools for investigation of large industrial accidents and man-made disasters. Whilst several investigation tools exist, assurance should be obtained about their effectiveness and robustness of determining the same root causes. This should form basis for inclusion of the tools in industry standards, and mainstreaming into appropriate policies. There is room for further research in this area.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The study reviewed disasters that have occurred in the Kenyan downstream sector of the petroleum industry between 2009 and 2022. Tripod Beta Methodology (TM) was applied in the investigation of the root causes of these disasters, and its effectiveness in DRR. Three different disaster case studies that occurred in the industry were investigated, with the aim of identifying lateral lessons and generic findings. Disasters in the following three sub-sectors of the downstream petroleum were investigated:

1. Bulk Storage and Distribution Terminals (BSDT)
2. Transportation via Bulk Road Vehicles (TBRV)
3. Storage/Sale Points at Petrol Stations (SPPS)

Following the identification of the root causes of the disasters, they were classified generically under Basic Risk Factors (BRFs). For each sub-sector (i.e., BSDT, TBRVs and SPPS), the appropriate BRFs that allowed the disasters to occur were identified, followed by analysis of the impact of these factors, and options for sustainable management of the petroleum industry.

The research focused on the petroleum industry in Kenya, with review of incident investigation reports of past disasters.

3.2 Study area

The following three disasters, which had high severity in terms of the number of fatalities, injuries and impact on the environment in each of the downstream sub-sectors, were investigated in the study and used as case studies:

1. The 2009 petroleum tanker rollover and explosion in Sachangwan, that caused over 120 fatalities. This study addressed risks involved in transportation of petroleum products via Bulk Road vehicles (TBRV) sub-sector. The community at Sachangwan is largely agrarian, with roadside traders of wares on the highway that transverses through Western Kenya to the republic of Uganda.
2. The 2011 petroleum pipeline disaster at Sinai, Nairobi Kenya that resulted in over 75 fatalities. The review addressed risks in the sub-sector of bulk storage and distribution terminals (BSDT). Sinai is a community of high-density population of workers, and the residential area has developed alongside the petroleum facilities in Nairobi Industrial Area, to provide workforce to the petroleum downstream industry.
3. The 2011 petrol station explosion in Nairobi, resulting in six fatalities and over 60 injuries. This occurred in the central business district of Nairobi, on Kirinyaga Road. The petrol station is located within a high-density population of both residential and trading facilities. The review addressed risks in the storage/sale of products in the Petrol Station (SPPS) sub-sector.

Sachangwan, where the oil tanker disaster occurred in 2009, is a small town about 238 Km North-West of Nairobi on the highway to Eldoret and Uganda. It is about 140Km from the city of Eldoret. The map in Figure 3.1 shows the location of Sachangwan.

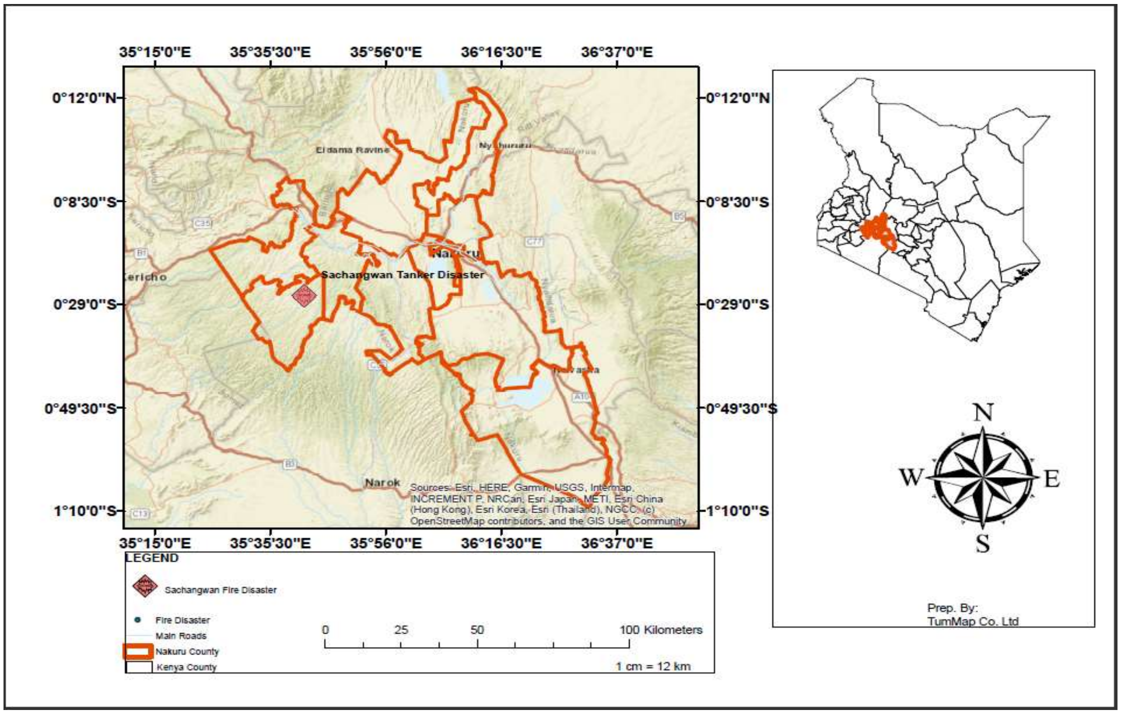

Figure 3.1: Map showing location of Sachangwan

Source: Author, 2022

After the disaster, a monument was erected in honour of the victims at the location where the oil tanker rolled over and where so many people died. The photo of the memoriam is shown in Plate 3.1.

Plate 3.1: Monument erected for Sachangwan disaster victims

Source: Author, 2021

The 2011 Petroleum Pipeline Leakage disaster took place in Sinai, a slum and residential area beside Nairobi's Industrial Area. A large population of people who live in Sinai work or engage in activities in the industrial area. The River Ngong runs through the settlement and Figure 3.2 shows the map of the disaster location.

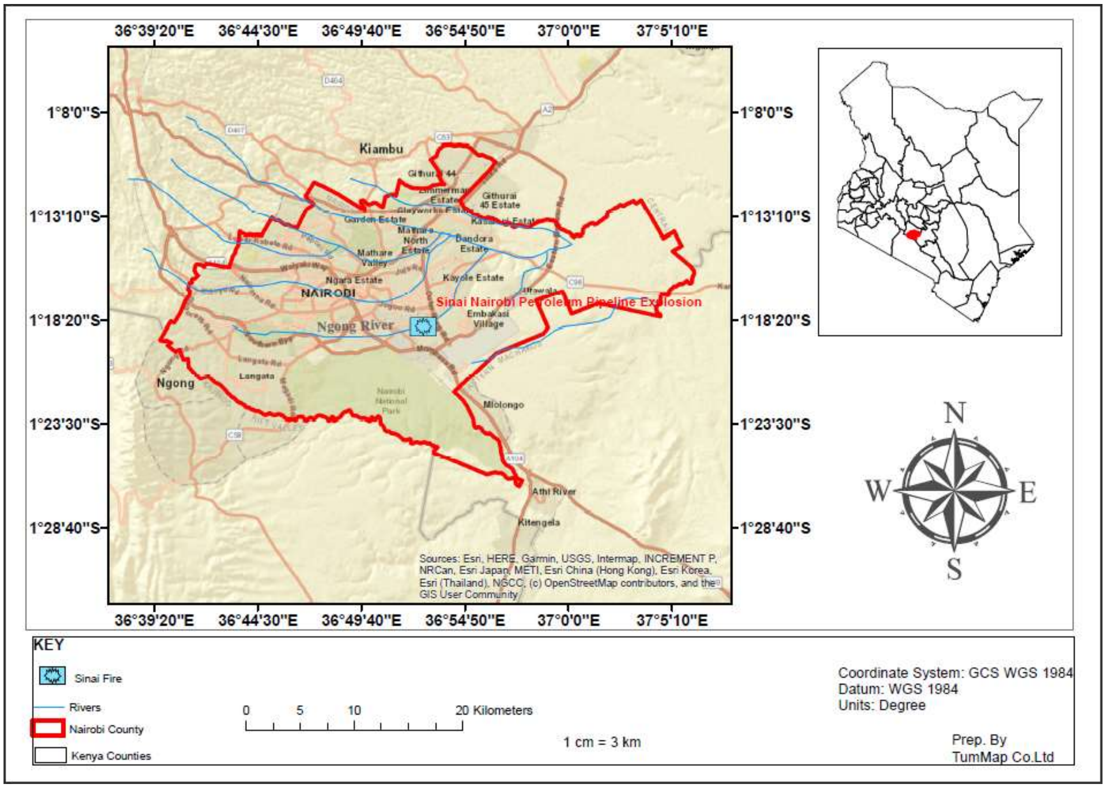

Figure 3.2: Map showing location of Sinai Nairobi Petroleum Pipeline explosion

Source: Author, 2022

The map of the location of 2011 petrol station explosion that took place on Kirinyaga Road, close to the Central Business District, Nairobi, is shown in Figure 3.3.

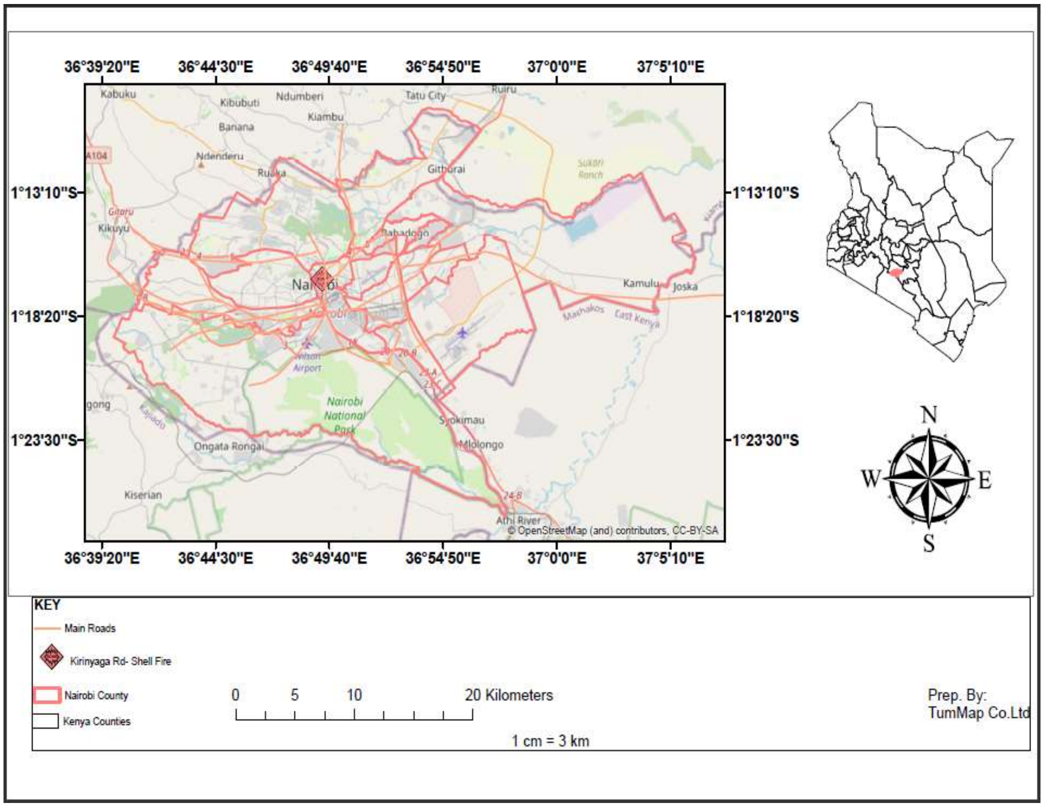

Figure 3.3 Map showing location of Kirinyaga Road Petrol Station explosion disaster

Source: Author, 2022

Plate 3.2: Kirinyaga Petrol Station explosion

Source: Kenya Shell Investigation Report (2012)

3.3 Study Population

The study population comprised tanker drivers of various transporters who worked with both local oil marketing companies and international oil marketing companies in Kenya. The drivers were the focus of the survey carried out in the study. Other players in the oil industry that were interviewed included staff of government regulatory agency, Energy and Petroleum Regulatory Agency (EPRA), Petroleum Institute of East Africa (PIEA), petroleum companies, staff and contractors working within the industry. Upon review of investigation reports of the three disaster case studies carried out by the petroleum marketing companies, regulatory bodies, research institutions and civil societies, parties who were involved in the disasters were identified. Where they could be found, witnesses to the disasters were interviewed, including staff of NGOs, emergency services, hospitals, and police officials who were involved in the disaster response activities.

3.4 Research Design

According to Cooper and Schindler (2006), research design constitutes the blue print for the collection, measurement and analysis of the data to achieve stated objectives. It’s a structure for investigating so as to obtain answers to research questions and for testing hypothesis (Kothari, 2008).

The research designs adopted included descriptive survey, correlation and evaluation. Use of the incident investigation tool, Tripod Beta Methodology (TM), ensured an in-depth study of the research problem and comprehensive enquiry of generic issues that contributed to disasters in the three sub-sectors of the downstream petroleum industry. Descriptive survey design was found appropriate for comparative analysis of root causes of accidents, injuries and spills by tanker drivers, and contributory behaviour that could have led to the disasters. Correlation survey design was used to investigate performance of three categories of transporters. Small Oil Transporters (SOT) have between one and nine tankers in their operations, whilst Medium Oil Transporters (MOT) have between 10 and 49 tankers, and Large Oil Transporters (LOT) operate at least 50 road tankers. The list of registered petroleum road tankers in Kenya (EPRA, 2020) was used to classify the transporters into the three categories.

Controls that can be applied by transporters for effective DRR were identified through analysis of feedback from tanker drivers. Using correlation research design, an in-depth study of risk reduction options was carried out, and effective controls identified.

Evaluative survey was used for evaluation of strategic options for sustainable management of the downstream petroleum industry. Table 3.1 presents the research design in accordance with the specific objectives of the study.

Table 3.1: Summary of research design as per the specific objectives of the study and respective measurable variables/indicators for road transportation of petroleum products

Specific Objective	Measurable Variables/Indicators	Research Design
1. To identify factors contributing to disaster risks in the transportation of petroleum products.	Drivers' performance, accidents, oil spill, injuries sustained.	Descriptive Survey
2. Analyse root causes of disasters in the transportation of petroleum products	Road Safety Performance of Transporters Effectiveness of controls in managing risks	Correlation
3. Evaluate strategic options for sustainable management of the industry.	Evaluation	Evaluative research

3.5 Model Selection

The study reviewed various incident investigations being used in the industry, and selected Tripod Beta Methodology (TM) because of its focus on human causal elements of accidents and disasters. TM concentrates on logical analysis of error-inducing systemic influences, and through controlling the working environment, human errors can be minimised (Energy Institute, 2005). It is 3-leg approach through which the Hazard can be prevented from colliding with the Object, to avoid the Event (Disaster). Therefore, TM is similar to the PAR model, which also uses a similar 3-leg approach. In PAR, the coincident intersection of Hazard and Vulnerability results in Disaster.

With PAR, the assumption is that the Hazard, being a natural phenomenon cannot be controlled, and only early warning signs would suffice. Whereas, TM seeks to identify barriers that can be placed in the path of both the Hazard and Object to prevent intersection. The ultimate objective of TM is the prevention of disasters through placing barriers in the path of both Hazard and the Object. This study identified opportunities for further research in the alignment of both the TM and PAR models.

The analysis of one of the disaster-causation paths, using the PAR model and TM for analysis of the Sachangwan disaster are presented in Figure 3.4 and Figure 3.5 respectively.

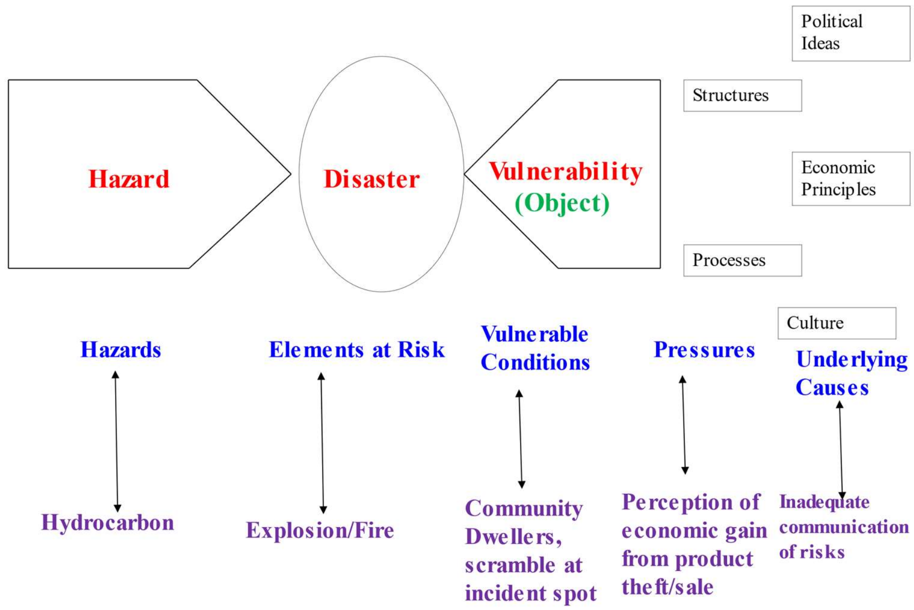

Figure 3.4: Analysis of disaster causation using PAR Model

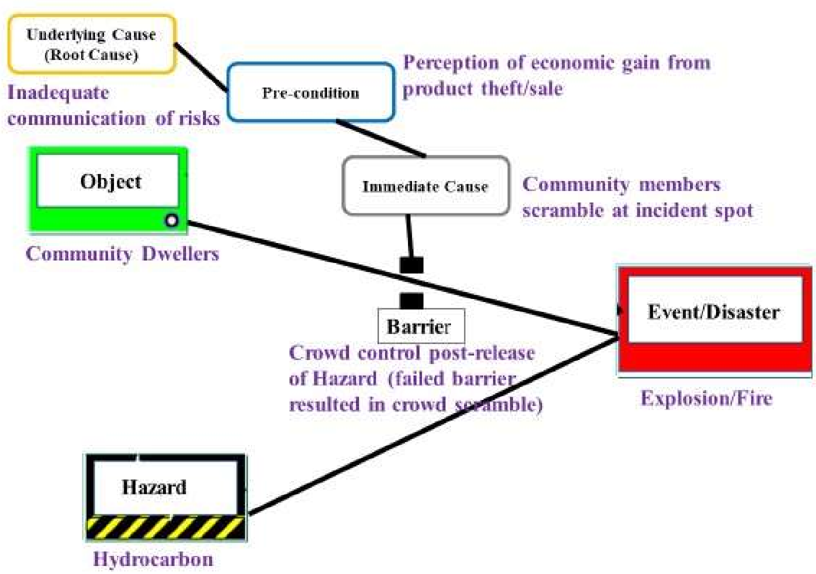

Figure 3.5: Analysis of disaster causation using the Tripod Beta Methodology (TM)

It was observed that the same outcome was obtained, using both models, though the TM analysis is able to provide more details on a single diagram, and identifies barriers required to prevent the disaster. In Figure 3.2, the analysis identified controls that should be placed on the path of the Object to prevent it from intersecting with the Event to cause disaster. The analysis can be equally applicable to identify controls to be placed on the path of the Hazard, to prevent its intersection with Event, to cause disaster. For example, a barrier on the Hazard path could be prevention of product leak, and this may be achieved by fabrication of a double-walled tank that can prevent leakage when there is a tanker rollover. This study adopted TM for the analysis of the three disaster case studies.

3.6 Sampling Design

Simple random sampling was used for the study. The tanker drivers who participated in the survey were selected randomly at the depot of the oil marketing companies, where the road tankers received consignment of petroleum products. Within each petroleum marketing company, tanker drivers were selected randomly, irrespective of the transporter they worked for.

3.6.1 Sample Size

The estimated number of Bulk Road Vehicles (BRV), called road tankers, in Kenya exceeds 5,300 as provided in the EPRA register of petroleum oil tankers (EPRA, 2020). However, road tankers from some other East African countries, like South Sudan, Uganda, Burundi, Rwanda and DRC receive supply of petroleum fuel from Kenya. It was estimated that another 5,000 road tankers travel from these countries for fuel haulage. It is therefore estimated that over 10,000 road tankers operate at different times across the country.

According to Mugenda (1999), when a study population is 10,000 and above, a sample size of 384 is adequate. This is arrived at using the following formula:

$$n \frac{Z^2pq}{d^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..3.1$$

Where:

n = desired sample size (if the target population is more than 10,000)

Z = the standard normal deviation at the required confidence level (95% for this study)

p = the proportion in the target population estimated to have characteristics being measured (will be estimated at 50% to maximize sample size)

q = 1-p

d = the level of statistical significance set (5%)

$$n = \frac{(1.96)^2(0.50)(0.50)}{(0.050)^2}$$

$$= \frac{(3.8416)(0.5)(0.5)}{(0.0025)}$$

$$= 384$$

Over 450 tanker drivers participated in the random sampling, though 391 submitted completed questionnaires. Of the tanker drivers who submitted questionnaires, some did not specify the names of the transporters they worked for. 318 tanker drivers specified the names of the transporters they worked for. The transporters were subsequently classified them into 3 categories, based on the number of road tankers in their fleet, for purposes investigating impact of organizational effectiveness on tanker drivers' performances. The number of transporters whose drivers participated in the survey were over 53, ranging from one-tanker transporter that supplied own petrol station to transporters with over hundred tankers lifting product from several marketing companies and supplying several petrol stations.

3.7 Data Collection

3.7.1 Secondary Data

The use of secondary data was an important part of this study. The disaster case studies considered by this study involved national emergency agencies, e.g., Fire Service, Red Cross, Police, etc. during the response period. These agencies, regulatory bodies, universities, research organisations and civil societies carried out individual or joint disaster investigations. The reports were a veritable source of data for the study. Data was also obtained from journals, electronic and print media reports about the disasters, books and research papers. Similarly, the internet provided vital resource in accessing online publications and reports. Other secondary sources of data covered reports from key industry sectors, including the Ministry of Energy, International Petroleum Industry Environmental Conservation Association (IPIECA), Petroleum Institute of East Africa (PIEA), Energy & Petroleum Regulatory Authority (EPRA) and the United Nations Environmental Programme (UNEP).

3.7.2 Primary Data

There were two phases of data collection for this research. The first phase comprised data gathering from petroleum industry facilities, companies and people that were involved in the disasters. Staff of oil transporting companies were interviewed on issues of transportation, risk awareness, communication, design, procedures for operation and organisation. The KPC facility at the Nairobi Industrial Area was visited, and technical problems that led to the release of petroleum products into public sewer drains were reviewed. The Kirinyaga petrol station where the explosion took place was visited, and inhabitants of the area were interviewed. The location of the Sachangwan oil tanker disaster was visited and interviews conducted with families of victims to review events leading to the disaster. This resulted in the identification of technical and hardware issues that contributed to the disasters. Interview notes were analysed and used for the Tripod Beta analysis of the 3 disasters that were used as case studies.

The second phase comprised issuance of pre-tested questionnaires, which were used to collect data from tanker drivers of oil transporters that worked for various oil marketing companies in Kenya. The transporters were later classified into SOT, MOT, and LOT.

3.8 Data Collection Instruments

The survey questionnaire was developed for tanker drivers, and was deployed through transport and logistics managers of oil marketing companies, and transporters. The transport/logistics managers were on hand to provide clarification whenever a driver had questions. Each depot used for loading petroleum products has a drivers' waiting room, which is used for engagements with tanker drivers, whilst awaiting product loading. The drivers' waiting room is also used for safety meetings, town hall discussions, hazards mapping reviews and training activities. The tanker drivers signified the transporters they worked for. Based on their fleet size, the contractors were categorized into three groups.

Interviews were held with transport/logistics managers of oil marketing companies and transporters, Line Managers of the companies, and staff of PIEA, EPRA and NTSA. Interviews were held with staff of Kenya Police, the Red Cross and members of Civil Societies about challenges of response to disasters.

3.9 Piloting of the Instruments

On development of the questionnaire, a pilot was carried out with tanker drivers deployed to work for Oil Libya Africa (OLA). Questionnaires were distributed to tanker drivers at OLA Nairobi Industrial Area Depot Drivers Waiting Room, whilst they were awaiting onloading petroleum products. OLA Logistics. Comments received were reviewed with OLA Logistics Manager. Following the review, it was identified that some of the drivers were unsure about the objectives of the survey, despite the assurance of the Logistics Manager. It was subsequently agreed to give drivers the option for anonymous submission, to encourage participation of reports without fear of reprisal.

3.9.1 Validity

It can be said that validity is the ability of the instrument to measure what it is supposed to measure (Walingo and Ngaira, 2008). It considers whether data obtained in the study represents the variables of the study This is important in research because conclusions drawn from such data are more accurate, relevant and meaningful. (Wabwoba, 2015). To test the validity of the instruments, the pilot survey was conducted with 40 tanker drivers (10% of 400) who were deployed to work for OLA. The aim of the pilot survey was to assess the clarity of the questionnaires through group discussions and submission of feedback. Items that failed to meet the anticipated usefulness of data were discarded. A pilot study is important in testing the validity of the instruments and clarity of language (Mugenda & Mugenda, 1999).

3.9.2 Reliability of Data Instruments

Reliability refers to consistency that an instrument demonstrates when applied under similar situations (Mugenda and Mugenda 1999). To test the reliability of instruments the researcher used the test method, with confirmation by supervisors of the tanker drivers. The instruments were pre-tested in a pilot study with OLA because the petroleum marketer had different categories of oil transport companies, i.e., LOT, MOT and SOT. A random sample of 10% of the 400 tanker drivers was drawn from the petroleum marketer, Oil Libya, for pre-testing.

3.10 Limitations of Study

The severity of the petroleum industry disasters generated a high level of emotions at the time of occurrence. There were concerns that the research could result in recall of trauma that victims and relatives went through. Therefore, engagements were handled with sensitivity and respect for affected families. There were fears from industry players about the possible impact of the research findings, if it resulted in apportioning of blame. To overcome these constraints, confidentiality agreements were reached with some staff interviewed, and assurance given to tanker drivers. The option of remaining anonymous was given to the drivers that participated in the survey. Despite this, some drivers did not provide names of the transporters they worked for. In line with agreements reached, the researcher has not mentioned any names in the report.

The deliverables of the research have been made available to researchers at Masinde Muliro University of Science & Technology and a caveat included protecting the confidentiality of all interviewees who took part in the survey.

3.11 Data Analysis & Presentation

Data were collected through questionnaires distributed through Transport/Logistics Managers of transporters and petroleum product marketing companies. Descriptive statistics such as frequencies and percentages were used during analysis and tables and graphs were used to present the findings by use of the Statistical package for social sciences (SPSS) and excel software. Spatial data was mapped using GPS and Garmin

USGS Intermap tool. The data collected for each of the Specific Objectives of this research are as follows:

i. Specific Objective 1: data collected included age of tanker drivers, driving experience, education level and monthly salary (remuneration), which were summarized in the form of tables and/or charts in Chapter 4.
ii. Specific Objective 2: data collected included drivers' compliance, perception of effectiveness of defensive, and frequency of safety meetings were summarized Chapter 5, and presented in the form of tables and/or charts.
iii. Specific Objective 3: data collected included frequency of driver's engagement with supervisors/managers. These are summarized in the form of tables and/or charts in Chapter 6.

The file containing data obtained from questionnaires is presented in Appendix-5, with legend.

CHAPTER FOUR

IDENTIFIFICATION OF FACTORS CONTRIBUTING TO DISASTER RISKS IN THE TRANSPORTATION OF PETROLEUM PRODUCTS IN KENYA

This chapter describes the demographic characteristics of the study area, and presents the findings of the study pertaining to specific objective one.

4.1 Demographic characteristics of respondents

The demographic characteristics of respondents, were as summarized in in Table 4.1.

Table 4.1: Demographic characteristics of respondents

Category	Classification	Frequency	Percentage
Gender	Male	391	100
	Female	0	0
Age Category (Years)	24 - 29 years	28	7
	30 - 40 years	160	41
	41 - 55 years	171	44
	56 - 69 years	30	8
	70 years +	1	0.3
Driving Experience (Years)	Less than 1yr	20	5
	1- 5 years	110	29
	6 - 10 years	143	37
	11 - 15 years	68	18
	15 years +	44	11
Educational Level	No Formal Schooling	11	3
	Primary School	80	21
	Secondary School	259	67
	Tertiary Education	38	10
Driver Monthly Salary (in Kenyan Shillings)	Less than 30,000/-	181	47
	31,000 - 45,000/-	147	38
	46,000 - 75,000/-	48	12
	76,000 - 100,000/-	9	2
	Above 100,000/-	2	1
Category of Transporters (based on # of Road Tankers operated)	SOT (less 10 Tankers)	57	18
	MOT (10 - 49 Tankers)	24	8
	LOT (Above 50 Tankers)	237	74

Source: Field data (2022)

The total number of tanker drivers who responded to the questionnaires was 391. The demographic characteristics sought by this study included gender, age bracket, driving experience, educational level, and salary of drivers. Though there was only a handful of female tanker drivers in the industry, all respondents that took part in the survey were male. The researcher did not meet a female tanker driver during the field study.

Upon review of completed questionnaires, it was observed that a tiny number of respondents did not provide data to some of the questions on the survey questionnaire. For example, whilst the total number of respondents was 391, it was observed that one respondent did not indicate the age group he belonged to. Therefore, the number of drivers (390), who responded to the question, was used in the analysis of drivers' age. In a similar manner, a tiny number of drivers did not provide data on driving experience, accidents, injuries and spills. This was one of the challenges this study grappled with, but the number of respondents involved was very small and could not have impacted the findings.

When the age brackets of the drivers were analysed, it was observed that 41% of the drivers were in the 30 – 40 years group, whilst 44% were in the 41 – 55 years group. The analysis is presented in Figure 4.1.

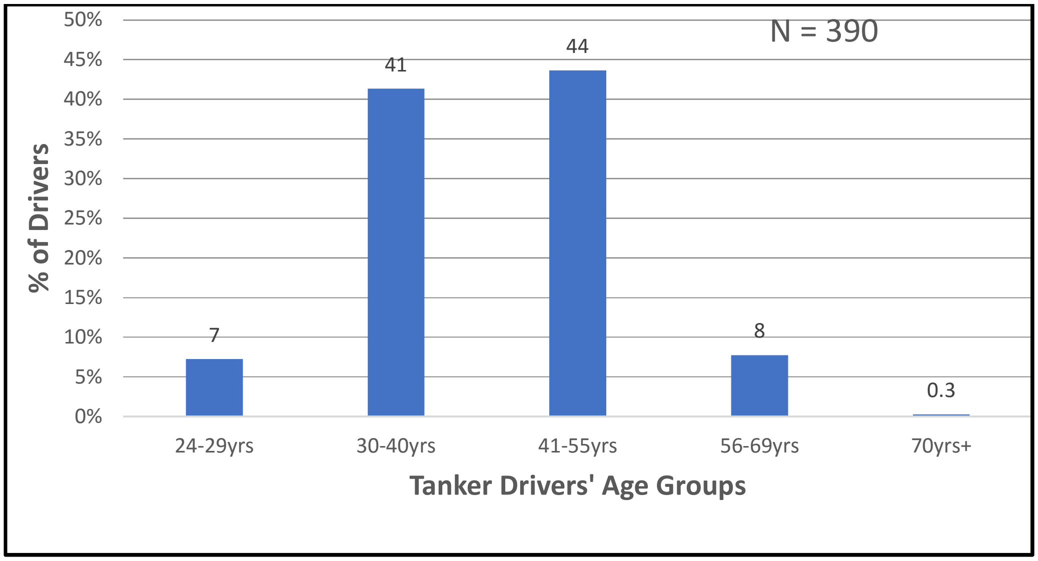

Figure 4.1: Distribution of age groups of tanker drivers that participated in survey

Source: Field data, 2022

The analysis implied 85% of tanker drivers were between 30 and 55 years old. Research in India has shown the age group 30-59 years as being the most economically active age group, and it is also the most vulnerable population group (Singh, 2017). It has been demonstrated by other studies that younger drivers tend to be a bit more reckless due to their high-risk behaviours.

Hordofar, et al (2016) showed that majority (about 75%) of fatalities arising from road traffic accidents were caused by young drivers in the age group of 18 – 30 years. Therefore, the study gave due consideration of the age group of tanker drivers as a factor.

The analysis of driving experience of the tanker drivers was carried out and results were presented in Figure 4.2.

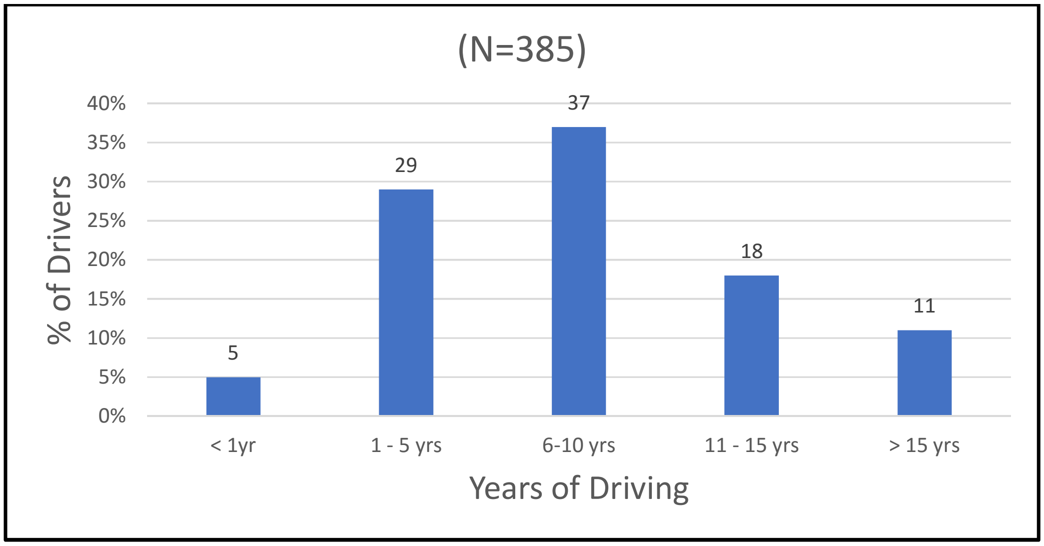

Figure 4.2: Graph showing breakdown of tanker drivers' experiences

Source: Field data, 2022

Out of the 391 drivers that completed the questionnaires for this study, it was observed that 6 of them did not respond about their driving experience. Therefore, the analysis was based on 385 drivers that provided the data.

Drivers with driving experience of 6 – 10 years represented the highest group at 37% of the entire population. Drivers with less than a year of driving experience, with a percentage of 5% of the total population, represented the lowest group. Experience of drivers is an important factor, as it was identified that careless and inexperienced drivers contributed to oil tanker accidents that resulted in fire disasters in Kenya in the past (Shileche, 2012). Road accidents involving tankers are often the first event that happens, leading to product spills, fire and explosion disasters, as in Sachangwan.

Fagnant & Kockelman (2015) have suggested that human error when driving contributes to approximately 93% of traffic accidents. Human factors consider the impact of individual differences (e.g., age, gender, experience, personality) on traffic safety and road transport system design. This study investigated the importance of driving experience on business performance of transporters and safe driving. An analysis of the educational levels of tanker drivers was carried out. The graph showing the breakdown of their educational levels is presented in Figure 4.3.

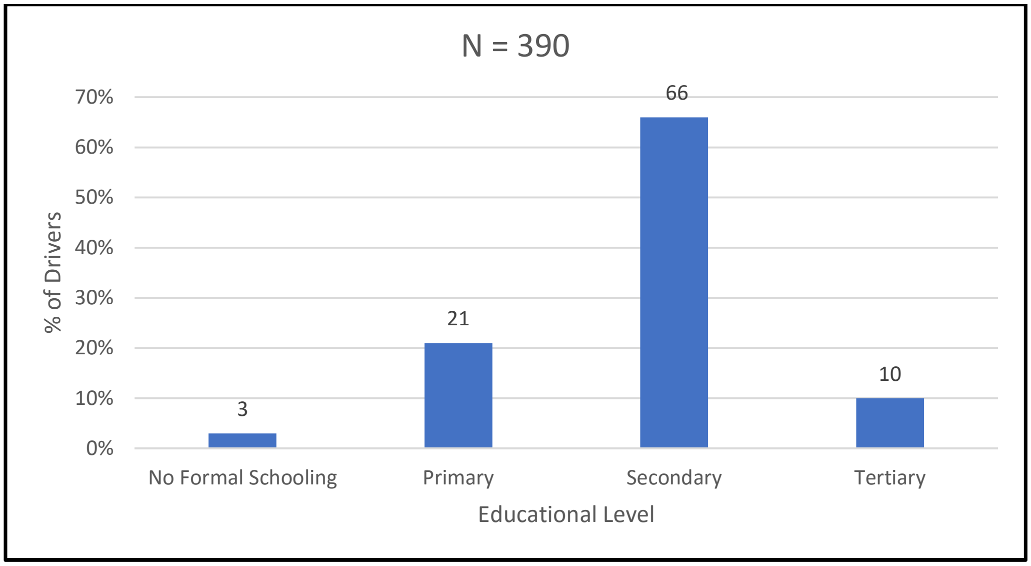

Figure 4.3: Graph showing breakdown of tanker drivers' educational levels

Source: Field data, 2022

The analysis revealed that 66% of the drivers had secondary school education, and only 3% did not have any formal education. This appeared to be a good trend in terms of driver's educational level. A study carried out in Ethiopia (Hordofa *et al*, 2018) showed that drivers who had primary level education or lower caused a large number of fatalities (56%), whilst fewer fatalities (23%) were caused by drivers that had a minimum of secondary level education.

In order to investigate the possible impact of salary and remuneration on the performance of tanker drivers, an analysis of their monthly remuneration was carried out. Figure 4.4 presents a breakdown of the monthly salary.

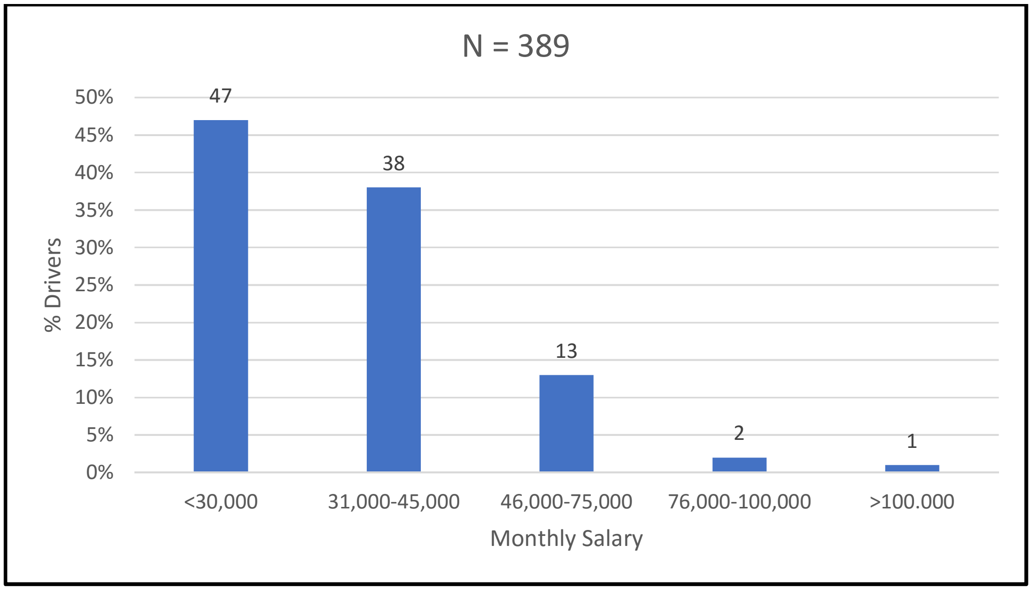

Figure 4.4: Graph showing breakdown of tanker drivers' salary

Source: Field data, 2022

4.2 Identification of Factors affecting disaster risks in road transport

This section presents factors that contribute to disaster risks in road transportation of petroleum products. The study revealed that age of tanker drivers, their driving experience and educational levels are factors that affect disaster risk reduction. The contribution of these factors to accidents, injuries and product spills during transportation were investigated.

4.2.1 Drivers' age and accident performance

An analysis was carried out on tanker drivers' involvement in motor accidents based on their age groups. Tables 4.2 to 4.4 present data of age of drivers versus accidents incurred, and their analysis, whilst Figure 4.5 presents results, showing the accident performance of the drivers based on age.

Table 4.2 presents a breakdown of tanker drivers' involvement in accidents, based on age.

Table 4.2: Breakdown of accidents by tankers drivers of different age groups

	Motor Vehicle Accident involvement by Tanker Drivers					
Driver Age	**No accident**	**1-5 Accidents**	**6-10 Accidents**	**11-15 Accidents**	**>15 Accidents**	**TOTAL**
70yrs +	1	0	0	0	0	1
56 - 69yrs	17	12	0	0	0	29
41 -55yrs	133	29	2	4	1	169
30 -40yrs	135	22	1	1	1	160
24 - 29yrs	26	1	0	1	0	28
TOTAL	312	64	3	6	2	**387**

Source: Field data, 2022

Out of the respondents, 312 (81%) indicated they had not been involved in any accident during the period of driving for their companies. Using data in Table 4.2, Chi-Square test was carried out to find out if the association between age groups of the drivers and motor vehicle accidents were statistically significant. The analysis was as presented in Table 4.3.

Table 4.3: Chi-Square test of the association between drivers age and motor vehicle accidents involvement

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	21.317[a]	16	.167
Likelihood Ratio	20.933	16	.181
Linear-by-Linear Association	4.603	1	.032
N of Valid Cases	387		

a. 19 cells (76.0%) have expected count less than 5. The minimum expected count is .01.

Source: Field data, 2022

From the table, we were interested in the results of the "Pearson Chi-Square". It was clearly seen that $\chi(1) = 21.317$, $p = 0.167$, which indicated there was no statistical significance association between age groups of the drivers and motor vehicle accidents. That is, drivers in all age groups equally cause road accidents. A one sample t-test was further carried out to determine if there was a difference in age group when it comes to no-accident performance. It was observed that the age group difference among the drivers who had zero-accident was not significant since the significant level of 0.102 was greater than 0.05 as shown in Table 4.4.

Table 4.4: One sample t-test to determine if there was a difference in age group of drivers who achieved zero-accident

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	Df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Drivers with No accident	2.115	4	.102	62.4000	-19.520	144.320

Source: Field data, 2022

An analysis was carried out to investigate the road transport accident performance of tanker drivers based on their age groups, The results are presented in Figure 4.5.

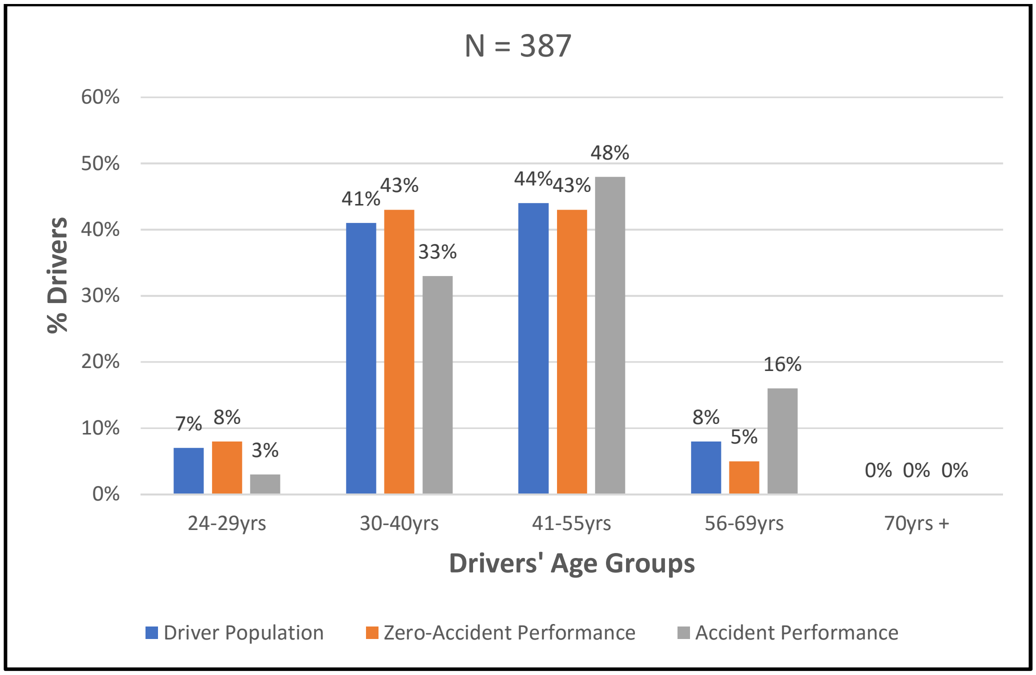

Figure 4.5: Accident performance of drivers based on age group

Source: Field data, 2022

It was observed that, though drivers in the age group of 24 – 29 years represented 7% of the population of tanker drivers, they achieved 8% to zero-accident performance, which is better performance compared to their proportionate size. The drivers in this age group contributed 3% of accidents. Drivers in the 30 – 40 years age group represented 41% of the population, achieved 43% of zero-accident performance, and contributed 33% of the accidents.

Drivers in 41-55 years age group represented 44% of the population, but achieved 43% of zero-accident and 48% of the accidents. Drivers in 56 – 69 years age group represented 8% of the population, but achieved 5% of zero-accident performance, and contributed 16% of the accidents. The only driver in the 70+ years age group was not involved in any accident.

From research, drivers aged 65 and above have higher odds of involvement in fatal intersection crashes than other age groups. It has been demonstrated that age, roadway condition, roadway type, time of day, collision location, and collision type were important determinants of accident severity (Eboli, *et al*; 2019). The analysis of accidents incurred by tanker drivers based on age is congruent with this theory, as the contribution to accidents of drivers in the age group of 56 – 69 years was twice its proportionate size of 8%. Drivers in this age group achieved lower zero-accident performance of 5%, and higher proportional accident rate.

From Figure 4.5, it was observed that drivers in the 30 – 40 years' group had the best performance, as they had the highest proportional contribution to zero-accident, and the least proportional ratio of accident rate when compared with their group size. This was followed by drivers in the 24 – 29 years' group, who achieved higher proportional zero-accident performance and lower proportional ratio of accident rate compared with their group size. However, this performance of drivers in 24 – 29 years' group was mitigated by the lower exposure driving period of this group of drivers.

4.2.2 Drivers' age and incidences of injuries

An analysis was carried out on tanker drivers' age and involvement in work-related injuries during their time of employment with their transporters. Tables 4.5 to 4.7 present data of age of drivers versus injuries sustained, and their analysis, whilst Figure 4.6 presents the results, showing injury performance of the drivers, based on age. Table 4.5 presents breakdown of work-related injuries sustained by drivers, based on age.

Table 4.5: Breakdown of driver's injury performance on basis of age

	NUMBER OF DRIVERS WITH/WITHOUT INJURIES AT WORK					
Driver Age	0 (No-Injury)	1	2	3	>4	**Total**
Above70yrs	1	0	0	0	0	1
56 - 69yrs	27	3	0	0	0	30
41 -55yrs	154	12	4	0	0	170
30 -40yrs	154	5	1	0	0	160
24 - 29yrs	27	1	0	0	0	28
TOTAL	**363**	**21**	**5**	**0**	**0**	**389**

Source: Field data, 2022

Whilst 391 drivers completed the questionnaires, it was noted that two of them did not provide data about injuries sustained during their driving period with their employers. Therefore, the analysis about injuries covered 389 tanker drivers It was observed that 363 (93%) of drivers did not incur any injury during their employment period with their transporters. A Chi-Square test was done from Table 4.5 to find out if the association between age groups of the drivers and injuries sustained were statistically significant. The analysis was as presented in Table 4.6.

Table 4.6: Chi-Square test of the association between drivers age and number of injuries sustained

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.965[a]	8	.540
Likelihood Ratio	7.589	8	.475
Linear-by-Linear Association	3.452	1	.063
N of Valid Cases	389		

a. 9 cells (60.0%) have expected count less than 5. The minimum expected count is .01.

Source: Field data, 2022

From the table, $\chi(1) = 6.965$, $p = 0.540$ which implies there was no statistical significance association between age groups of the drivers and those that sustained injuries; i.e., drivers equally sustain injuries irrespective of age groups. A one sample t-test was carried out to determine if there was a difference in age groups that achieved zero-injury performance. It was discovered that the age group difference among the drivers who did not sustain injuries was not significant since the significant level of 0.097 was greater than 0.05, as shown in Table 4.7.

Table 4.7: One sample t-test to determine if there was a difference in age group of drivers who sustained zero injuries

One-Sample Test						
	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	Df	Sig. (2-tailed)	Mean Difference	Lower	Upper
0 (No-Injury)	2.163	4	.097	72.6000	-20.602	165.802

Source: Field data, 2022

The outcome of analysis of the injury performance of tanker drivers, based on their age, was as presented in Figure 4.6.

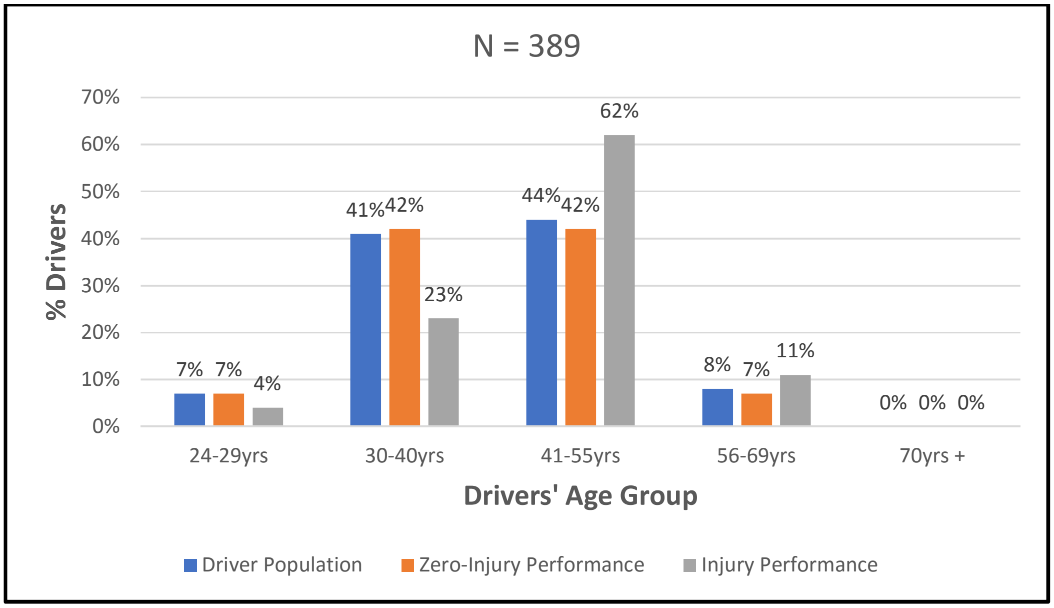

Figure 4.6: Injury performance of drivers based on age

Source: Field data, 2022

It was observed that, of all the age groups, only drivers within 30 – 40 years achieved a zero-injury performance that was better (i.e., higher) than its proportional size. This group achieved 42% of zero-injury, whilst its group size was 41%. Simultaneously, the group contributed lower proportional injury performance of 23%, when compared with the group size. Every other group had either lower or equal proportional zero-injury performance, whilst some had higher proportional contributions to injury rates. However, drivers in the 24 – 29 years' group had a lower injury performance of 4% compared with size of 7%. The good performance of this group of drivers is over-shadowed by their low driving exposure.

The analysis of injuries incurred revealed two groups of drivers, 41 – 55 years and 56 – 69 years, contributed more to occurrence of injuries among the tanker driver population. Whilst the population size of drivers in the 41 – 55 years group was 44%, they contributed 62% of the overall injuries.

Bucsuházy *et al.,* (2020) have highlighted reduced capability to meet road transport contingencies are apparent in road accidents caused by older drivers. It was revealed that mental and somatic handicap, health indisposition and reduction of cognitive function and psychomotor rate become more apparent at older age. Therefore, increase in longevity will involve greater risk of being involved in road accidents, as reaction time reduce, and ability to correctly estimate the traffic situation may develop, resulting in risk of higher injury rate when accidents occur.

Injuries result in lower productivity by affected drivers due to absences from work on health grounds. Each day's absence from work results in losses to employers in terms of salaries for work not done, medical treatment expenses and sometimes legal costs, where third parties are involved. These factors affect both the productivity and profitability of the transporters the drivers work for. This study revealed drivers in the 41 – 55 years and 56 – 69 years contributed more to lower productivity, including eroding profitability of their transporters.

Besides loss of life, traffic accidents result in medical costs, physical pain, permanent disability and travel anxiety, as well as affecting household income and national economy; and they also reduce quality of life. Therefore, road traffic crashes affect not only the health of individuals, but also their family members, as the impact can drive households into poverty when they struggle to cope with the long-term consequences of the events, including the costs of medical care, rehabilitation and loss of family (Hordofa, et *al.*, 2018).

Research has established that road traffic accidents claim the largest toll of human life and tends to be the most serious problem, not only in Kenya, but also around the world. Globally, millions of people are coping with the death or disability of family members from road traffic injury (Wycliffe, 2019). Therefore, the focus should be to reduce accident rate within the industry to improve economy and GDP, as well as reduce human suffering and loss. The study showed that drivers in the 30 – 40 years' group contributed the least injury rate, and minimal injury performance out of the population of tanker drivers that participated in the survey.

4.2.3 Drivers' ages and product spill incidences

An analysis was carried out on tanker drivers' age and involvement in products spills. Tables 4.8 and 4.9 present data of age of drivers versus product spills, and their analysis, whilst Figure 4.7 presents spill performance on the basis of driver's age. Each driver provided data on the estimated volume of spill incurred during their work experience with the transporters. The breakdown of number of spills based on drivers' age group is shown in Table 4.8.

Table 4.8: Breakdown of oil spills (in litres) by tanker drivers based on their ages

	Number of Drivers' Spills classified in volume (litres)					
Drivers' Age	**Zero spill**	**1 - 1,000**	**1,000 -20,000**	**21,000 -100,000**	**>100,000**	**Total**
> 70yrs	1	0	0	0	0	1
56 - 69yrs	25	5	0	0	0	30
41 -55yrs	149	19	1	0	1	170
30 -40yrs	141	14	2	1	1	159
24 - 29yrs	25	2	0	0	1	28
TOTAL	**341**	**40**	**3**	**1**	**3**	**388**

Source: Field data, 2022

Out of the 388 respondents on spill performance, 341 (88 %) tanker drivers indicated they had not been involved in any product spill. Analysis revealed there was no significant difference of age group among the drivers that had spills, since 0.090 was greater than 0.05 as shown in Table 4.9.

Table 4.9: One sample t-test to determine if there was a difference in age group of drivers who had oil spill

One-Sample Test						
	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	**Df**	**Sig. (2-tailed)**	**Mean Difference**	**Lower**	**Upper**
Drivers that had spills	2.224	4	.090	9.4000	-2.334	21.134

Source: Field data, 2022

An analysis was carried out to investigate the product spill performance of tanker drivers based on their age. The result is presented in Figure 4.7.

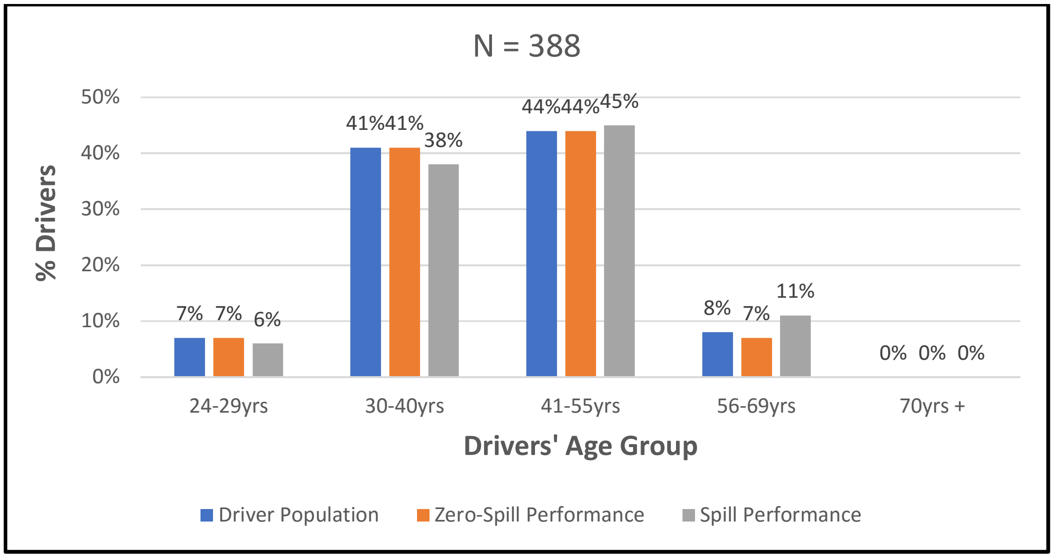

Figure 4.7: Spill performance of drivers, based on age

Source: Field data, 2022

It was observed that drivers in the 56 – 69 years age group, who represented 8% of the total population, achieved 7% of zero-spill performance. So, the contribution of this group of drivers to good performance (zero-spill) was proportionally lower. The other three groups of drivers (i.e., 24 – 29 years, 30 – 40 years and 41 – 55 years) achieved zero-spill performance equal to their proportional size. The only driver in the 70yrs+ group incurred zero-spill, as well.

The analysis revealed that only drivers in 24 – 29 years age and 30 – 40 years age groups incurred spills lower than their proportionate size, with the former achieving 6% of spills, and the latter 38%. Drivers in 41 – 55 years group, who represented 44% of the population, contributed 45% of spills. Drivers in 56 – 69 years age, who represented 8% of the population, contributed 11% of the spills. For both groups of drivers, 41 – 55 years and 56 – 69 years, their contribution to oil spills was higher (worse) than their respective population sizes. Therefore, both groups of drivers negatively impacted the performance of the transporters and the oil marketing companies they worked for.

This analysis revealed drivers in the age group of 56 – 69 years had the worst product spill performance of the population of drivers that participated in the survey. This finding is agreement with the findings of researches (Eboli, et al; 2019), who identified that drivers in the age range of 65 years and above had the worst road transport performance, including fatalities.

After review of the foregoing analyses of drivers' age and their performance, it was observed that drivers in the 30 – 40 age group had the best performance in terms of prevention of accidents, injuries and spills, and they made the most effective contributions towards sustainability of the business. These drivers made the highest proportionate contributions towards achievement of zero-accident (43%), and had the least percentage (33%) of accidents when compared with its group size of 41% of total driver population. The same group of drivers achieved zero-injury performance of 42%, which is better than its group size, and had the least contributions to injuries (23%) compared with its size of 41%. When the spill performance is assessed, this group of drivers achieved good performance, contributing 38% of the number of spills compared to its size. Therefore, this group of drivers made the greatest contributions to driving safely and performance, through minimal spill; and greatest contributions to productivity through minimal accidents and injuries. This study highlighted that, if focus is given to recruitment of drivers in that age group (30 – 40 years), followed by adequate training, it could contribute to reduction in accidents and DRR in road transportation of petroleum products.

The challenge of reckless driving by tanker drivers in the Kenya petroleum industry has been identified by other studies (Omuterema, et *al.*; 2009). Reckless driving and inadequate assessment of risks can eventually result in disasters, as the case with the Sachangwan petrol tanker disaster.

It has been shown that young drivers do not have enough experience with driving, estimating speed, distance or risks presented by other road users. They overestimate their driving skills, which can also lead to speeding and non-adjustment of driving. Young drivers incur more mistakes during assessment of difficulty of the route, or the road surface (Bucsuházy, *et al.* 2020). This group of young drivers were found to be usually in the late teens to early twenties.

Research in India identified the age group 30-59 years as the most vulnerable population group of drivers. More than half of the road accident fatalities are faced by this group, which accounts for less than one third of the total population (Singh, 2017). However, this study revealed that, within that broad population group of 30 – 59 years, which is the economically most active period, drivers in the 30 – 40 years age group incurred the least proportional injuries amongst tanker drivers, and had best accident and best spill performance.

4.2.4 Driving experiences and accidents

In this section, the accident performance of tanker drivers, based on their driving experience, was investigated. An analysis was carried out on driving experience of drivers and involvement in accidents. Tables 4.10 to 4.12 present data of accidents incurred on the basis of driving experience, and their analysis, whilst Figure 4.8 presents accident performance on the basis of driving experience. The breakdown of number of motor accidents incurred by tanker drivers based on their years of driving experiences were as indicated in Table 4.10

Table 4.10: Breakdown of vehicle accidents performance, based on driving experience

Driving experience	Number of Motor Vehicle Accidents					
	0	**1-5**	**6-10**	**11-15**	**>15**	**TOTAL**
>15yrs	30	11	0	1	2	44
11-15yrs	47	16	0	5	0	68
6-10yrs	121	20	2	0	0	143
1-5yrs	94	15	1	0	0	110
<1yr	18	2	0	0	0	20
TOTAL	**310**	**64**	**3**	**6**	**2**	**385**

Source: Field data, 2022

A Chi-Square test was carried out from table 4.10 to find out if the association between driving experience of the drivers and the number of motor vehicle accidents they were involved in were statistically significant. The analysis was as presented in Table 4.11.

Table 4.11: Chi-Square test of the association between drivers experience and number of motor accidents

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	44.614[a]	16	.000
Likelihood Ratio	35.669	16	.003
Linear-by-Linear Association	17.670	1	.000
N of Valid Cases	385		

a. 16 cells (64.0%) have expected count less than 5. The minimum expected count is .10.

Source: Field data, 2022

It was clearly seen that $\chi(1) = 44.614$, $p = 0.000$ confirmed there was a statistical significance association between driving experience of the drivers and motor vehicle accidents; i.e., drivers with different experience do not equally cause road accidents.

The One-Sample t-test analysis revealed there was significant difference among the drivers with different driving experience.

Table 4.12: One sample t-test to determine if there was a difference of driving experience among drivers who had no accidents

One-Sample Test						
	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	Df	Sig. (2-tailed)	Mean Difference	Lower	Upper
0 Accidents	3.162	4	.034	62.0000	7.558	116.442

Source: Field data, 2022

Table 4.12 indicated a significant difference among the experienced tanker drivers who achieved zero-accident, since the significance level of 0.034 was less than 0.05. An analysis of the driving experience of tanker drivers against accidents incurred was carried out, and results graphically represented in Figure 4.8.

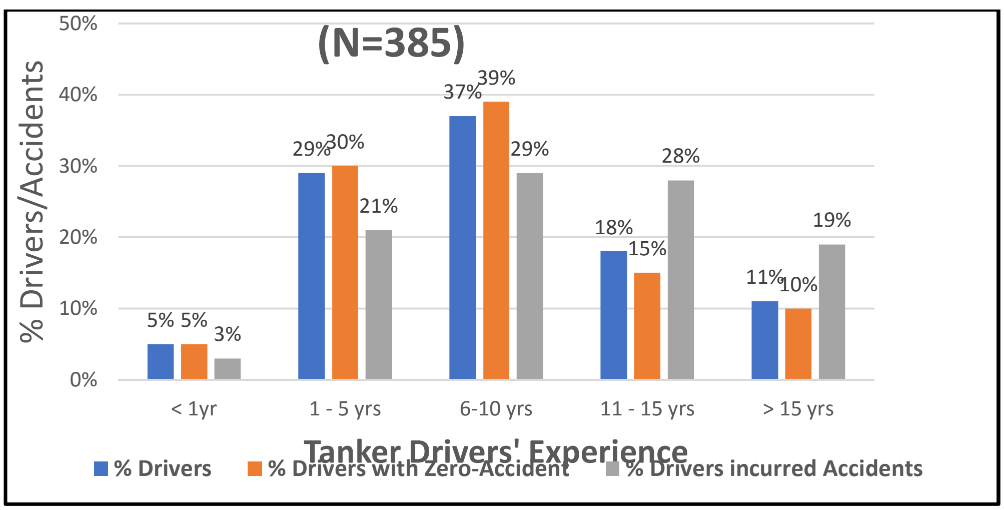

Figure 4.8: Graph showing tanker driver's experience and the percentage of accidents caused

Source: Field data, 2022

For sustainable management of transportation of petroleum products, transporters' objective should be to encourage drivers to aim for achievement of zero-accident performance, and minimize accident rate. Figure 4.8 highlights that, only drivers who had 1 – 5 years' driving experience and 6 – 10 years driving experience achieved higher proportional zero-accident performance compared with their respective group sizes. Drivers with 1 – 5 years' experience, who represented 29% of the population, achieved 30% of the overall zero-accident performance, whilst they contributed 21% of the overall number of accidents. Drivers with 6 – 10 years' experience represented 37% of total population and contributed 39% of the zero-accident performance, whilst contributing 29% of the accidents. From the analysis, it was observed that the zero-accident performance of drivers with 6 – 10 years' experience was marginally better than drivers with 1 – 5 years' experience.

The analysis revealed drivers in the group of 11 – 15 years' experience, who represented 18% of the population, achieved 15% of the overall zero-accident performance, but incurred 28% of the overall number of accidents. In like manner, drivers with over 15 years' experience, who represented 11% of the tanker driver population, achieved 10% of the zero-accident performance, whilst contributing 19% of the overall accidents.

It was observed that drivers with less than one year experience, who represented 5% of the overall driver population, achieved 5% of zero-accident performance, and contributed 3% of the total accidents. This performance is mitigated by the fact that the lower percentage of accidents, compared to group size, could be due to low driving hours exposure.

The foregoing analysis implied drivers in the experience groups of 1 – 5 years and 6 – 10 years contributed more to the business performance through improved zero-accident performance compared to their group size, and lower proportional accident rate. The analysis further revealed that drivers with 6 – 10 years' experience had the best overall performance with respect to zero-accident performance and proportional accidents incurred when compared with tanker drivers of different driving experience.

Unlike the research by Hordofa, *et al* (2018) that suggested driving experience of drivers was not a determinant factor for fatal accidents, this study has shown drivers with driving experience of 6 – 10 years contributed most to safe driving without incurring accidents, and had the least accident rate.

Inexperienced drivers represent high risks to other road users and, in newly motorized societies, the risk gets increased due to relatively high proportion of new drivers in the driving population. In countries like India where this growth is accompanied by inadequate driver training and testing facilities, the risk gets further increased (Singh; 2017).

Road accidents involving tankers are usually the first event that happens, leading to product spills, fire and explosion disasters, as in Sachangwan tanker disaster. Ewbank, *et al* (2019) have demonstrated the role of road safety in prevention of road tanker disasters. The importance of appropriate driving experience, and effectiveness of defensive driving training, in the prevention of disasters during road transport of petroleum products has been well documented. The findings of this study are in consonant with earlier research, and revealed that experience of tanker drivers can contribute to prevention of accidents.

Over the years, road accident data has been used to evaluate improvement in road safety and effectiveness of initiatives deployed to reduce deaths, injuries, spills, fire and explosion. However, understanding the underlying factors that lead to the accidents would enable risk reduction techniques to be explored. Abbasi *et al.,* (2017) identified vehicle accident initiating events as vehicle defects, human factors and road defects. Therefore, when focus is given to these initiating events, instead of road accident data and statistics, sustainable improvement can be achieved.

Both vehicle defects and road defects can also be considered outcome of human factor failures. Vehicle defects that are not addressed or identified, and deficient road infrastructure are outcome of human failures Therefore, it can be concluded that human factors are the most significant issue in road accident initiation. Olemo (2016) found out that human factors in road accident causation in Nairobi could be as high as 94%. Road accidents have become a global public health concern, with a big percentage of the accidents coming from low and middle-income countries. Despite the fact that Africa is the least motorized (2%) of the world, it accounts for 16% of the globally recorded deaths from road accidents (Uzondu *et al*., 2018). Continuous training of tanker drivers, in addition to considerations of appropriate level of driving experience, should improve performance of transporters in the petroleum industry and contribute to sustainability.

From the foregoing analysis and findings, driving experience of tanker drivers is one of the factors that should be considered in disaster risk reduction during transportation of petroleum products. This is in addition to the age of drivers, as identified in the previous section.

4.2.5 Education and performance of tanker drivers

The study investigated the educational levels of tanker drivers that participated in the survey. An analysis was carried out on the accident performance of tanker drivers based on their educational levels. The breakdown of number of motor accidents incurred by tanker drivers based on their educational level were as indicated in Table 4.13.

Table 4.13: Breakdown of accidents based on educational levels of drivers

		Drivers who incurred Motor Vehicle Accidents					
Education Level	**Number of Drivers**	**Zero**	**1-5**	**6-10**	**11-15**	**>15**	**Total Drivers incurred Accidents**
No Schooling	11	7	3	1	0	0	4
Primary	80	61	14	0	4	0	18
Secondary	259	213	40	2	2	0	44
Tertiary	40	32	8	0	0	0	8
Total	390	313	65	3	6	0	74

Source: Field data, 2022

Of the drivers that provided data about their educational levels, 80% (n = 313) indicated they had not been involved in any accident. Figure 4.9 presents accident performance of the tanker drivers, based on their educational levels.

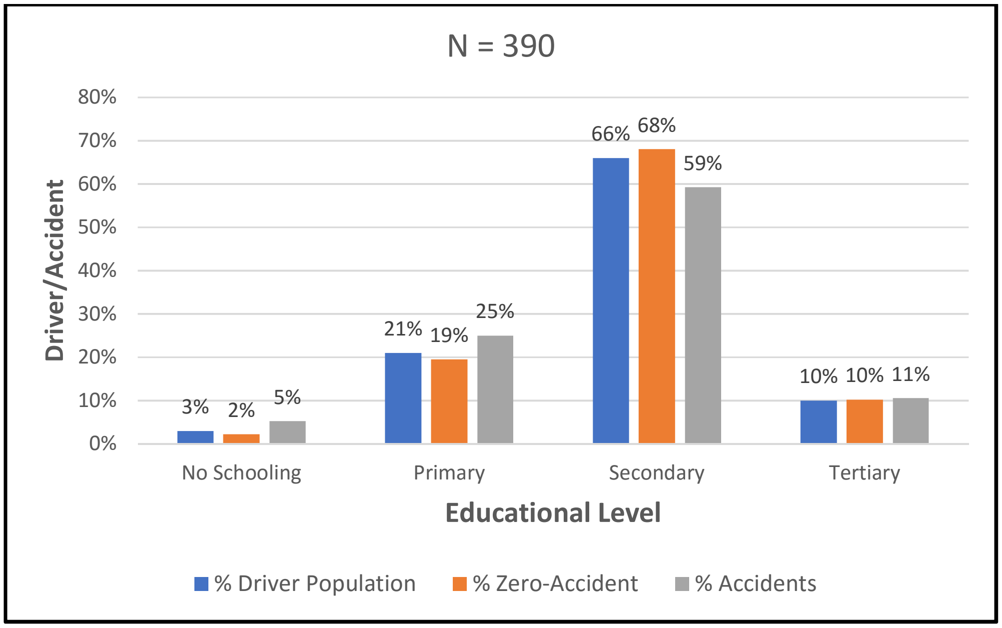

Figure 4.9: Accident Performance of drivers based on educational levels

Source: Field data, 2022

It was observed that, whilst drivers with no formal education represented 3% of the entire population, they achieved 2% of the zero-accident performance, whilst contributing 5% of the accidents. Drivers with primary education represented 21% of the entire tanker driver population, and achieved 19% of zero-accident, but contributed 25% of the accidents. Drivers with secondary education represented 66% of the population, achieved 68% of zero-accident performance, and contributed 59% of the total accidents. Drivers with tertiary education represented 10% of the driver population, achieved 10% of zero-accident and contributed 11% of the accidents incurred.

From the foregoing analysis, tanker drivers with secondary education achieved the best road safety performance, achieving proportionally higher zero-accident performance, and contributing proportionally lower to accident rate. Drivers with tertiary education had the next good performance, but with marginally higher accident rate (11%) than its group size. It was observed that drivers with no formal schooling had the worst performance, as they achieved proportionally lower zero-accident and contributed almost twice the accidents proportionally compared with their size. As expected, there is a strong correlation between level of education and accidents incurred. It can be summarised those drivers with minimum secondary education had good road safety performance compared with drivers with no formal schooling or primary education alone.

Education is important in understanding traffic rules, transport policies, guidelines, and provides knowledge for encouraging compliance. Researchers have concluded that educational level plays a crucial role as a factor in road accidents. The high mortality rate of illiterate and low-literate in various age groups indicate that educational level is an important factor in road accidents, requiring related organizations to take necessary measures and introduce appropriate policies (Lofti *et al.,* 2019). Higher educational levels seemed to improve awareness of risks.

Research has also shown that educational level of drivers can be a predictor of fatal accidents, as drivers with low education incurred high percentage of fatal incidents compared with drivers with higher level of education (Hordofa et *al.*, 2018). This study is in consonance with contemporary findings of research, and has highlighted educational level as a factor that contributes to disaster risk reduction. Improvement in risk awareness at higher educational levels would enable the tanker drivers to become safer by not getting involved in risk-taking manoeuvres.

4.3 Remuneration and the performance of tanker drivers

An analysis was carried out to determine if salary of tanker drivers could contribute to reduction of disaster risks, and improve their performance. The analysis investigated the relationship of salaries to the performance of drivers, and if it influenced their motivation to drive safely without accidents. The graphical representation of the drivers' performance based on monthly salary is shown in Figure 4.10.

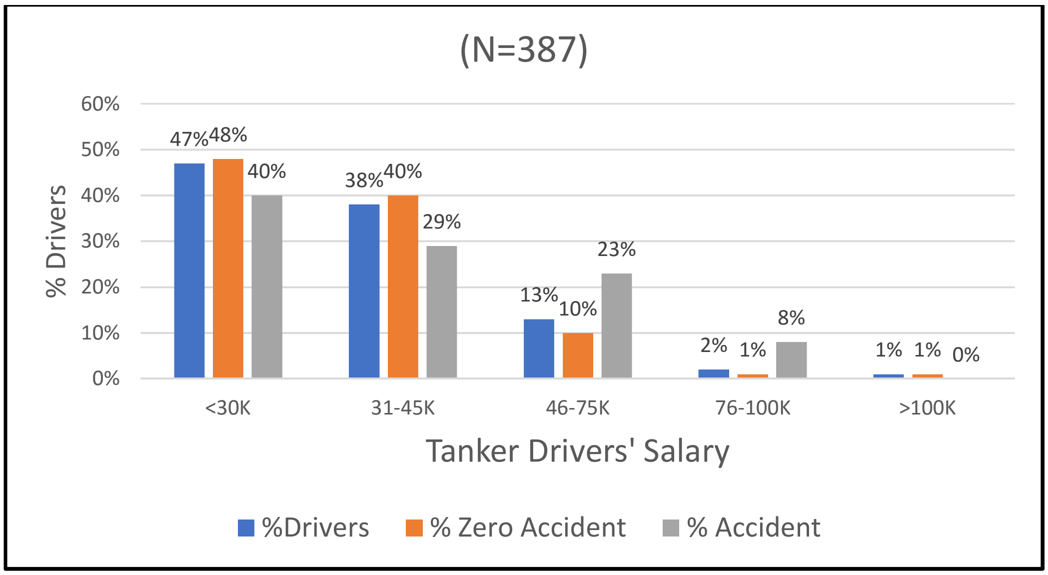

Figure 4.10: Graph showing tanker drivers' salaries versus accident performance

Source: Field data, 2022

Of the 387 drivers who provided responses on salary and accidents, 81% (n=312) of them had not been involved in any accident. 47% (n=181) of the drivers earned monthly salary less than 30,000 Shillings ($200) achieved 48% of the overall zero-accident performance and incurred 40% of the accidents. 38% (n=148) of the drivers earned salary between 31,000 and 45,000 Shillings ($207 - $300), achieved 40% of zero-accident performance, and incurred 29% of accidents.

13% (n=49) of the drivers earned between 46,000 and 75,000 Shillings ($307 - $500), but achieved 10% of zero-accident performance and 23% of the accidents. 2% (n=9) of the drivers earned between 75,000 and 100,000 Shillings ($507 - $667), but achieved 1% of zero-accident performance, and 8% of accidents incurred. 1% (n=2) of the drivers earned salary over 100,000 Shillings ($667), achieved 1% of zero-accident performance, with no accident.

The foregoing analysis revealed that, apart from drivers who earned above 100,000 Shillings ($667) the lower-paid drivers' groups of both those earning less than 30,000 Shillings ($200) and those earning between 31,000 – 45,000 Shillings ($207 - $300) achieved consistently good accident performance. These groups of drivers achieved higher zero-accident performance compared with their size, and lower proportional accident rate. Drivers in salary groups of 46,000 – 75,000 Shillings ($307 - $500) and 76,000 – 100,000 Shillings ($507 - $667) achieved lower zero-accident performance and higher proportional accident rate.

The foregoing analysis implies salary levels cannot be directly linked to disaster risk reduction. This is not in consonance with the conclusion by Rodriguez, et al (2003) that higher salary and pay raises are related to lower expected crash counts and to a higher probability of zero crash counts, all other things being equal. This study reveals salary alone cannot be a motivating factor for driving safely to prevent accidents. Instead, the need to stay alive, family considerations and good working environment may be more compelling factors for safe driving. However, it was observed that the two best-paid drivers, earning over 100,000 Shillings ($667) per month, were not involved in any accident. This performance may imply that earning a good salary could be an encouragement for safe driving, even if it not a factor in DRR.

4.4 Summary

From foregoing analysis in this chapter, the age group of drivers who contributed most to safe driving, and prevention of motor accidents, injuries and spills, are those in the 30 – 40 years group. This group of drivers are energetic, teachable and adaptable to changes in a fast-moving world. It has been posited that the age of crew members could have impact on their safety awareness and involvement in accidents. Nævestad *et al* (2019) demonstrated that the youngest group of crew members had the highest rate of injuries in the maritime transport industry. Due to reasons of maturity and responsibility that come with age, it is recommended that tanker drivers should be minimum 30 years. Eboli *et al.,* (2019) demonstrated that age of drivers is a significant factor in road accidents. Some researchers have shown that majority of accidents (about three-quarters) are caused by young drivers between the ages of 18 – 30 years (Hordofar, *et al*. 2018). This is congruent with this study, which revealed that age range of 30 – 40 years is best performing age for tanker drivers. It is recommended that government and industry regulators put in place legislation and standards to ensure recruitment of tanker drivers comply with the minimum age requirement in order to prevent future disasters in the transport of petroleum products.

Driving experience of drivers has been identified as an area for improvement in safe driving and prevention of accidents/disasters. Whilst Olemo (2016) estimated that approximately 94% of road accidents were caused by human factors, Hordofar *et al.*, (2018) estimated 89% of fatal accidents were caused by drivers, whilst 6% were caused by pedestrians, bringing total human factors contributions to about 95%.

A high percentage of accidents are caused by the lack of experience of young drivers, as well as their high risk-taking behaviour (Hordofar, *et al.,* 2018). This underscores the importance of experience and safety awareness in prevention of accidents, injuries and spills that could lead to disasters. It is the responsibility of supervisors to ensure drivers have the appropriate experience, and are exposed to relevant training to improve their safety awareness, before being allowed to drive road petroleum tankers. This study revealed that drivers with experience of 6 – 10 years made most contributions to prevention of accidents. Through training, drivers will improve their safety awareness and avoid risk-taking behaviour. This study has suggested that industry regulators establish the minimum driving experience as six years for tanker drivers. Following the establishment of the minimum driving experience, industry regulators should ensure it is fully enforced. Enforcement of compliance with industry rules is seen as a key area for prevention of disasters during road transport of petroleum products in Kenya.

A major aspect of human factors issue is risk awareness, and three types of drivers have been identified according to their driving style. These are Defensive, Neutral and Risky drivers (Bucsuházy *et al.,* 2020). Defensive drivers drive with due respect to his/her own abilities, obey rules of road traffic, and safety focus. These drivers have developed adequate awareness about road safety, and can anticipate errors from other road users. Risky drivers are less likely to predict the development of the traffic situation and the behavior of other traffic participants. They take risk and overestimate their driving skills. Neutral drivers are at the border between Defensive and Risky drivers; they do not intentionally violate driving rules, and if so, they do not repeat it. Neutral drivers mostly trust their abilities, but get involved in accidents because they do not anticipate others driving unsafely. The intention of the defensive driving course for tanker drivers is to increase their safety awareness and get them into the first type of drivers – Defensive.

The results of the survey point to drivers in the age group of 30 – 40 years, with driving experience 6 – 10 years, as being most suitable for training to develop safety awareness to be able to prevent accidents, and achieve breakthrough performance in the industry.

Researchers and practitioners have gradually recognized the importance of organizational culture in road transport safety performance. Safety climate can be taken as a single factor containing management values, communication, training and safety systems that will improve road safety behaviour (Keffane, 2014). This study revealed the educational level of the driver affected his/her ability to benefit from training received. Tanker drivers with no formal schooling had the poorest driving safety performance, followed by drivers with only Primary level education. The study revealed drivers with secondary education achieved the best performance.

Given the responses by tanker drivers to the questionnaire in this study, analysis of the data, and engagements with tanker drivers, the study revealed human factor issues have enormous impact on occurrence, or prevention, of accidents and disasters in road transport of petroleum products. From the study, factors influencing disaster risks during road transport of petroleum products include:

1. Age of tanker drivers. The study identified drivers between 30 – 40 years as being the best performing group, with good potentials for driving safely.

2. Driving experience. The experience of drivers, with proper training, provide ability to cope with the challenges of transportation of petroleum products. The study revealed drivers with 6 – 10 years' experience had the best performance.
3. Educational level of tanker drivers. The educational level of drivers provides the ability to understand traffic rules, and also ability to benefit from the training the job entails. The study revealed minimum educational level should be completion of secondary education.

These factors require the attention of management of transport companies, petroleum products organizations, and regulators, in particular EPRA and NTSA. The certification process for tanker drivers should be reviewed to include minimum age, driving experience, and minimum educational level. In addition, there should be mandatory attendance at defensive driving and petroleum product handling courses.

CHAPTER FIVE

ROOT CAUSES OF DISASTERS DURING TRANSPORTATION OF PETROLEUM PRODUCTS

This chapter discusses findings of the study for DRR in road transportation of petroleum products by haulers, and analysis of root causes of disasters. Petroleum products marketing companies use specialist haulers to transport products, including petrol, diesel, kerosene, lubricating oil, liquefied petroleum gas (LPG), etc. The haulers are responsible for managing their tanker drivers to drive safely and prevent accidents that could lead to disasters. In the previous chapter, focus was on tanker drivers. In this chapter, focus is on haulers (transporters) and the managers responsible for supervising the drivers. For the purpose of this study, the transporters who work in the petroleum industry were divided into the three groups presented under Research Design in Section 3.4:

1. Small Oil Transporters (SOT): these are small transporters that have up to nine tankers in their fleet to provide services to oil marketing companies
2. Medium Oil Transporters (MOT): these are medium-sized transporters that have between 10 and 49 tankers in their fleet
3. Large Oil Transporters (LOT): these companies have 50 or more tankers in their fleet.

The drivers that participated in the survey for this study belonged to one of the three categories, given their employers provided petroleum product transport services to the oil marketing companies in Kenya. The petroleum products marketing companies involved in this study did not own or directly operate road tankers. It was observed that some tanker drivers did not provide the name of their transporters (employers), despite repeated reminders for inclusion of the names. It is suspected some drivers refused to provide the names of their employers for fear of possible retribution. As a result, data of those

drivers could not be included in the analysis for transporters.

5.1 Road safety performance of transporters

The analysis of the motor accident and spill performance of each of the three categories of transporters was carried out. Tables 5.1 to 5.3 present data of accidents and spills incurred of tanker drivers of the transporters, and their analysis, whilst Figure 5.1 presents accident spill performance of the three classes of transporters. The breakdown of the performance of the three classes of transporters in terms of accidents and spills was as presented in Table 5.1.

Table 5.1: Breakdown of Transporters Accident and Spill Performance

Transporter	Total # of Drivers (%)	Drivers with Zero-Accident	Drivers who had Accidents	Drivers with Zero-Spill	Drivers with who had Spill
SOT	57 (18%)	48	3	55	1
MOT	24 (8%)	18	6	19	4
LOT	237 (74%)	182	51	211	24
TOTAL	318 (100%)	248	60	285	29

Source: Field data, 2022

The analysis of variance and comparison of means among the three oil transporters was carried out, and the analysis was as shown in Tables 5.2 and 5.3.

Table 5.2: The ANOVA of transporters and level of accidents and oil spill

Tests of Between-Subjects Effects					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	108619.500[a]	6	18103.250	5.672	.011
Intercept	96721.000	1	96721.000	30.302	.000
Transporters	58170.500	3	19390.167	6.075	.015
Accident & Spill	50449.000	3	16816.333	5.268	.023
Error	28727.500	9	3191.944		
Total	234068.000	16			
Corrected Total	137347.000	15			

a. R Squared = .791 (Adjusted R Squared = .651)

Source: Field data, 2022

From Table 5.2, there was a significant difference in the transporters with regards to causing accidents and oil spills. The mean comparison of the three transporters was presented in Table 5.3, and it implied that transporters made different contributions to causation of road accident and spill, which could be attributable to how the transporters manage their drivers.

Table 5.3: Multiple comparisons of the three transporters

Multiple Comparisons						
					95% Confidence Interval	
(I) Transporters	(J) Transporters	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
SOT	MOT	15.0000	31.50551	.885	-81.6676	111.6676
	LOT	-90.2500	31.50551	.064	-186.9176	6.4176
MOT	SOT	-15.0000	31.50551	.885	-111.6676	81.6676
	LOT	-105.2500*	31.50551	.036	-201.9176	-8.5824
LOT	SOT	90.2500	31.50551	.064	-6.4176	186.9176
	MOT	105.2500*	31.50551	.036	8.5824	201.9176

Based on observed means.
The error term is Mean Square(Error) = 1985.194.

*. The mean difference is significant at the 0.05 level.

Source: Field data, 2022

From Table 5.3, there was a significant difference in MOT and LOT transporters in terms of causing road accident and oil spill; since for both 0.036 was less than 0.05, i.e., drivers in MOT and LOT transporters had differences in terms of causing accident and spill.

The analysis of performance of the transporters, in terms of accidents and spills, compared with the size (percentage) of their drivers' population is presented in Figure 5.1.

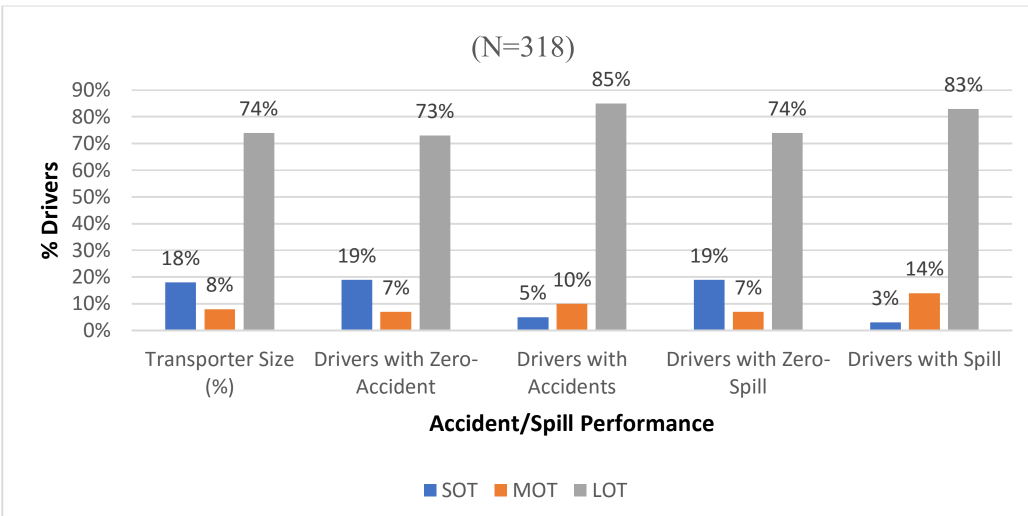

Figure 5.1: Accident and spill performance of transporters compared with their size

Source: Field data, 2022

With respect to zero-accident and zero-spill performance, SOT transporters were the only group that achieved performance better than their proportionate population size, achieving 19% of the overall performance, though size was 18% of overall population. SOT transporters incurred 5% of accidents and 3% of spills, against their population size of 18%. So, for both types of performance, zero-incident and accidents/spills, SOT transporters performed better than their proportionate size.

MOT transporters contributed 7% of zero-accident, and also 7% of zero-spill, though their size was 8%. This implies MOT transporters had worse performance with respect to prevention of accidents and spills. MOT transporters contributed 10% of the accidents and 14% of the spills, also worse (higher) than their population size.

Whilst LOT transporters represented 74% of the tanker driver population, their drivers contributed 85% of the accidents and 83% of the spills. The drivers also contributed 73% of zero-accident performance, which was worse than their size, and 74% of zero-spill, which was the same ratio as their size.

From this analysis, LOT is considered the worst-performing group of transporters. The study reviewed some of the issues that could have been responsible for the performances of the transporters in the analysis of the root causes of disasters in transportation of petroleum products in the area of study.

5.2 Analysis of the root causes of disasters in road transport of products

In order to arrive at the root causes of disasters in the transportation of petroleum products, the study reviewed the performance of the three categories of transporters with respect to their operations, compliance with rules and effectiveness of the organisations in managing tanker drivers.

5.2.1 Transporters' non-compliance with procedures and rules

The research survey covered compliance with road transport directives, legislative requirements and general driving rules put in place to prevent accidents. The questionnaire focused on establishing if drivers understood rules that are applicable in the transport industry, and agreed or disagreed with them. Disagreement with the rules, possibly due to lack of understanding of the rules, and their objectives, could be a first step towards non-compliance with rules. A conscious violation of rules could be either due to lack of understanding or non-agreement. Hence, this study summed both scenarios under non-compliance.

A breakdown of drivers that disagreed with, or expressed lack of understanding of, driving rules was carried out, and classified as non-compliance. This was followed by an analysis of impact of non-compliance on transporters performance. Tables 5.4 and 5.5 present data of non-agreement with driving rules/procedures, whilst Figure 5.2 presents analysis on potential non-compliance by the three categories of transporters. Table 5.4 presents the breakdown of drivers' responses on the 10 rules covered in the questionnaire, based on age of the drivers.

Table 5.4: Breakdown of disagreement with rules, or lack of understanding, based on drivers' age

	Number of tanker drivers indicated non-agreement or lack of understanding					
Driving rules	24-29yrs	30-40yrs	41-55yrs	56-69yrs	>70yr	Total #
Minimum age limit of 30yrs	12	76	61	6	0	155
Hold valid national driving license	3	27	19	0	0	49
Hold transporter's driving permit	2	28	35	3	0	68
Minimum 5yr driving experience	5	20	21	2		48
Be medically certified every year	0	9	7	0	0	16
Check that all wear seatbelts in cabin	0	4	3	1	0	8
Never use mobile phone when driving	0	0	1	0	0	1
Be well rested (driving hours, etc)	0	7	7	3	0	17
No alcohol or drugs	1	6	5	1	0	13
In-cabin On-board Computer (OBC)	2	31	27	3	0	63

Source: Field data, 2022

Analysis of the responses revealed four rules had the highest numbers of non-compliance, after discountenance of the rule for national driving license, which is a mandatory legal requirement. It was surprising that tanker drivers could disagree with the legislative requirement for driving license. However, it subsequently became clear it was not unconnected with the misunderstanding about various classes of driving license. The misunderstanding covered different driving licenses for cars, trucks and professional driving licenses, for which there appeared to be inadequate clarity.

The four rules with highest numbers of disagreement were: 30-year age limit; driving permit issuance by transporters; minimum 5-year driving experience; and use of in-cabin on-board Computer (OBC). The four rules were analysed on the basis of category of transporters and the breakdown of disagreements with the rules is presented in Table 5.5.

Table 5.5: Breakdown of drivers' disagreement & lack of understanding with the four key road transport rules

times	No. of Drivers	Rule of 30yrs age limit	Rule of Minimum 5yrs Experience	Transporter Driving Permit	Rule of OBC
SOT	57	16	5	1	12
MOT	24	2	1	2	3
LOT	237	94	20	30	31
TOTAL	**318**	**112**	**26**	**33**	**46**

Source: Field data, 2022

In order to evaluate the spread of potential non-compliance amongst the three transporters, the analysis investigated the percentage of drivers that disagreed with the four rules. An overview of disagreement or lack of understanding with the rules is shown in Figure 5.2.

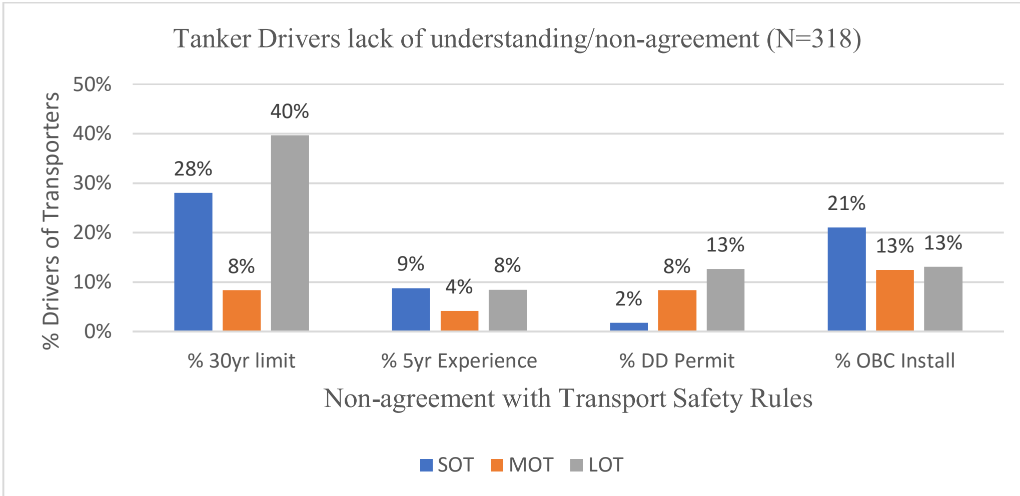

Figure 5.2: Breakdown of tanker drivers' non-agreement with rules or lack of understanding

Source: Field data, 2022

It was observed that LOT drivers, who had the highest contributions to accidents (Figure 5.1), also had the highest percentage (40%) of disagreement with the rule of minimum 30-years age for tanker drivers. That is, of the LOT drivers that responded to the survey, 40% of them disagreed with the rule. The analysis revealed that, LOT drivers had the worst level of non-agreement with driving rules in general, and also had the worst accident and spill performance. This could be an indication that the performance of transporters and their drivers could be linked to their level of compliance with rules and procedures. LOT drivers also had the highest percentage (13%) of non-agreement with the rule on issuance of driving permit by the transporters. The permit is normally issued by transporters to tanker drivers after the drivers have participated in defensive driving training.

SOT tanker drivers had the best accident and oil spill performance (Figure 5.3). It was observed that 28% of the drivers disagreed with the 30-year age limit, whilst 21% of them disagreed with the implementation of On-board Computers (OBC) in the tanker truck cabin.

The analysis of level of disagreements by drivers of the three categories of transporters revealed MOT as having the least level of non-compliance, with 8% non-compliance with the rule on 30-year age limit. In addition, MOT drivers had the least non-compliance of 4% on the rule for minimum five years' driving experience.

Disagreement with the rule on OBC implied the tanker drivers did not understand its importance in monitoring the driving behaviour of drivers, and highlighting areas for improvement, to prevent accidents. The OBC monitors parameters such as harsh-braking, over-speeding, over-revving, engine idling period, driver duty period, driving hours, rest periods, night driving, and compliance or non-compliance with use of authorized routes. By reviewing these parameters on completion of journeys, each driver can be counselled on infractions and areas of non-compliance. In the petroleum products transport industry, the OBC is referred to as the "silent policeman", given it provides adequate data for monitoring the driver, in order to encourage compliance with driving rules. The study observed not all transporters have installed OBC in the cabin of their trucks, neither has the regulator made it mandatory.

Disagreements with procedures and driving rules implied inadequate safety awareness by the drivers, which led to non-compliance. It was also perceived to be a reflection of the level of management engagement with the drivers in the organization, to ensure they understand the importance of safety and compliance with road transport rules. Procedures are put in place to ensure drivers carry out their activities safely, and avoid accidents. Procedures identify barriers that need to be put in place to prevent accidents, and the roles of the action parties - in this case, the drivers and their supervisors – to ensure the barriers are effective. However, where procedures and rules are not being complied with, accidents and disasters occur.

The importance of a comprehensive pre-licensing program for drivers, training and renewal has been highlighted by researchers (Uzondu, 2018). After successfully attending defensive driving course, transporters issue driving permit to tanker drivers. The defensive driving course and refreshers are to ensure drivers develop skills to identify road hazards and prevent accidents in difficult environments, in spite of the mistakes of other road users. However, 13% of LOT drivers expressed non-agreement with the driving permit, which was the highest percentage of non-compliance with that specific rule by the three categories for transporters. By disagreeing with the driving permit rule, the tankers drivers implied they did not require training or refreshers in defensive driving skills for improving safe-driving behaviour, and thereby prevent accidents on the road.

Where there is non-compliance with procedures and rules, the likelihood of accidents would increase, with consequential economic loss (Tob-Ogu *et al.,* 2017). The findings of this study are in agreement with this assertion, because LOT transporters had the worst level of non-compliance, and also had the worst accident performance. It is the responsibility of transporters' management to emphasize the importance of compliance. Supervisors and managers should educate tanker drivers on the importance of driving rules, which are derived from controls required to prevent accidents and spills. In order to achieve significant improvement, and prevent accidents/spills, institutional roles and responsibilities for important functions of road safety management must be defined, i.e.

who should be responsible for the accident data register, road maintenance, vehicle inspection, vehicle register, driver training, driver testing, driving-license register, enforcement of traffic rules, emergency assistance, traffic safety analyses, research and documentation services, and training of professionals (Varhelyi, 2016). With these in place, tanker drivers would appreciate the importance of compliance with driving rules as a critical step in accident and disaster prevention.

Non-compliance with rules is largely due to lack of adequate safety education (Uzondu, 2018). It is the responsibility of managers to improve safety awareness of the drivers in their organization, and ensure they understand the importance of rules. Raising compliance with traffic safety law has been a key contributor to success in countries that have shown lower levels of road safety incidents in Europe e.g., France, Luxembourg, Belgium and Portugal (ETSC, 2007). Road transport safety procedures and rules are put in place to act as barriers to accidents that could ultimately lead to disasters. When drivers comply with such rules, they significantly reduce the risks of accidents. As drivers are often on their own, without direct supervision when they drive, their compliance or non-compliance would depend on whether they understand the rules, and believe the rules are important in prevention of accidents. Through training, the organisation can ensure drivers understand the need for each rule, and how they contribute to accident prevention. When the importance of compliance with procedures is well communicated, and drivers understand the benefits, as well as knowing procedures are meant for their own safety, they would comply naturally, rather than being forced to comply. It is appreciated that drivers and workers generally do not go to work each day with the intention of creating accidents, but the environment (organisation) in which they work also creates the environment for accidents to happen.

5.2.2 Effectiveness of Transporters' Organization

In this section, an evaluation was carried out of the effectiveness of the transporters' organization. Their overall performance was reviewed, based on contributions of tanker drivers, their driving experience and age. Figures 5.3 and 5.4 present the driving experience and age of the drivers in each of the three categories of transporters.

The study observed that the quality of tanker drivers working for transporters reflected the effectiveness of transporters in attraction, recruitment and retention of drivers, and in turn impacted the performance of the transporters. Driving experience and age group of drivers were used to evaluate the transporters. Analysis of driving experience within the categories of transporters carried out, and findings were as presented in Figure 5.3.

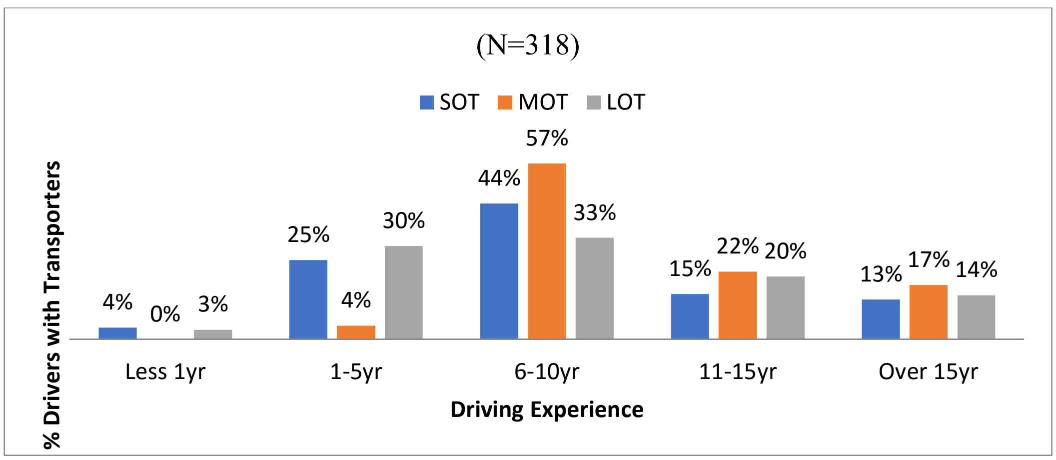

Figure 5.3: Driving Experience of Transporters' Drivers

Source: Field data, 2022

The study revealed tanker drivers with experience 6 – 10 years represented the most dominant group, being 46% of the overall tanker driver population. In Chapter 4, the study revealed the drivers in this experience group had the best safe-driving performance of the various age groups (as highlighted in Section 4.2.4). It was observed from Figure 5.2, LOT transporters had the lowest percentage (33%) of drivers in the group of 6 – 10 years' experience, whilst MOT drivers had 57% of these drivers, and SOT had 44% of these drivers. This showed that selection and recruitment of the right experience level by each transporter contributed to their performance.

The age of tanker drivers within the organisation could have contributed to the performance of the three categories of transporters. The study therefore carried out an analysis of the age of tanker drivers within the transporters' organisations, as presented in Figure 5.4.

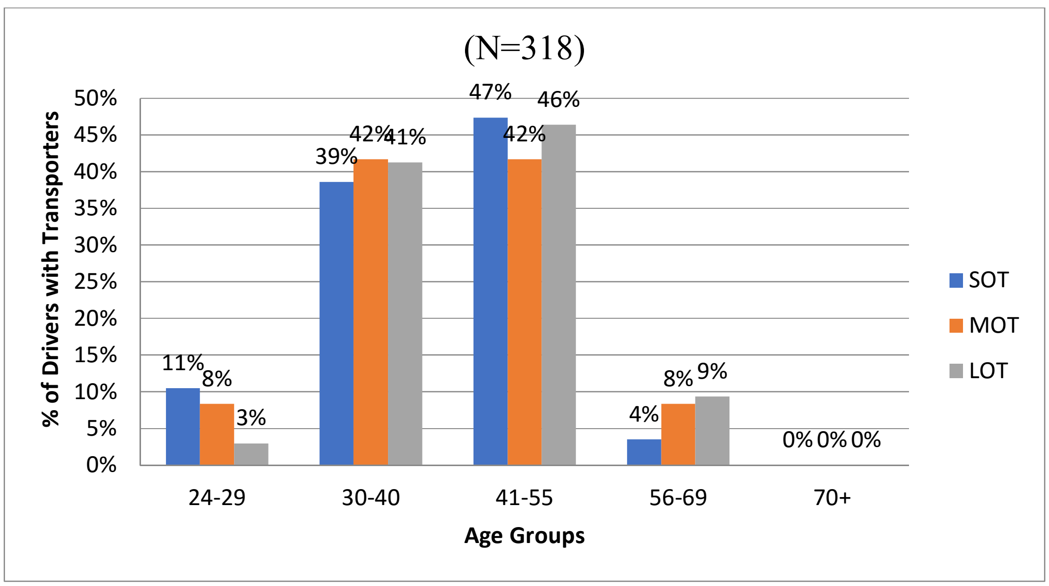

Figure 5.4: Age distribution of drivers amongst the transporter groups

Source: Field data, 2022

It was observed that LOT transporters had the highest percentage of ageing drivers within the group of 56 – 69 years, at 9%. MOT had 8% whilst SOT had 4% of drivers within the same age group. SOT transporters had the highest ratio of young drivers between ages 24 – 29 years at 11%. All the transporters had most of their drivers within the age groups of 30 – 40 years and 41 – 55 years, representing between 84% and 88%

of each transporter group. It was observed that the most active period in the working lives of tanker drivers was between the ages of 30 and 55 years. An analysis of variance of the tanker drivers' age within the transporters' organisations was carried out and the results were as shown Table 5.6.

Table 5.6: The ANOVA of transporters and age group

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	DF	Mean Square	F	Sig.
Corrected Model	5345.067[a]	6	890.844	109.755	.000
Intercept	6000.000	1	6000.000	739.220	.000
Age Group	5344.667	4	1336.167	164.620	.000
Transporters	.400	2	.200	.025	.976
Error	64.933	8	8.117		
Total	11410.000	15			
Corrected Total	5410.000	14			

a. R Squared = .988 (Adjusted R Squared = .979)

Source: Field data, 2022

As indicated in Figure 5.6, there were no differences in the drivers' ages amongst the three transporter groups ($p>0.05$). The educational level of tanker drivers in the transporters' organization were further considered, and the breakdown was as presented in Table 5.7.

Table 5.7: Breakdown of drivers' educational levels

Drivers' Educational Level	Tertiary	Secondary	Primary	Drivers With No Formal Schooling	Total
SOT	5	40	12	0	57
MOT	2	19	3	0	24
LOT	28	148	51	10	237
TOTAL	**35**	**207**	**66**	**10**	**318**

Source: Field data, 2022

The analysis of variance was done to find out the significance of education level in oil transporters and the result was as shown in Table 5.8.

Table 5.8: The ANOVA of the transporters and education levels of drivers

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8671.333[a]	5	1734.267	48.929	.000
Intercept	7500.000	1	7500.000	211.599	.000
Education Level	8671.333	3	2890.444	81.549	.000
Transporters	.000	2	.000	.000	1.000
Error	212.667	6	35.444		
Total	16384.000	12			
Corrected Total	8884.000	11			

a. R Squared = .976 (Adjusted R Squared = .956)

Source: Field data, 2022

The level of education of the drivers was significantly different amongst the transporters. The analysis from Table 5.7 showed that 21% (n=66) of tanker drivers had primary education, 65% (n=208) had secondary education, and 11% (n=34) had tertiary education. Only 3% (n=10) of the total driver population did not have formal education. The educational levels of drivers of the 3 types of transporters are shown in Figure 5.5

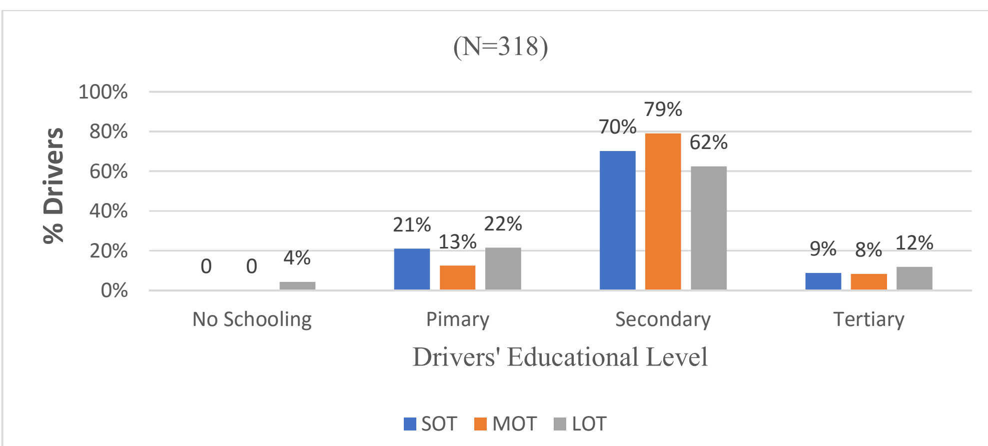

Figure 5.5: Educational levels of transporters' tanker drivers

Source: Field data, 2022

All SOT and MOT drivers had formal education, and both groups of transporters had good percentage of drivers who had secondary education, with 70% and 79% of their respective populations. The good accident and spill performance of both SOT and MOT drivers could be related to the fact that there were no illiterate drivers in the group.

It was observed that LOT drivers had the highest variable of driver education, from those with no formal education (4%) to those with tertiary education (11%). LOT transporters were the only group that had tanker drivers with no formal education. This could have contributed to the higher accident rate of LOT transporters compared to the other categories of transporters. With no formal education, it would be difficult for drivers to understand rules, procedures or traffic signage.

Sami *et al* (2013) have found significant relationships between educational level and mortality rate in road traffic accidents. It was shown that youths and uneducated people suffer more fatal road accidents. The employment of drivers without any formal schooling cannot be justified in these times.

Varhelyi (2016) has posited that best-practices in road safety management system must focus on results, and importance of governmental and top management leadership and management capacity. This emphasises the importance of transporters' leaders and managers in setting the direction for good performance. The analysis of performance of the transporters in this study revealed SOT transporters had the best performance, and 44% of their drivers had driving experience 6 – 10 years' experience. On the other hand, LOT transporters had 33% of their drivers within the experience age of 6 – 10 years' experience. This difference between the two categories of transporters reflected the ability of transporters' management in attraction, recruitment and retention of appropriate calibre of tanker drivers.

Akerboom and Maes (2006) have demonstrated that root causes (i.e., latent failures) are the result of fallible management decision, which have their origin in the organization's culture. Therefore, the transporter's organisation and its culture can be influenced by decisions taken by the management. There is no gainsaying that, by creating the right environment, management can improve the organisation's culture, contribute to addressing root causes, and reduce accidents and disasters.

The role of the transporter and its management in improving the safety awareness and performance of drivers has been well highlighted. Oggero *et al* (2005) identified the need to train transport professionals as a major issue in the prevention of accidents and disasters. Transport professionals include fleet managers, driving trainers, road safety managers, operations managers, journey managers and road transport contract holders who work closely with drivers in their business activities and their development. The leaders of transporter organisations are expected to set up guidelines for recruitment of the right calibre of drivers that can be trained to contribute towards prevention of accidents. The criteria to be considered by the transporter organisation during recruitment should include driving experience, age, education, health, among others. Organisational issues set the framework for sustainable transport operations, where accidents and disasters can be prevented through the performance of well-trained drivers and other staff.

Ewbank, *et al.* (2019) identified the most significant contributing factor to both morbidity and mortality in transportation of petroleum products was scooping of fuel. This is largely driven by underlying social environment factors when tanker accidents or rollover occur, in which a rare opportunity to gather spilled fuel by nearby community members is perceived to vastly improve one's personal and family circumstances through the use or sale of reclaimed fuel. This is a challenge that transporters need to train tanker drivers to be prepared for; to be able to warn the public and initiate access control measures that would minimize crowd access to the event site. Tanker drivers with the appropriate level of education, and increased safety awareness through training, will be prepared for this role.

5.2.3 Impact of transporter's safety awareness

The study investigated the effect of transporters safety awareness as one of the root causes of accident in road transport of petroleum products. The role of road safety in preventing oil tanker disasters is supported by the United Nations 2030 Agenda for Sustainable Development, which was enacted in 2015, in which Sustainable Development Goal 3.6 states "By 2020, halve the number of global deaths and injuries from road traffic accidents" (Ewbank, *et al.*, 2019)

One of the tools for measuring safety awareness in an organisation is the participation in safety meetings and the frequency of meetings. Figure 5.6 presents the breakdown of safety meetings frequency within each of the transporters.

The skills and awareness of drivers can be enhanced through attendance at safety meetings. The survey covered the frequency of safety meetings arranged for, or by, drivers. These meetings may or may not involve their supervisors. Sometimes, the drivers prefer to hold safety meetings without their supervisors, so they could speak freely without fear of possible reprisal or suppression by line management. Analysis of frequency of safety meetings held by the transporters was carried out, and results presented in Figure 5.6.

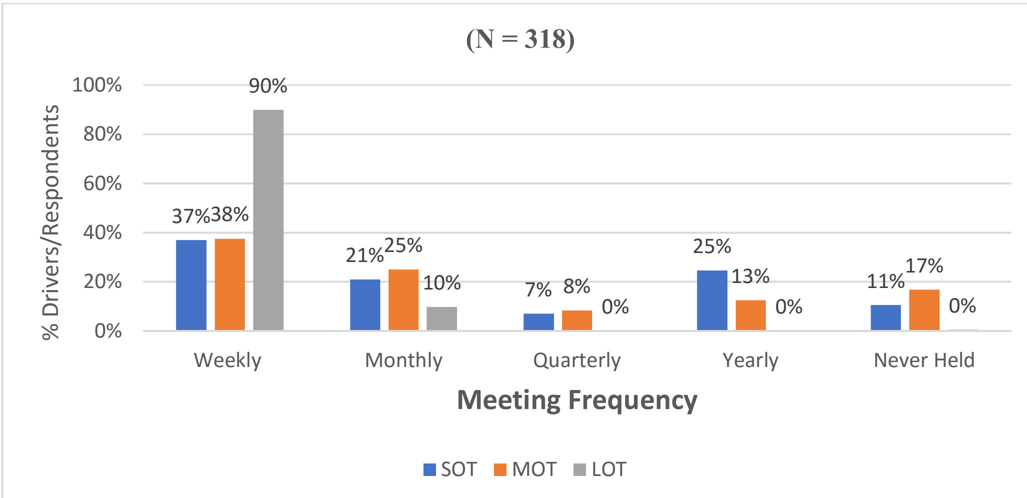

Figure 5.6: Frequency of drivers' safety meetings

Source: Field data, 2022

It was observed that 90% of LOT drivers indicated they held safety meetings weekly, whilst the remaining 10% held theirs monthly. This was a reflection of good safety engagement amongst drivers of LOT transporters. Such engagement should influence safety awareness and improve the performance of this group of tanker drivers. However, despite the good frequency of safety meetings, LOT drivers had relatively high contribution to accidents (85%) and spills (83%) compared with their group size (74%), as shown in Figure 5.1.

It is worthy of note that none of the respondents within the LOT transporters indicated that no safety meetings were held, or any meeting frequency below monthly. So, LOT transporters had emphasised the importance of safety meetings, and they were being held regularly, with good frequency. The resulting inadequate performance could have implied safety meetings had not been effectively carried out, and may have become a "tick-in-the-box" exercise by participants. That is, meetings were held simply for the sake of being seen to be doing so, without accruing benefits. Alternatively, the poor performance by LOT transporters, whilst safety meetings were being held regularly, may have implied the meetings did not necessarily improve the safety awareness, therefore they had no impact on the performance. The study reviewed this latter inference, i.e., that safety performance had no immediate impact on overall performance of transporters, given the safety meeting responses of MOT and SOT transporters.

It was observed that 38% of MOT drivers held safety meetings weekly, whilst 25% held monthly. The remaining 8% held the meetings quarterly, 13% annually and 17% never held meetings. It was of concern that 17% of the MOT drivers indicated they had never attended any safety meeting. The safety meetings scheme by MOT Transporters was adjudged unacceptable, as a total of 30% of the drivers had either never attended any safety meeting, or attended only once a year. When compared with LOT transporters, MOT drivers had better accident/spill performance, but their safety awareness and meeting frequency were worse.

The analysis revealed 37% of SOT drivers held safety weekly meetings, 21% monthly, whilst 7% held the meetings quarterly, 25% yearly and 11% never held meetings. The safety meetings scheme of SOT transporters was also adjudged unacceptable, as 36% of the drivers had either never attended any safety meeting, or attended only once a year. The study observed that SOT transporters had the worst safety meetings scheme and, by extension, the worst level of safety awareness. On the other hand, SOT transporters achieved the best accident/spill performance.

When a transporter has an effective Safety Management System in place, safety meetings can be used effectively for sharing lessons from accidents, which are reviewed in a proactive manner, so that drivers can avoid making similar mistakes in future. This naturally improves the safety awareness of the drivers, and within the transporter's organisation in general. Safety Management systems are based on the principle that, because there will always be hazards and risks in road transport operations, a structured approach is required to identify and address safety concerns, before they lead to accidents. For that reason, it is so important for road transport operators to apply a management system, which is helpful to organize the road transport operations in the safest way possible (Guide; Road Transport Safety Management Systems, 2016). The management system aims to identify and evaluate risks in operations of the company, and active participation of the workforce in safety activities. A mechanism to increase the frequency of safety meetings and effectiveness of the engagement with tanker drivers was recommended by the study.

Whilst the focus of this study is risk reduction with the aim of disaster prevention, it also considered the importance of safety awareness within communities in Kenya where accidents could happen during transportation of petroleum products. Research has revealed that people in communities ignore official advice not to siphon petroleum products, and are willing to risks their lives in the process. This has led to fatalities in the past, and has been blamed on poverty (Shileche, 2012). With adequate safety awareness, this situation can be addressed. The government, industry and NGOs can collaborate to set up enlightenment campaigns in communities on all highways, to improve their safety awareness.

5.3 Summary

The study carried out analysis and identified two key root causes of disasters in road transportation of petroleum products. These are:

1. Non-Compliance: It was observed that transporters who had a high level of non-compliance also had a high rate of accidents and oil spill. Conversely, where there is good compliance, there was good performance, evident by lower rate of accidents and spills. The study revealed non-compliance with procedures and driving rules was more evident in transporters that had higher rate of accidents and spills. There was a direct correlation between non-compliance and poor accident/spill performance. Therefore, when compliance is improved, it will be result in reduction in accidents, injuries and spills in the long term.
2. Ineffective Management (Organisation): The study identified lapses with transporters' management effectiveness, evident by recruitment of drivers that did not meet standard of minimum age, driving experience and educational level. The petroleum industry requires effective transporters' organisation that attract the right calibre of drivers, and subsequently influence them through through structured training and mentoring to prevent both accidents and disasters. The responsibilities of managers of tanker drivers include ensuring each driver appreciates he/she is the critical individual in prevention of disasters. This will make tanker drivers understand their role in prevention of accidents or rollovers that could lead to disasters.

Whilst safety awareness is an important part of disaster reduction, the study concluded it was not a predictor nor determinant of accidents and spills. Therefore, safety awareness of drivers and transporters was not considered one of the root causes of disasters. The study did not find evidence of direct impact of safety awareness on accident/spill performance of transporters. This is not to imply there could not be indirect contributions, or long-term impact of safety awareness to the sustainability of transporters' business.

The study identified the need for enlightenment campaigns across all relevant communities in the country, to prevent siphoning of petroleum products that has led to disaster in the past. Ewbank *et al.*, (2019) identified acts of scooping or siphoning petroleum products, after a road tanker is involved in an accident or rollover, as the most significant factor in high mortality rate in low- and low-middle-income countries (LMIC). Therefore, the need for an innovative campaign scheme to address this challenge cannot be over-emphasised.

CHAPTER SIX

STRATEGIC OPTIONS FOR SUSTAINABLE MANAGEMENT OF PETROLEUM PRODUCTS TRANSPORT IN KENYA

In this chapter, the study evaluated strategic options for sustainable management of the downstream sector of the petroleum industry in Kenya. The human factors and organizational issues affecting tanker drivers and transporters have been analysed in previous chapters. In this chapter, the study investigated the culture within an organisation that allowed the factors and issues to exist, and evaluated options to address systemic challenges in order to bring improvement to road transport of petroleum products. Programs and actions to facilitate DRR in road transportation of petroleum products have been identified, and opportunities for prevention of future disasters were evaluated. Each failure that led to a road tanker accident or disaster in the past, during handling of products, can be traced to the culture within the organisation, and a leader who failed to do, or did, something that contributed indirectly to the accident. Therefore, this chapter evaluated options for management to prevent accidents, and contribute to sustainable petroleum business industry.

6.1 Organizational Culture

In this section, a review was carried out of the transporter’s organizational culture, based on tanker drivers’ perception of effectiveness of defensive driving training. Figures 6.1 presents different levels of culture that can exist in an organisation, whilst Figure 6.2 presents perception of defensive driving training effectiveness by tanker drivers.

Research has shown that human behaviour and attitude contribute enormously to road carnage. Neither the past road safety measures nor prescriptions of the legal notices adequately address the behaviour and attitude of road users and regulators. Change of behaviour and attitude of road users and regulators therefore have great potential of reducing road crashes (Wycliffe, 2019). Industry often develops standards, procedures and rules, after evaluation of requirements for safe operations and sustainable business. Procedures in general are required to be fit for purpose and simple to use. Unfortunately, no matter how simple procedures and rules are, compliance depends on perceived benefits; what is in it for me? That is where the industry needs a change in behaviour and attitude. Over a period of time, a culture is created within an organization, which becomes the way business is done within the company. It becomes the unspoken response of what staff believe is good for them. When staff believe rules will benefit them, they comply naturally. Therefore, the challenge is to develop a culture in an organization, where rules/procedures are perceived as beneficial to staff. People will change their behaviour and attitude when they believe rules and procedures are for their own good. Research has developed a culture ladder through which an organization can evolve (Hudson, 2001). The culture ladder is presented in Figure 6.1.

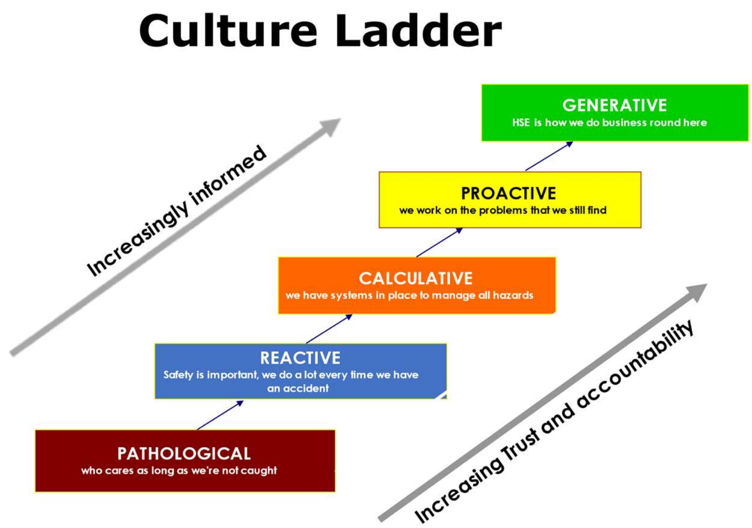

Figure 6.1: Culture Ladder of an organization

Source: Energy Institute, Hearts & Minds model, 1999

There are several factors that contribute to the culture level of an organization. The Hearts and Minds research team also developed a tool kit for assessment of the culture level. The perception of the effectiveness of defensive driving training can be a pointer to the culture level of the transporter.

The study investigated the perception of tanker drivers about the effectiveness of defensive driving training. The feedback from the drivers was analysed on the basis of the three categories of transporters they work for, and presented in Figure 6.2.

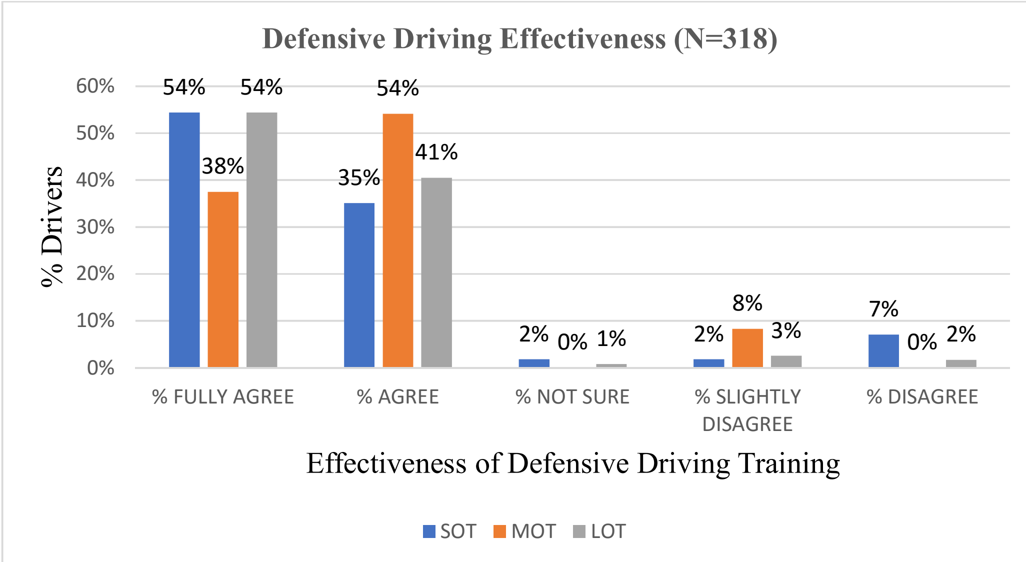

Figure 6.2: Perceptions about defensive driving effectiveness amongst transporters

Source: Field data, 2022

It was observed that 54% of tanker drivers of SOT transporters fully agreed about effectiveness of defensive driving training, whilst 35% of the drivers agreed, 2% were not sure, another 2% slightly disagreed and 7% disagreed. For MOT drivers, 38% of them fully agreed about effectiveness of the training, 54% agreed, none was unsure, 8% slightly disagreed and none disagreed. It was observed that 54% of drivers of LOT transporters fully agreed about effectiveness of the training, 41% of them agreed, 1% was unsure, 3% slightly disagreed and 2% disagreed.

The analysis showed an average of 92% of the drivers across all the three categories of transporters believed that the defensive driving course was effective, as they either agreed or strongly agreed. These tanker drivers were more likely to comply with road transport safety rules and procedures, which were emphasized during the training. It was however observed that 9% of the drivers working for SOT transporters, 8% of MOT drivers and 5% of LOT drivers either disagreed or strongly disagreed about the effectiveness of the training. When drivers appreciate usefulness of the training, they would naturally comply with all rules and procedures, and prevent accidents. Involvement of supervisors and managers of drivers, through engagement and face-to-face meetings, where individual performance and challenges are discussed, is considered essential to change the perception of these drivers, and win their "hearts and minds".

From the review of the feedback from the drivers, the study came to the conclusion that the three categories of transporters were in the lower rungs of the culture ladder, between Pathological and Reactive levels. LOT transporters had the highest ratio (95%) of drivers, who had the perception that the training was beneficial; that is Fully Agree or Agree. This is a reflection that the culture in the transporters' organisations is closer to Reactive, whilst the other two are closer to Pathological.

One of the strategic issues highlighted by this study was the need to develop a culture where drivers believe rules are provided for their benefits and will therefore aim to comply by default. The leaders and management of the transporters should educate tanker drivers on the criticality of compliance. When drivers understand rules and regulations have been placed for their safety and wellbeing, they will comply naturally. However, the small percentage of drivers who disagree with defensive driving effectiveness are the drivers more likely to break rules, and eventually get involved in accidents and disasters. The challenge is how to identify such high-risk drivers, engage and win their hearts and minds, before the accidents occur. Transporters should therefore focus on improving the culture in their organisation and climb up the culture ladder.

The improvement of the transporters' culture ladder is a long-term solution to improvement of their accident performance. Research has shown that enforcement of driving rules, by persuading drivers to comply through use of traffic police or industry regulators, can be effective as a means to prevent accidents in the short term. While training, education and engineering improve safety in the longer term, effective enforcement leads to a rapid reduction in deaths, injuries and spills (ETSC, 2015). This study has shown that a combination of enforcement, training and winning the hearts and minds of tanker drivers will achieve sustainable management of transportation of petroleum products in Kenya and across Africa.

Experiments carried out have provided evidence that traffic enforcement efforts by police contribute to deter dangerous driving behaviour, and greatly improve road safety (Demers, 2021). The experiments showed that additional traffic enforcement coincided with enormous reductions in per capita rate of motor vehicle accidents, collisions resulting in injuries, traffic fatalities and speed-related fatalities. This study identified the need for each transporter to set up its enforcement system through which compliance by tanker drivers could be monitored and enforced. In addition to use of OBC installed in truck cabins that can monitor speed violations, driving hours, use of approved routes, etc., an inspection team in unmarked vehicles could be used on highways to monitor performance of tanker drivers. However, use of an inspection scheme may be considered as an industry initiative, which may be supplemented by NTSA officials, in collaboration with the police.

6.2 Management of tanker drivers

In this section, a review was carried out of management of tanker drivers, through engagement with their supervisors and managers. Figures 6.3 presents frequency of engagement by the different categories of transporters.

To appreciate the importance of effective management of drivers, one should focus on the cost of accidents. Putting a monetary value on prevention of loss of human life and limb can be debated on ethical grounds. However, doing so makes it possible to assess objectively the costs and the benefits of road safety measures and helps to make the most effective use of generally limited resources. This approach has been adopted by the European Transport Safety Council (ETSC). The Value of Preventing one road Fatality (VPF), estimated for 2009 in its 5th PIN Annual Report, was updated to take account of changes to the economic situation in the intervening years. As a result, the monetary value of the human losses avoided by preventing one road death for 2017 was taken to be € 2.11 million. The total value of the reductions in road deaths for 2017 compared to 2010 was estimated at approximately €13 billion, and the value of the reductions in the years 2011 - 2017 taken together compared with five years at the 2010 rate was about €70 billion. If the EU had moved towards the 2020 road safety target through constant progress of 6.7%, the greater reductions in road deaths in the years 2011-2017 would have increased the valuation of the benefit to society by about €40 billion to about €110 (ETSC, 2018).

From foregoing research carried out by ETSC (2018), the costs saved by preventing one road fatality cannot be underestimated. The cost of preventing road accidents closely follows this. When management of transporters appreciate these economic indices, it follows that, efforts would be made to prevent all accidents, and the need to effectively supervise the drivers arise. By virtue of their operational activities, tanker drivers work alone most of the time, especially when they drive long distances to make deliveries of petroleum products. As a consequence, close monitoring of their driving skills, attitude and behaviour is difficult. Whilst the OBC installed in the cabin, and connected to the truck engine, provides some feedback on the way they drive, other factors can contribute to improving the performance of the drivers (Ayres, *et. al;* 1996). One of the most effective ways of contributing to drivers' performance improvement is through direct engagement with supervisors and managers, getting to know the drivers well, and supporting them.

The engagement involves discussing road hazards, feedback from the OBC monitoring, personal challenges, improvement opportunities, etc. Through engagement, the manager has opportunities to influence the driver and achieve continuous improvement. The manager may be able to identify high-risk drivers through the engagement, and endeavour to influence them positively. The more frequent the engagements, the more the likelihood of improved performance. Figure 6.3 presents feedback on the responses by drivers about the frequency of the engagements with their supervisors/managers.

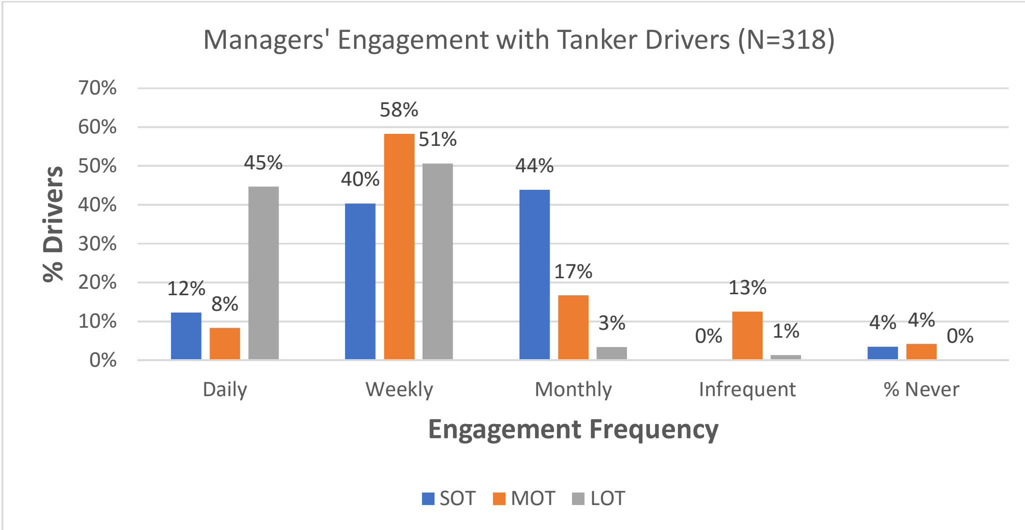

Figure 6.3: Frequency of engagement between managers and tanker drivers

Source: Field data, 2022

Of the three transporter types, 45% LOT drivers had daily engagements with their supervisors, whilst 51% had weekly engagements and 3% monthly. The analysis revealed 96% (45% + 51%) of LOT drivers had at least weekly engagements with their managers. Such engagements are expected to result in improved performance, reflected by improvement in compliance, and reduction in accidents and spills. However, LOT drivers had the highest non-compliance levels and the worst accidents/spills performance, though they had the best engagement scheme with their managers. This could be an indication the engagements held were not effective enough. It has highlighted the need for preparation of a toolkit for transporters' supervisors, to help them become more effective in engagement with, and the supervision of, drivers. The supervisors should know what things to look out for, in addition to providing feedback about results and findings of the OBC. That way, the driver would be able to use the engagements in a proactive manner to prevent accidents, injuries and spills.

For MOT transporters, 8% of the drivers had daily engagements, 58% weekly, and 17% had monthly engagements. However, 13% of these drivers had infrequent engagement and 4% had not had any form of engagement with their manager. MOT drivers represented 8% of the tanker drivers' population (see Figure 5.1), and contributed 10% of the accidents. In the same manner, MOT drivers were responsible for 14% of spills incurred by the entire population of tanker drivers. It is expected that, when the engagement between managers/drivers is improved, it will lead to performance improvement, with lower accident rate and lower spills.

The analysis revealed 12% of drivers in SOT transporters had daily engagements with their managers, 40% weekly, 44% monthly, whilst 4% of them had never held an engagement. SOT drivers represented 18% of the tanker drivers' population, yet contributed 5% of the accidents and 3% of the spills by the total population of tanker drivers that participated in the survey. Though the engagement frequency by SOT drivers and their managers was low, it was not reflected in their drivers' performance.

The reasons for the variations in the frequency of engagements between managers and tanker drivers may not be unconnected with the workload and productivity of the categories of transporters. LOT transporters are most active and the most widely used transporter type, as they haul products for a wide range of marketing companies, both local and international. The IOCs prefer to use LOT transporters, as there is an assumption that the LOT would perform better by virtue of the size of their fleet, and would contribute to overall performance improvement. The demand for good performance by their clients may have contributed to LOT managers spending more time in engagements with tanker drivers monitoring their trips compared with the other categories of transporters.

The study did not reveal a direct link between the frequency of engagements with drivers and transporters accident performance. However, such engagements are expected to contribute to improvement of the organisational culture in the long term. It is an effective tool to influence the behaviour of drivers, and win their hearts and minds. Researchers have shown that human factors failures that result in accidents and disasters are connected to underlying failures rooted in malfunctions developed by individuals at various organisational and operational levels (Ambituuni, *et al.,* 2015). Therefore, this study demonstrated that focus should not be on the tanker driver alone, but other parties within the transporter organisation, including supervisors, journey planners and managers, who can contribute indirectly to accident/spill performance. By improving the engagement between drivers and supervisors, an integrated approach to elimination of disasters in road transport of petroleum products can be achieved.

6.3 Strategic Options for Sustainable Management

In its Global Status Report on Road Safety 2015 (WHO, 2015), the World Health Organisation reported that the highest road traffic fatality rates are in the low and middle-income countries (LMIC), in particular on the African continent. Despite the fact that Africa is the least motorised (2%) region of the world, it is responsible for 16% of all recorded deaths arising from road crashes. Furthermore, a high proportion of disasters that occur during road transportation of petroleum products occur on the continent, possibly linked to the economic circumstances and the propensity for scooping fuel by nearby community dwellers after an accident or rollover occurs.

Disasters have been caused by inadequate awareness of hazards and risks associated with transportation of petroleum products. Regulators and other industry players have recognized that lack of risk knowledge and safety awareness form part of key underlying issues in disasters (Ambituuni, *et al.,* 2015). Tanker drivers need to be trained to understand hazards associated with their operations, the associated risks, and importance of compliance with rules in the prevention of accidents and disasters.

Uzondu *et al.,* (2018) have identified transport users' behaviour as the main cause of road traffic accidents. It has been shown that unsafe driving behaviour accounted for up to 90% of accidents. This includes inappropriate speeding and speed-related factors, poor knowledge of traffic regulations, including road signs and markings, drink driving, dangerous driving, driver fatigue and inappropriate overtaking.

A review of strategic options for sustainable management of transportation of petroleum products must address foregoing challenges. This study has therefore identified the following key issues for DRR in the industry:

1) Hazard awareness
2) Industry standards on tanker driver recruitment
3) Compliance
4) Enforcement
5) Professionalism and mentoring of tanker drivers
6) Community-based disaster management (CBDM)
7) Review registration of petroleum road tankers
8) Tanker driver rest points
9) Competence development for supervisors and managers of transporters

10) Mandatory use of on-board computers (OBCs) on all tankers: Technology

11) Enhancement of public awareness on the dangers of petroleum products

12) Alignment of National Road Safety Management Program

6.3.1 Hazard Awareness Training

Defensive driving training provides drivers the ability to identify hazards and take proactive steps to prevent accidents. There are both visible and invisible hazards on the road, and drivers can be trained in management of such hazards. Borowsky et al. (2013) highlighted that ability to identify hidden hazards can be enhanced through driving experience and training. When tanker drivers undergo defensive driving training, they develop skills in being able to identify both visible and invisible (potential) hazards on the road, therefore are able to anticipate dangers before they occur. It is recommended that tanker drivers should participate in annual one-day defensive driving refreshers, where developments on road safety and lessons from recent incidents are disseminated. In addition to hazards on the road, tanker drivers also need to be trained on hazards associated with the petroleum products they transport (Energy Institute, 2020). The training addresses generic hazards and risks that road tanker drivers encounter in terminal operations, control and mitigating measures that need to be understood and applied to ensure safe work practices, and prevention of disasters. When tanker drivers are trained in product handling, they become conversant with steps to be taken in the event of spills or accidents.

6.3.2 Industry Standard on Tanker Driver Recruitment

This study has identified human factor issues of tanker drivers related to age, experience, educational level, and structured training to facilitate improvement of their skills and competence. It is suggested that a legislative approach be considered to provide industry regulators a framework for establishment of a recruitment process that will cover these issues. Eboli *et al*., (2019) have shown that driver's age is one of the contributory factors to road accidents. Singh (2017) demonstrated that inexperienced drivers represent higher risks on the road. This study identified minimum age of 30 years, minimum driving experience of six years and educational level of minimum secondary school certificate should be considered as baseline criteria for recruitment of tanker drivers. Following recruitment of tanker drivers, other training and developmental requirements should be established and implemented to enable the drivers become more competent in being able to drive safely without accidents, in spite of the mistakes and poor awareness of other road users. NTSA should be engaged by the petroleum industry in establishing standards for recruitment of tanker drivers, and subsequent training requirements.

6.3.3 Compliance

Compliance is the bedrock upon which the improvement in tanker drivers' performance can rest. It requires the interplay by all stakeholders, including regulators, NGOs, transporters, etc. NGOs will provide encouragement and challenge to both the regulators and transporters towards the establishment of an environment in which technical/safety standards can thrive. NGOs will become the conscience of the industry (ETSC, 2015).

Transporters will be required to meet minimum industry standards, and have mentoring programs for development of drivers and improve their safety awareness. Transporters should also introduce programs to facilitate assessment of organisational safety culture, identify gaps, agree road map to achieve proactive culture, and monitor progress towards agreed goals. This requires the use of Hearts & Minds consultants to carry out an evaluation of the current organisational culture, and prepare a road map on actions to be taken to climb up the culture ladder. When a proactive culture is achieved, drivers and workers comply by default, because they understand rules and procedures are meant for their own good. Transporters should establish shared vision with tanker drivers and other staff, and obtain buy-in for implementation of agreed plans.

6.3.4 Enforcement

In dealing with the behavior and attitude of road users, it was established that drivers were aware of the rules relating to road use, but do not comply unless there is an enforcement officer within sight. Lack of compliance with legal requirements was a major problem. Unless road users respect and observe traffic rules and regulations, the noble goals and objectives of road safety policies will be difficult to achieve (Wycliffe, 2019). In Europe, the Strategic Action Plan on Road Safety recognises the importance of enforcing safe behaviour as a major step in reducing fatalities from road transport. This needs to be shared across the continent of Africa. Enforcement is a means of preventing vehicle accidents by way of persuading drivers to comply with safety rules. Deterrence is based on giving drivers the feeling that they run too high a risk of being caught when breaking rules. Intensified traffic law enforcement activities played an important role in bringing the number of road deaths down in Poland. Roadside drink-driving checks increased by 81% over the period 2010-2015 (ETSC, 2015). This road enforcement strategy needs to be shared in Kenya, and across other countries in Africa.

In the longer term, government agencies (traffic police, EPRA, NTSA, etc) should be involved in to improvement of road safety through enforcement on roads, especially for road tankers. The requirements should include speeding, tests for drink-driving, drugs and use of OBCs. In the shorter-term, an industry-based enforcement scheme may be put in place to ensure tanker drivers comply with driving rules, fatigue management, and speed limits, including use of approved drivers rest-points along highways. Approved rest points are essential in fatigue management during long haul journeys. The use of OBCs as a mandatory requirement for all road tankers will facilitate enforcement, as drivers' performance can be monitored remotely

6.3.5 Professionalism of tanker drivers

As technological solutions have improved, behavioural factors contributing to road accidents by truck drivers have risen in importance (Douglas, *et al.,* 2017). The transporters must therefore establish a working environment where drivers are encouraged to improve their attitudes and behaviours. They should feel appreciated, believe all accidents are preventable, and aspire to the best they can be in their chosen professional careers. Through professionalization of tanker drivers' role, they can develop personal pride in their job and the desire for good performance. Improvement in attitudes and behaviour can be achieved through development of tanker drivers' professionalism, which can be linked to deployment of OBCs across the fleet of transporters. Field experiences and case studies show that feedback of records from OBCs lead to a favourable modification of drivers' behaviour (Lehmann & Cheale, 1998). Drivers who have shortcomings that are identified by the OBC reports are counselled, Experience has shown that such corrective interviews, held by supervisors with the drivers, have contributed to improvement in attitudes and behaviour of drivers.

A Drivers' league scheme can be developed in which tanker drivers can earn points for safe driving, and be recognized and rewarded accordingly, through rising in ranks to higher levels of professionalism. This league system can be linked to a driver behaviour monitoring scheme which is recorded by the OBC. Drivers who are taking too much risk will stand out on the Driver League Table in red. the best drivers will appear in green, and those in between will be amber (Quartix, 2024).

The Drivers' League scheme may be implemented within each transporter organization. Points will be earned for safe driving, attendance at safety meetings, compliance monitored through OBC feedback, reporting of quality route black-spots during journeys, near-misses, incidents, etc. Points would be deducted for non-compliance with OBC parameters, absence from safety meetings, involvement in accidents - where investigations reveal lapses by the drivers involved. At the end of each month, the drivers would receive feedback about their positions on the league, and points remaining to gain promotion to the next level. For each level attained, there will be recognition and rewards that will encourage drivers to strive for excellence. The league scheme will result in healthy competition amongst the drivers, and the transporter will use results from each driver's OBC monitoring for assessment of performance. This would make the scheme relatively fair and unbiased. This scheme can encourage professionalism and breakthrough performance amongst tanker drivers in the industry.

6.3.6 Development of a community-based disaster management scheme

The role of the community in disaster management cannot be over-emphasized, and it is required to improve the awareness of the society and ensure community members understand their roles. Shileche (2012) highlighted that ignorance on the part of local people plays a big role in the fire disasters, whilst poverty and poor road infrastructure also contribute to the disasters. To improve the safety awareness within the communities in which they operate, it is proposed that petroleum product transporters should initiate a scheme for each tanker driver to adopt a school along a route in which they often operate. The scheme will be called "Adopt-a-School", and each driver would be allocated a specific school along his route that he would be required to visit, possibly once a term, to hold an open-day forum with students and teachers. Such forum would be arranged with the school head-teacher, and the role of the driver would be to educate students and staff on road safety and dangers of petroleum products. The driver would teach the students about the risks of pilfering products from tankers involved in accidents, as it had resulted in high number of fatalities in the past. The students will be an effective medium to communicate risks of petroleum products to their parents and other members of their communities. Through this scheme, transporters and drivers will be actively involved in corporate social responsibility activities and contribute to prevention of future disasters.

Given the sensitivity of the Adopt-a-School initiative, the study recommends that it should be presented to the PIEA, the professional body with responsibility for training in the petroleum industry, which in turn can engage the ministry of education at both national and county levels about the benefits that can accrue from this community-based disaster management scheme. It will improve societal awareness about dangers of released petroleum products and lead to eradication of pilferage. The ministry of education could consider inclusion of petroleum products hazards in its curriculum at appropriate levels of education, to leverage the Adopt-a-School initiative.

In addition to this, each county should be requested to train community leaders on how to respond to accidents that involve petroleum road tankers. This would include evacuating members of the community from the scene of any accident, emergency telephone contacts and identification of early responders for safeguarding the site until emergency services arrive.

6.3.7 Review registration of road tankers

There is a register of road tankers in Kenya that is updated annually by the regulator (EPRA, 2020) However, it covers the registration of road tankers based in the country. The study revealed there are a lot of tankers that cross the boarders of Kenya to take delivery of petroleum products. These road tankers are not currently registered by the EPRA, neither are their integrity being assured. In the past, some of the tankers from outside Kenya had been involved in accidents within the borders of the country. Therefore, this study highlighted the requirement for all foreign road tankers that collect petroleum products from Kenya to be properly registered, as well as their technical integrity guaranteed through an audit program by EPRA. The drivers of the road tankers should also be tested for their competence as well as road safety awareness. It is understandable this exercise would involve inter-governmental cooperation and additional resources from all parties, but it is considered critical to the prevention of disasters that could arise from transportation of petroleum products within the East Africa region.

6.3.8 Tanker drivers' rest points

The contribution of driver fatigue to accident is well documented. It was one of the contributory factors of the Sachangwan disaster. Research by Sallinen *et al.*, (2014) revealed drivers more frequently used fatigue countermeasures while fatigued at the wheel but most of these countermeasures, with the exception of caffeine, can be regarded as inefficient (e.g., opening a window for fresh air). The results indicate that long-haul truck drivers respond to fatigue at the wheel but the countermeasures they use are not optimal. It is likely that, in addition to driver fatigue management training, changes in shift and trip planning practices and sleeping facilities at rest-stops are needed to improve the situation.

In the Sachangwan disaster investigation, it was highlighted that unplanned stop by tanker drivers during journeys to make deliveries should be minimized, as it was identified as one of the contributory factors to the disaster. Accidents have arisen in the past when tanker drivers park on the highway to take comfort breaks. As highlighted by Sallinen, et al. (2014), provision of approved rest points along highways will facilitate fatigue management, which will result in prevention of accidents. It will be required that various agencies, e.g., NTSA, KNHA, EPRA, KURA, etc. collaborate to determine highway corridors that would benefit from construction of rest points, which would be equipped with emergency facilities, accommodation, communication control room, etc. These facilities will minimize current risks posed by tankers on highways, prevent accidents, and facilitate monitoring of compliance through adequate journey management plans. The rest points should also have emergency facilities like ambulance, fire-fighting tenders and other equipment, to facilitate fast response in the event of accidents along the corridors.

6.3.9 Competence development for managers of transporters

The study investigated engagement between tanker drivers and their managers, and identified the need for more effective face-to-face engagement. Supervisors and managers can indirectly contribute to accidents and disasters through creating a culture where non-compliance is allowed to thrive. Huang *et al.*, (2016) demonstrated that truck drivers' safety climate perceptions were linked to the employees' level of job satisfaction, engagement, and turnover rate. Job satisfaction was also a significant mediator between safety climate and the two human resource outcomes, i.e., employee engagement and turnover rate. The study was among the first to assess the impact of safety climate beyond safety outcomes among lone workers (using truck drivers as an example). Through frequent engagement with tanker drivers, supervisors can train them and contribute to a culture in which there is the belief that all accidents and disasters can be prevented.

The supervisors and managers need to be trained on how to engage effectively and lead, through their own personal examples, by walking the talk. An organisation where managers demonstrate that staff are the greatest resource encourages tanker drivers to give their best. This study highlights the need for an agency, like PIEA. be charged with development of a resource pack to be used for improving the competence of supervisors and managers of transporters.

6.3.10 Mandatory use of OBC on road tankers

The study identified the effectiveness of on-board computers (OBC) in monitoring driving behaviour and compliance of tanker drivers. The OBC can be used to monitor several parameters including speed, harsh-braking, driving hours, duty periods, rest times, geo-fencing, etc. It can be used to positively improve the skills and behaviour of a driver (Quatix, 2024). It is recommended that OBC should be installed in the cabin of all road petroleum tankers, with remote monitoring in a central location at transporters' office. The output of the OBC should be reviewed with each driver at the end of every round trip, to provide feedback on compliance with authorized routes, driving speed, harsh braking, driving hours/rest-breaks, etc. Through this scheme, disasters can be prevented, with the aim of total elimination. It is therefore recommended that OBCs become a mandatory requirement on NTSA and EPRA standards, and compliance enforced.

6.3.11 Enhancement of public awareness on dangers of petroleum products

The problem of pilfering of oil products whenever a tanker gets involved in an accident is widespread across Africa. It is recommended that the government initiates a scheme to improve the awareness of the general public on the dangers of petroleum products. Close collaboration between NTSA/EPRA/PIEA can lead to development of safety awareness packs for public use. The awareness packs can be rolled out through media adverts on both electronic and newspaper media, public announcement in townhall meetings, and training by civil societies. This scheme will complement the “Adopt a School” scheme proposed in the CBDM initiative under section 6.3.5, and the packs can also be used by the tanker drivers during their presentations to schools.

6.3.12 Alignment with National Road Safety Management Program

Kenya has a National Road Safety Management Program, with its Vision 2023, whose objective is to fast-track implementation of the National Road safety Action Plan to achieve the targets of reducing the incidence of road crashes and their impact on the Kenya economy. In addition to the public awareness campaign that will be launched, there is a requirement to align the foregoing efforts with the National Rad Safety Management Program. Establishment of tanker drivers’ rest points will (6.3.8) should be carried out in collaboration with NTSA and the National Road Safety Management program, to ensure such facilities are effectively utilised and there is no duplication of efforts.

6.4 Benefit analysis of strategic options for sustainable management

In order to evaluate the benefits of foregoing strategic options, an analysis of the recommendations was carried out on the basis of ease of implementation and perceived benefits. The results are presented in the matrix in Figure 6.4.

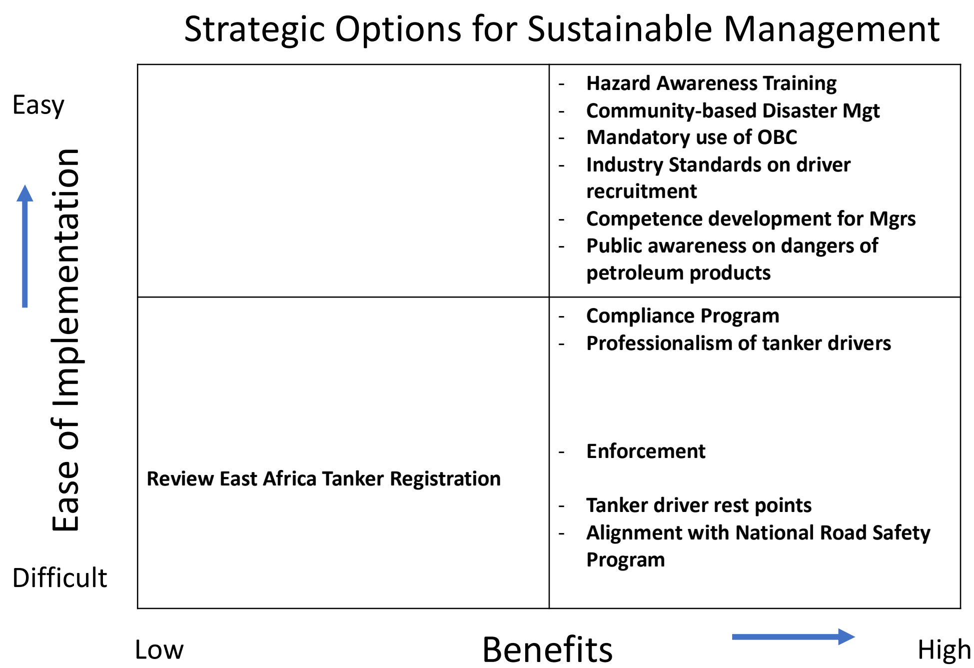

Figure 6.4: Cost-Benefits analysis of strategic options

Source: Author, 2022

The analysis of the benefits that accrue from the strategic options and the ease/difficulty of implementation revealed a ranking order in subsequent policies and revision of industry standards and procedures. This study highlighted the need to give high priority to the items on the top righthand corner of the matrix. These are the high hanging fruits, with huge benefits.

Top of the list on the matrix is the hazard awareness training for tanker drivers, with possibility of annual refreshers. Improvement in hazard awareness will lead to appreciation of the need for industry rules and compliance, with resultant prevention of disasters. Almost all transporters have driver trainers and mentors that can be easily deployed for implementation of this initiative.

Next in terms of both benefits and ease of implementation is the community-based disaster management scheme, Adopt-a-School scheme, which is a community training scheme to be undertaken by the tanker drivers to make presentations at schools along their route about the hazards of petroleum products, and the dangers of pilfering from a road tanker. Children can be effective in communicating the hazards to parents and other members of the community. The scheme would need collaboration with education authorities to facilitate presentations by the tanker drivers. By undertaking these presentations, tanker drivers will be sharing their hazard awareness skills with members of the communities along their routes.

Mandatory use of OBC on all road petroleum tankers should be given due consideration and can become an industry standard. Through the OBC, tanker drivers driving behaviour can be monitored remotely, journey management can be enforced, feedback given to the driver at the end of each trip and many more benefits. Use of OBC can improve road safety tremendously.

Establishment and review of recruitment standards for tanker drivers will ensure the right calibre of drivers are employed and trained to imbibe a mindset that all accidents are preventable. The standards should cover minimum age, experience, education, training, certification, etc.

Competence development for supervisors and managers of transporters should be given due consideration to facilitate effective engagement with tanker drivers, so they can share the belief that all accidents/disasters can be prevented, and compliance is the bedrock.

Given the challenges of scooping/pilferage of petroleum products, consideration should be given to setting up of a public enlightenment program on the dangers of petroleum products. Industry regulators, petroleum companies, and civil societies should participate in the setting up, and transporters can integrate it into the “Adopt-A-School” initiative. The program can include dissemination of information and broadcasts through both the print and electronic media. This is expected to reduce, and possibly eliminate, incidences of product pilferage if a road tanker carrying products is involved in an accident.

CHAPTER SEVEN

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter outlines summary of the research findings, conclusions and recommendations drawn based on the findings of each specific objective of the research done on DRR in transportation of petroleum products in Kenya.

7.1 Summary of findings

The overall objective of the study was to determine the factors contributing to disaster risk reduction in the transportation of petroleum products in Kenya. There were three specific objectives, and the following is the summary of the findings of each objective; namely:

i) To identify factors contributing to disaster risks during the transportation of petroleum products in study area. The study found three factors, which are: age of tanker drivers, driving experience and educational levels. It was identified that recruitment of tanker drivers did not consider age and their level of maturity to be able to manage a critical industry asset like a road tanker, which has capacity for enormous damage and disaster, if not handled properly. Furthermore, some drivers did not have adequate driving experience and skills to manage transportation of highly explosive products. Thirdly, the educational level of tanker drivers affected their ability to read and understand road traffic signs, including capacity to acquire more knowledge and skills through training. As a result of these factors, there was inadequate awareness of disaster risks amongst tanker drivers in particular, and across the industry and society in general. This was exemplified by reckless driving, over-speeding, extended duty/driving hours, leading to fatigue, poor hazard identification and poor anticipation by the tanker drivers. In addition, disaster investigations identified poor awareness by society in general regarding risks associated with handling petroleum products, leading to pilfering of products by community members whenever spills occurred after road accidents. These are issues that require focused attention by the industry and relevant government agencies including NTSA and EPRA.

ii) To analyse the root causes of disasters during the transportation of petroleum products in the study area. The study analysed root causes of accidents/disaster, and posited that each accident or disaster in road transportation of petroleum products can be traced back to how the tanker drivers had been managed by the organisation. The analysis identified two root causes of disasters, viz. non-compliance with rules/procedures and ineffective transporter's organisation. Whilst inadequate safety awareness was highlighted by the study as a possible root cause, the study did not reveal a direct impact on disasters, but instead may be linked to other issues within transporter's organisations. The study found out there was a culture of non-compliance with industry standards and safety procedures, both by tanker drivers and transporters. There were neither tools for enforcement, nor deterrence to encourage compliance. In addition, the recruitment of tanker drivers did not balance the criticality of assets being handled by tanker drivers against their suitability and capability. These lapses resulted in controls being breached, which led to accidents, injuries, spills and disasters. The study therefore recommended that transporters make their organisation more effective through training of managers and supervisors, who would engage effectively with tanker drivers, to get them to share in the belief that all disasters are preventable.

There is also a need for enforcement of compliance by tanker drivers, and each transported should consider setting up a road inspection team that can undertake unscheduled inspections of the tanker drivers on routes they ply. In the longer term, the traffic police can take over the role of road safety inspections. Given the competing priorities, inadequacy of traffic police and NTSA personnel, and the realism it may not happen immediately, the study recommends the setting up of an industry enforcement arm, which could be established immediately by PIEA and EPRA.

iii) To evaluate strategic options for sustainable management of the transportation of petroleum products in Kenya. The study identified petroleum products transportation as a critical business for the growth and prosperity of the country, but could be impacted by accidents and disasters during road transport. The study identified the environment in which the tanker drivers work, which is referred to as the organisational culture, is critical to the prevention of disasters. Regretfully, disasters have occurred when road tankers get involved in accidents, or rollovers, and members of the surrounding communities participate in scooping/pilferage of products from the site, which later resulted in fire and explosion with high numbers of fatalities and injuries. The study has highlighted the need for tanker drivers to be able to secure site post-accident and warn surrounding communities about the dangers of product. Tanker drivers should be trained in product handling, and a campaign to sensitize the society about the hazards posed by petroleum products should be taken by both the national and state government. There is also a proposal for tanker drivers to participate in an “Adopt-A-School” initiative that will facilitate improvement in awareness of school children, who can be used for dissemination to their parents.

The government has a key role to play in these initiatives. The study has also made recommendations on six “low hanging fruits” activities that can be easily implemented with great benefits and prevent future disasters. These are shown on the top right quadrant of the benefit analysis matrix (Figure 6.4).

7.2 Conclusions

The study came up with the following conclusions, based on the 3 specific objectives:

i) Tanker drivers play a key role in DRR in transportation of petroleum products through improved awareness of associated hazards, and personal intervention to minimize risks. The study identified factors that can contribute to DRR, and has recommended recruitment of tanker drivers minimum 30 years old, with minimum six years driving experience, and minimum secondary school education level. Through recruitment of these qualified candidates, continued training, and exposure to best practices, the tanker driver can become confident and develop the belief that all accidents can be prevented.

ii) Whilst accident investigations tend to focus largely on the tanker driver that caused the accident or disaster, the study revealed contributory factors can always be traced to remote parties in different roles within the transporter organization, particularly the supervisors/managers, who manage the drivers. The study identified the root causes of disasters during transportation of petroleum products as non-compliance with rules/standards, and ineffective management in transporters' organisations. Therefore, transporter leaders need to focus on processes that would achieve competence improvement through managers and supervisors, who can indirectly contribute to the goal-zero (zero-accidents) vision of transporters through effective engagement with tanker drivers to "win their hearts and minds". That is, doing the right thing by default, rather than being compelled. Management can share its goal-zero vision with tanker drivers through engagements, re-training and improvement of the safety culture of the organisation. This will also make the transporters' organisations more effective.

iii) The study evaluated strategic options for sustainable management of the industry and came to the conclusion that transporters need to create a culture in which the drivers feel valued and believe their managers/supervisors have their best interest at heart. Government agencies, regulators, NGOs and the communities also have a role to play in the community-based disaster management (CBDM) schemes identified by the study, which include "Adopt A School" initiative, for tanker drivers, as well well-structured public campaign schemes about the dangers of petroleum products during road transportation. The scheme will also place tanker drivers in a position where they feel valued as change agents in the society through moulding young minds, who in turn will be able to share dangers of petroleum pilferage with their parents.

7.3 Recommendations

The study suggested 3 broad recommendations, in accordance with the 3 specific objectives, as follows:

i) In liaison with the EPRA, NTSA is requested to revise the national standards for certification as a tanker driver. The requirements should include minimum age of 30 years, heavy-goods driving experience of six years and minimum educational level of secondary school certificate. Other requirements include annual medical certification, attendance of defensive driving training and product handling courses, including annual refreshers for the driving course.

Tanker drivers can play a key role in DRR in transportation of petroleum products through awareness of hazards associated with product transport and minimization of associated risks, thereby preventing accidents/disasters. Therefore, all tanker drivers should attend a mandatory "Product Handling and Transport" course, which should henceforth be a pre-requisite for certification as a tanker driver. Key aspects of the course should be included in defensive driving refresher courses for tanker drivers. It will help the driver understand how to implement access controls, including warning community members, after an accident.

ii) EPRA and NTSA are requested to jointly set up an enforcement team for road safety surveillance of road tankers in the country, to ensure they comply with technical standards, and drivers comply with both certification requirements and driving rules. Compliance requirements should also include checks for use of approved rest-points, driving/duty hours, and mandatory use of OBC in the truck cabin, which help with fatigue management of tanker drivers. In addition, use of OBC will facilitate proactive counselling of tanker drivers, using findings from the OBC results about the driver's performance during previous trips.

Transporters in the petroleum industry should develop structured "hearts & minds" program for tanker drivers to improve their awareness and understanding of the procedures and rules associated with product transportation. The aim is to win the hearts and minds of tanker drivers, and facilitate full compliance with driving rules, when they appreciate the benefits. The Hearts & Minds scheme should include supervisors/managers of the transporters and their competence development in management of tanker drivers. By taking transporters' managers through Hearts & Minds scheme and other appropriate training, their competence will be improved and they will develop skills for effective supervision of tanker drivers.

iii) Transporters are encouraged to establish the “Adopt-a-School” initiative for tanker drivers, through an engagement process between the PIEA and the ministry of education at both national and county levels. Following approval by the ministry, each tanker driver will be allocated a specific school to for engagement once a term. The scheme would require one visit by the driver each term of the academic year to make presentations to students and staff about the hazards of petroleum products and the dangers of pilferage from tankers involved in accidents. The initiative can be well coordinated in liaison with PIEA, EPRA, NTSA and the county ministry of education. When implemented, the scheme will improve students’ awareness about risks associated with petroleum products, and they will in turn share their knowledge with parents and relatives, thereby improving awareness within the society in general.

The petroleum industry through government agencies, in collaboration with transporters and NGOs, should develop and implement a public awareness program, through print and electronic media, about the risks of petroleum products, to discourage siphoning when there is an accident. The public awareness campaign will complement “Adopt-A-School” initiative of the tanker drivers.

7.4 Suggestions for further research

The study has identified some similarities between the PAR and Tripod Beta Methodology models. This could be the focus of further studies, to investigate further alignment, and create synergy between both models, in addition to identifying improvement opportunities.

Given the impact of disasters, including human losses and suffering, thought should be given to developing models that will facilitate quantification of costs for industrial and man-made disasters. This should further draw attention to the need to appreciate DRR opportunities, with the ultimate goal of elimination of future disasters.

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APPENDICES

Appendix 1: TM Analysis of Sachangwan Disaster

A TM analysis of the disaster was carried out and presented in diagrammatic manner:

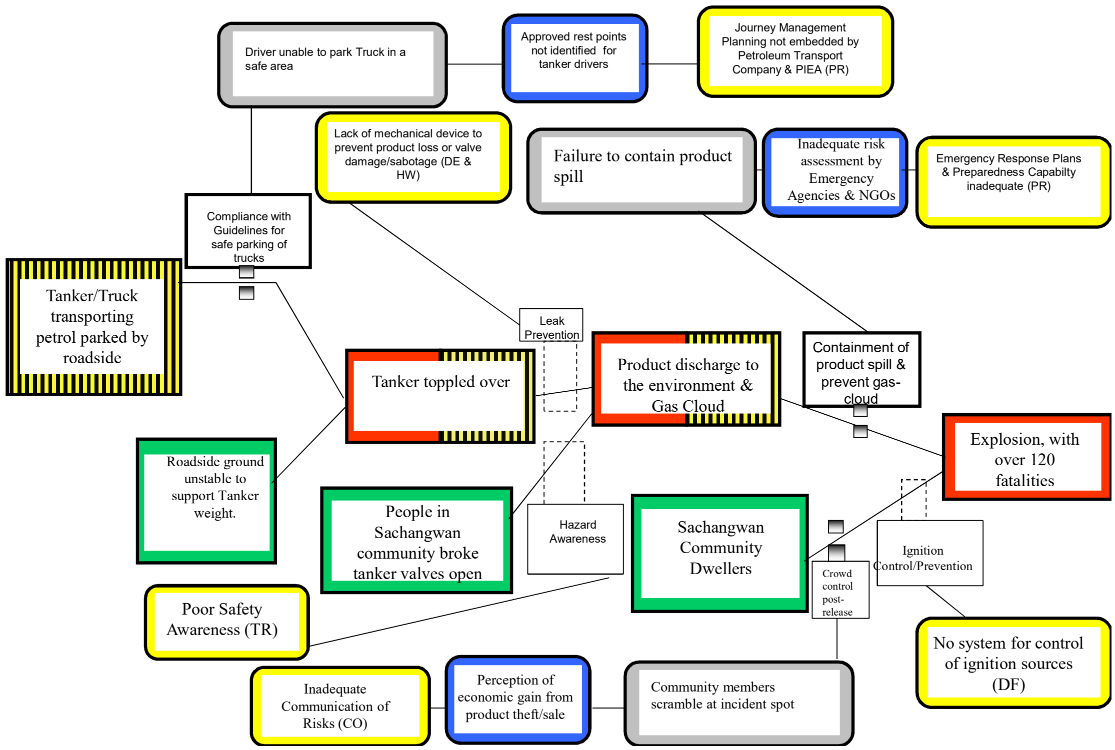

Figure P.1: Tripod Analysis of Sachangwan Tanker Disaster (complete overview)

In line with the Tripod terminology, the tanker transporting petrol was the Hazard that should be managed, and the Object is roadside where the tanker was parked. The Event that occurred by the intersection of the Hazard and Object was Tanker Rollover. The analysis showed the barrier that could have prevented the Event (disaster) from being achieved was compliance with guidelines for safe parking of trucks, especially oil tankers. Therefore, the immediate cause of the disaster was the fact that the driver was unable to park the oil tanker in a safe location. However, addressing the immediate cause of the disaster will result in short-term solutions, but will not prevent recurrence of the disaster. A short-term solution could be asking drivers not to park road-tankers along the route on their journey. It will not guarantee incident will not reoccur, as there would be similar requirements in future.

Therefore, there was the need to look at both the precondition and underlying causes, which allowed the immediate cause to arise. These are the systemic issues that will prevent recurrence. The pre-condition is that approved rest points along the route had not been identified for use of the drivers. The underlying (root) cause that led to the precondition was that journey management planning had not been embedded by the company/owners of trucks being used for haulage of petroleum products. If there was adequate journey management, drivers would be trained on specific areas they should stop at for comfort break and rest, to prevent fatigue on the journey. One of the underlying causes of the disaster, lack of embedding of journey management planning, can be classified under the Basic Risk Factors (BRFs) as Procedure (PR).

Following further analyses of the disaster, the summary of underlying causes are as follows:

Table P.1: Summary of Root Causes on Sachangwan Tanker Disaster (TBRV) – from the Tripod Analysis shown in Figure P1

Root Cause	BRFs Classification	Recommended Action
Journey Management Planning not embedded	Procedure (PR)	PIEA will be requested to enforce use of Journey Management and rest-points in the industry
The company had not embedded HSE into its business/staff	Organisation (OR)	PIEA will be requested to enforce minimum HSE Standards for all companies trucking oil products

Lack of spill-proof manhole for to prevent product loss during accidents/rollover	Design (DE)	Introduce technical standards all tankers to have installation
Lack of mechanical device For prevention of valve Damage or sabotage	Hardware (HW)	Develop technical standards for protection of valves
Poor Safety Awareness product across Kenya communities	Training (TR)	NTSA/PIEA to develop oil safety awareness pack
Poor Safety Awareness Across Kenya communities	Communication (CO)	Government (Govern of Info) to disseminate via TV/Radio
Inadequate Emergency Preparedness Capability	Procedure (PR)	Train and improve capability of Emergency Response Agencies
Inadequate communication Of Risks	Communication (CO)	Ministry of Information & its to develop campaign on risks
No system for control of ignition sources during emergencies	Defence (DF)	Develop scheme to ensure crowd control and prevent ignition sources
Control of ignition sources ignition sources during emergencies	Training (TR)	Train Emergency Response team on crowd control and ignition sources

Out of the TM standard eleven BRFs, the analysis of the Sachangwan tanker identified seven of the BRFs contributed to the disaster. Three of the BRFs (Procedure, Training and Communications) occurred twice. These BRFs will be correlated with those identified for the disasters in the other downstream industry sub-sectors. Figure P2 shows the BRFs.

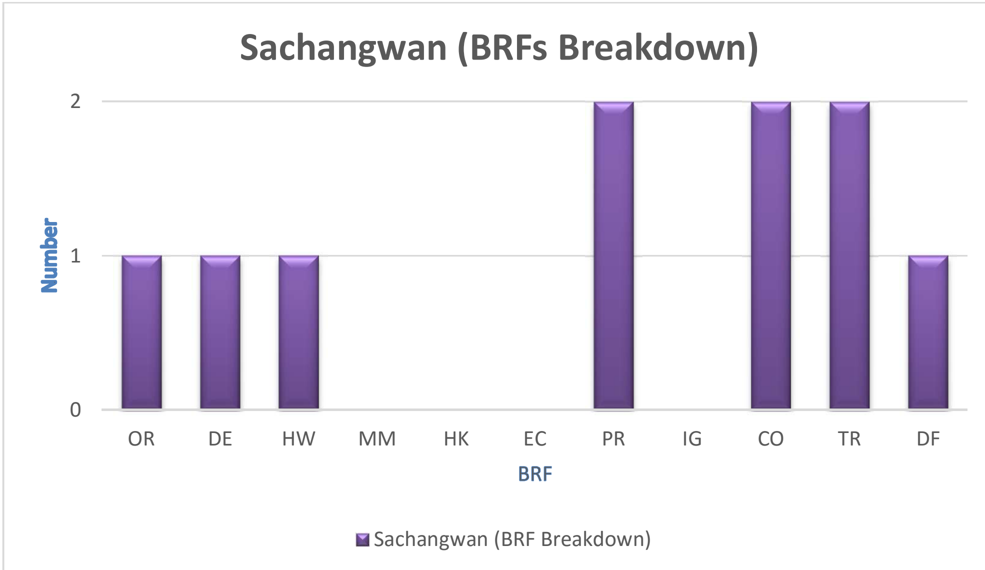

Figure P2: Breakdown of Basic Risk Factors (BRF) from Tripod Analysis for Sachangwan tanker disaster (breakdown obtained from Table P.1)

Appendix 2: Oil Fire/Explosion at Sinai Community

A TM analysis of the Sinai Fire Disaster was carried out, and represented diagrammatically:

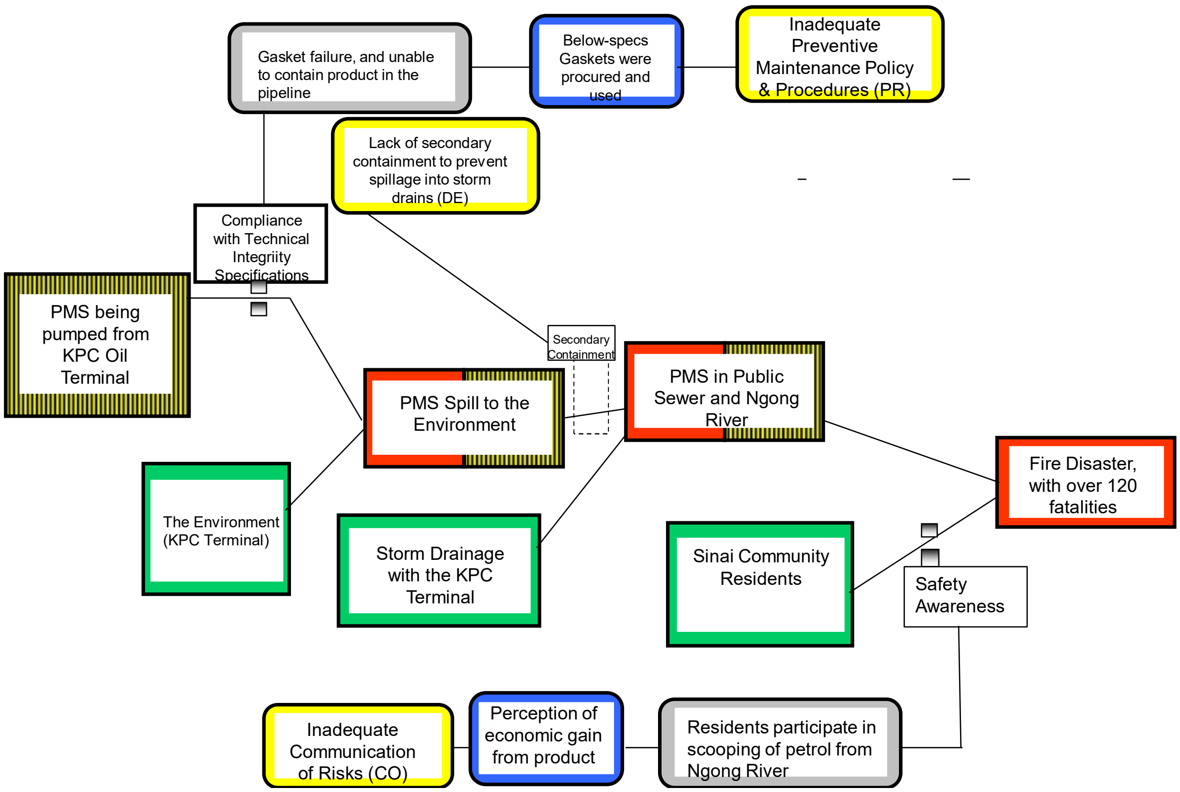

Figure P3: Tripod Analysis of Sinai Fire Disaster (complete overview)

Using the TM terminology, the PMS (petrol) was the Hazard that should be managed, and the initial Object was environment. The Event that occurred by the intersection of the Hazard and Object was the release of the petrol into the environment because of the failure of the pipeline gaskets. The analysis showed the barrier that could have prevented the Event (disaster) from being achieved was compliance with technical integrity specifications, through procurement and installation of the appropriate type of gaskets. The investigations report highlighted an off-spec gasket had recently been installed on the pipeline, and it had failed only after a few hours. Therefore, the immediate cause of the disaster was the failure of the gasket, which led to the loss of control of the PMS, spilling into the environment. However, addressing the immediate cause of the disaster alone will result only in short-term solutions, as it will not prevent another off-spec item from being used in future.

There was need to look at both the precondition and root causes, which facilitated the existence of the immediate cause. These are the systemic issues that will prevent recurrence. The pre-condition was a perception that shortcuts were allowed and cheap products encouraged across the company. This influenced the procurement of poor quality and off-spec gasket that was installed on the pipeline. The underlying (root) cause that led to the precondition was that there was inadequate preventive maintenance policy in place, which should have ensured use of the right quality of items, and given focus to development of a robust technical integrity system. One of the root causes of the disaster, lack of adequate preventive maintenance policy, can be classified under the BRFs as Procedure (PR).

Once PMS was released into the environment, it triggered other events. The released PMS became a Hazard, and the Object became the Storm Drainage system within the KPC terminal. Following further analyses, the summary of root causes is presented in Table P2.1.

Following the foregoing analyses, the summary of root causes are as follows:

Table P.2: Summary of Root Causes on Sinai Fire Disaster (BSDT) – from the Tripod Analysis shown in Figure P3

Root Cause	BRFs Classification	Recommended Action
Inadequate Preventive Maintenance Policy	Procedure (PR)	KPC and other Oil Terminals should have effective Maintenance Policy PIEA to provide guidance on policy.

Lack of Secondary Containment devices	Design (DE)	PIEA will be requested to review existing facilities to ensure secondary containment In place KPC to inspect all drains and ensure no effluent discharge without passing through oil/water separators
Competence of Technical Staff inadequate	Organisation (OR)	Develop Competence Assurance Scheme and Technical Authority System
Inadequate communication of risks	Communication (CO)	PIEA to develop oil product safety awareness pack for Kenya and disseminate to Communities via Radio/TV

The TM analysis of the Sinai disaster identified four root causes disaster that need to be addressed to prevent recurrence. These root causes are classified into four BRFs: Organisation, Design, Procedure and Communication. The breakdown of the BRFs is shown below:

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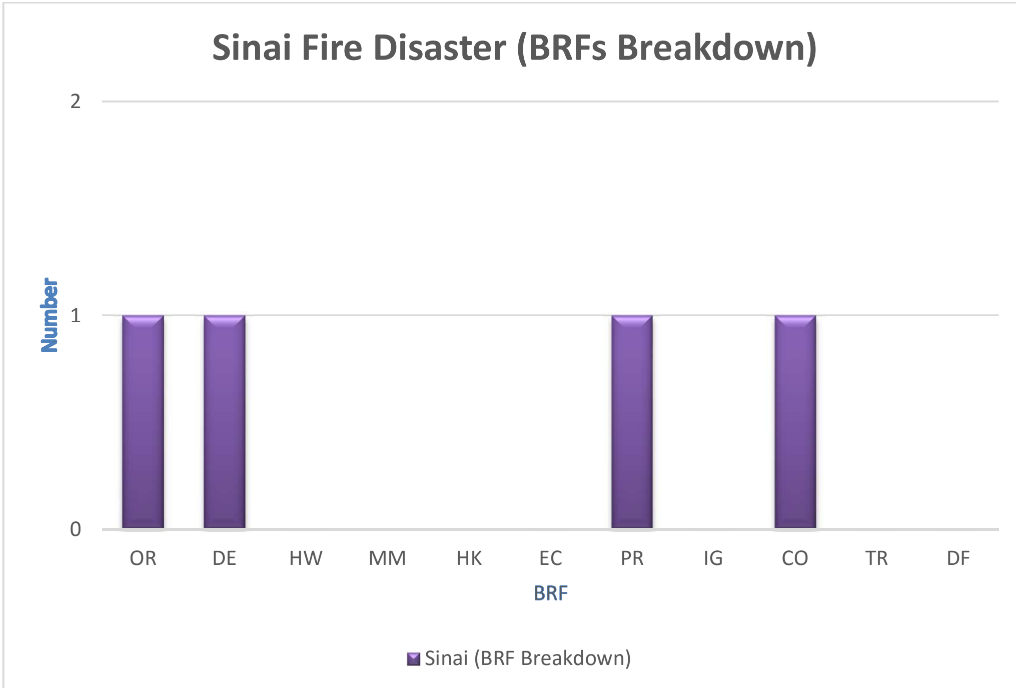

Figure P.4: Breakdown of Basis Risk Factors (BRFs) from Tripod Analysis for the Sinai Fire Disaster (breakdown obtained from Table P.2)

Appendix 3: Kirinyaga Road Petrol Station Disaster

A TM analysis of the Sinai Fire Disaster was carried out, and represented diagrammatically:

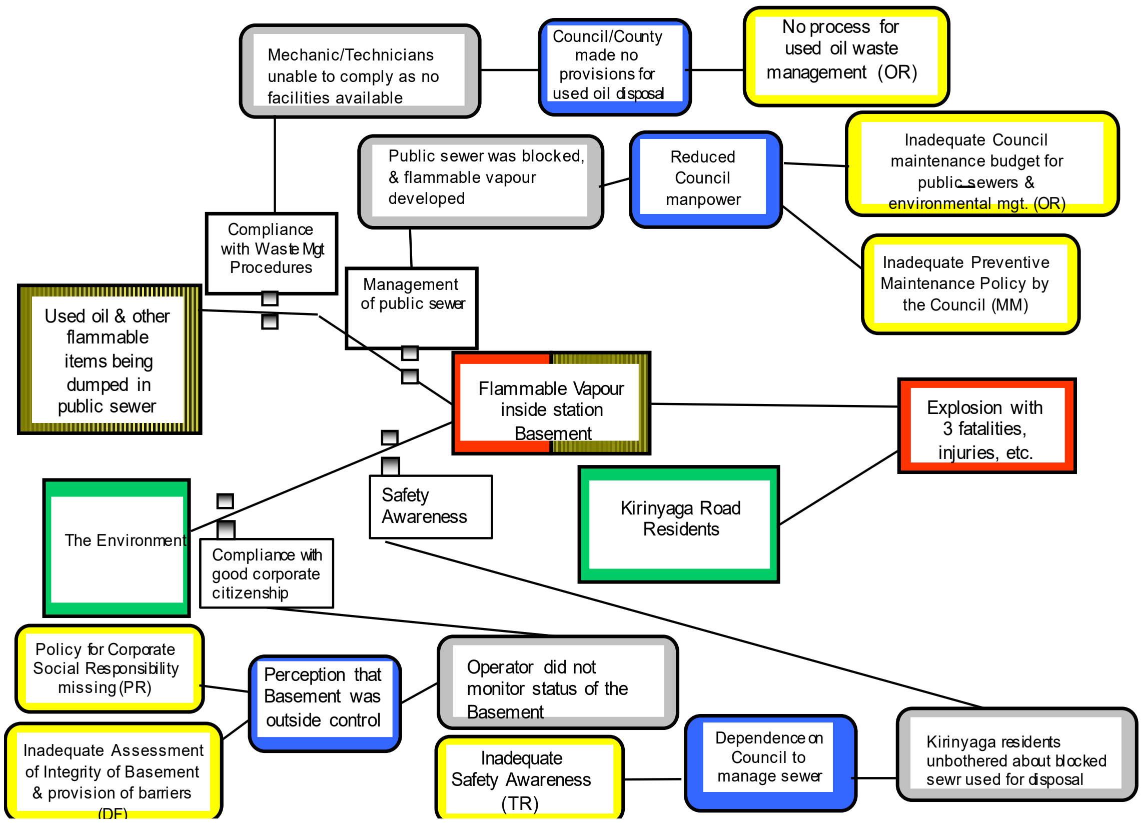

Figure P5: Tripod Analysis of Kirinyaga Road Petrol Station Disaster

The Hazard identified by the TM analysis was used oil and other flammable materials, like cleaning solvents, etc. that were being dumped in the public sewer. The Object for the Hazard was the Environment. The barrier that should have prevented the existence of the Hazard was compliance with appropriate waste management practices, as the public sewer was not meant to be used as a waste dump. The intersection of the Hazard (used oil) with the Object (environment) led to the Event, which was the formation of a gas cloud in the basement. The Immediate Cause of this Event was that mechanics and technicians were unable to comply with the waste management procedures because there were no appropriate waste facilities, nor used oil recycling facilities at Kirinyaga Road. The Precondition that facilitated the existence of the Immediate Cause was the failure of the Nairobi Council to provide waste oil recycling or collection facilities in the neighbourhood of the garages. The root cause of the disaster therefore was the lack of a process for waste oil management by the Nairobi Council, and this can be classified as Organisation under the BRFs.

Following the foregoing analyses, the summary of root causes are as follows:

Table P.3: Summary of Root Causes on Kirinyaga Road Fire Disaster (SPPS) - from the Tripod Analysis shown in Figure P5

Root Cause	BRFs Classification	Recommended Action
No process for oily waste mgt management process.	Organisation (OR)	NEMA to establish a waste oil to be adopted by each county PIEA to provide support for
Inadequate budget provision for public health/sewer framework maintenance	Organisation (OR)	Joint taskforce between NEMA & Dept of Public Health on for budget and scope for counties
Inadequate Preventive public Maintenance Policy by The Nairobi Council	Maintenance (MM)	NEMA to develop process for sewers preventive maintenance for adoption by counties
Develop Corporate Social operator Responsibility	Procedure (PR)	PIEA to provide support for to develop CSR Plans
Inadequate Assessment	Defence (DF)	The operator to fence off the

of the Technical Integrity (done) of the Basement		basement for productive use
Poor Safety Awareness across Kenya communities	Training (TR)	PIEA to develop oil product safety awareness pack
Inadequate Safety Awareness by community	Communication (CO)	PIEA to develop oil product safety awareness pack for Kenya and disseminate to Communities via Radio/TV

Out of the standard eleven BRFs the following were identified for the Kirinyaga Road Petrol Station fire disaster: Organisation, Maintenance, Communication, Procedure, Training and Defence. The analysis chart is shown below:

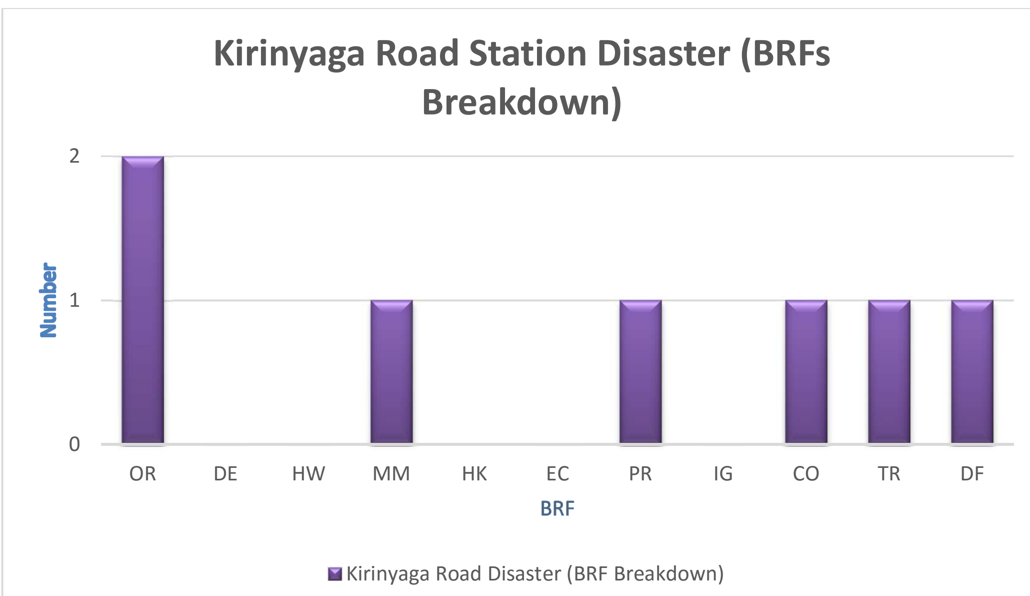

Figure P.6: Breakdown of Basis Risk Factors (BRFs) from Tripod Analysis for the Kirinyaga Road Fire Disaster (breakdown from Table P.3)

Appendix 4: Questionnaire for Tanker Drivers

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This questionnaire is a build-up to determining critical factors in disaster risk reduction and sustainable management of the petroleum industry in Kenya. Your assistance and input as a professional driver will be highly valued.

Name: (Optional)…………………………………… Sex (M/F) ……. Transporter's Name: ……………………… Oil Company Name………………

Instructions: ***PLEASE, TICK THE OPTION THAT DESCRIBES YOU, OR YOU MOSTLY AGREE WITH, IN ALL THE SECTIONS***

1. What is your age ?		**2. How many years as a professional tanker driver ?**	
70yrs and above		Above 15yrs	
56 – 69 years		11 – 15 years	
41 – 55 years		6 – 10 years	
30 – 40 years		1 – 5 years	
24 – 29 years		Less than 1 year	

3. What is your monthly take-home pay, including allowances, trip bonuses, etc?		**4. How many Motor Vehicle Accidents, including minor crashes, have you been involved in under the Journey Management System of your company/transporter?**	
Above Ksh 100,000		Over 15	
Ksh 76,000 – 100,000		11-15	
Ksh 46,000 – 75,000		6 – 10	
Ksh 31,000 – 45,000		1 - 5	
Less than Ksh. 30,000		0 (None)	

5. How many serious injuries (i.e. injuries that prevented you from going to work) have you been involved in whilst working with your company?		**6. What is approx. the total quantity of product spills you have been involved in since joining the company?**	
4 and above		Above 100,000 Litres	
3		21,000 – 100,000 Litres	
2		1,000 – 20,000 Litres	
1		1 – 1,000 Litres	
0 (no injury)		0 Litres (no spill at all)	

7. Which part of the Rules for Drivers or Tools (below) do you not understand, or disagree it contributes to prevention of Motor Vehicle Accidents or serious injuries ?	**Don't Understand or Disagree (Tick only)**
a. Be 30yrs or older	
b. Have valid Kenyan Driving License (for vehicle type)	
c. Have valid Driving Permit (issued by transporter/client after assessment) & regular renewal	
d. Have minimum of 5 years' experience of truck driving	
e. Be certified medically fit every year	
f. Check that all in the vehicle wear their seatbelts	
g. Never use a Mobile Phone (NOT even hands-off type) whilst driving	
h. Be well-rested: max driving hours: HGV: 2hrs/15min rest, Max 12hr shift: 9-hrs driving	
i. NO alcohol, drugs or medicine that could cause drowsiness	
j. In-cabin On-Board Computer (OBC)/In-Vehicle Monitoring System (IVMS)	

8. What is the frequency of Safety Meetings in your company or at the location where you work?		**9. How often do your Supervisors/Managers engage drivers in Safety discussions/Pep-talks ?**	
Weekly		Daily	
Monthly		Weekly	
Quarterly		Monthly	
Once a year		Infrequent	
Never Held		Never	

10. Defensive Driving Training claims all accidents are preventable. Whats your opinion ?		**11. What is your highest education level? Please circle One:**	
Fully Agree		**A) No formal schooling**	
Agree		**B) Primary**	
Not sure/known		**C) Secondary**	
Slightly Disagree		**D) Tertiary: College/University**	
Disagree			

Appendix 5: Collated Tanker Drivers Response from Questionnaire

Embedded file contains the spreadsheet with data of the response from the tanker drivers

Microsoft Excel
97-2003 Worksheet

Legend:

Drivers'Age: 24 – 29yrs =27; 30-40yrs =35; 41 – 55yrs = 48; 56 – 69yrs = 63; 70+ = 70

Salary: Less than 30K = 1; 31 – 45K = 2; 46 – 75K = 3; 76 – 100K = 4; More that 100K=5

Experience: Less 1yr = 1; 1-5yrs = 2; 6-10yrs = 3; 11-15yrs = 4; More than 15yrs =17

Accidents: Zero =0; 1-5 =3; 6-10 = 8; 11-15 = 13; More than 15 accidents = 15

Appendix 6: NACOSTI Approval

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

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NAIROBI-KENYA

Ref. No. **NACOSTI/P/17/12261/14273**

Date: **10th January, 2017**

Oladapo Tunde Oguntoyinbo
Masinde Muliro University of
Science and Technology
P.O. Box 190-50100
KAKAMEGA.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Validation of the tripod methodology in disaster risk reduction in the petroleum industry in Kenya and Nigeria,"*** I am pleased to inform you that you have been authorized to undertake research in **Nairobi County** for the period ending **10th January, 2018.**

You are advised to report **the Principal Secretary, Ministry of Energy and Petroleum, the Chief Executive Officers of selected government agencies, the County Commissioner and the County Director of Education, Nairobi County** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

BONIFACE WANYAMA
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The Principal Secretary
Ministry of Energy and Petroleum.

National Commission for Science, Technology and Innovation is ISO 9001: 2008 Certified