

RISK ASSESSMENT OF ROAD TRANSPORTATION OF PETROLEUM PRODUCTS

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Abstract

The transportation of petroleum products via road networks plays a vital role in meeting global energy demands. However, this mode of transportation poses inherent risks to human life, the environment, and infrastructure. A comprehensive risk assessment of road transportation of petroleum products is crucial to identify potential hazards, evaluate their likelihood and consequences, and develop robust mitigation strategies. This research aims to provide a systematic analysis of the risks associated with the road transport of petroleum products and propose effective risk management measures.

This study employs a multidisciplinary approach, integrating elements of engineering, logistics, environmental science, and safety management. It begins with an extensive literature review of existing studies, industry best practices, and regulatory frameworks related to the transportation of petroleum products. The identified risks are categorized into various domains, including operational, technological, environmental, and human factors.

Based on the risk assessment results, this research develops a comprehensive framework for risk management in road transportation of petroleum products. The framework incorporates preventive and mitigative measures, including improved vehicle design, driver training programs, route optimization, emergency response planning, and regulatory enhancements.

The outcomes of this research will contribute to enhancing the safety and sustainability of road transportation of petroleum products. The findings will help policymakers, industry stakeholders, and transportation companies in formulating effective risk management strategies, improving regulatory frameworks, and implementing safety measures to minimize the occurrence and impact of accidents and incidents. Ultimately, this research aims to foster a safer and more resilient transportation system for petroleum products, ensuring the protection of human life, the environment, and critical infrastructure.

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Acronyms/Abbreviations

NOCMA- National Oil Company of Malawi

MERA- Malawi Energy Regulatory Authority

HAZMAT- Hazardous Materials

SIMSO- Simama and Sons

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CHAPTER 1: INTRODUCTION

Background information

The road transportation of petroleum products through trucks poses numerous risks and potential consequences for unintentional environmental releases of hazardous materials. These releases can result in a wide range of safety and environmental repercussions, depending on several factors. The volume of the released material plays a significant role in determining the scale of the impact. Larger releases can have more severe consequences, potentially leading to widespread contamination and damage.

The chemical properties of the released material also influence the nature of the impact. Petroleum products contain a variety of substances with different toxicity levels, flammability, and persistence in the environment. Some components may be highly toxic to humans and wildlife, while others may pose fire and explosion hazards. The specific properties of the released material greatly affect the potential harm to ecosystems and the severity of the risk to human health.

The sensitivity of the surrounding environment is another crucial factor. In many developing countries, towns and villages are often situated in close proximity to major roads, which serve as vital transport corridors. This spatial arrangement increases the likelihood of accidents occurring near populated areas, thereby raising the potential for human exposure and environmental damage. The proximity of human populations to transportation routes intensifies the urgency of addressing the risks associated with road transportation of petroleum products.

The presence of human populations nearby amplifies the potential consequences of accidents. In the event of a release of hazardous materials, nearby communities may be directly exposed to toxic substances, leading to immediate health risks. Inhalation of toxic fumes, contact with contaminated soil or water sources, and other forms of exposure can have detrimental effects on human well-being. Moreover, the indirect impacts on communities, such as disruptions to livelihoods and economic activities, can be substantial.

Developing countries face unique challenges in managing these risks due to their specific socioeconomic and infrastructural contexts. Limited resources for accident prevention, emergency response, and regulatory enforcement can hinder the implementation of effective risk management measures. Additionally, the lack of adequate conditions and maintenance of roads and transport systems can contribute to increased accident rates and the severity of their consequences.

Addressing the risks associated with the road transportation of petroleum products in developing countries requires a comprehensive approach. It involves strengthening regulatory frameworks to ensure compliance with safety standards and promoting the adoption of best practices in the industry. Enhancing emergency response capabilities, including training and equipping local responders, is crucial for minimizing the impacts of accidents. Additionally, strategic urban planning that considers the location of human settlements in relation to transportation routes can help mitigate the potential risks. (Fabiano et al., 2002).

The transportation of petroleum products gives rise to a perpetual clash between two contrasting perspectives. On one hand, operators involved in the petroleum industry are primarily driven by the pursuit of profitability, aiming to maximize their financial gains. On the other hand, regulatory agencies have the paramount objective of safeguarding public welfare and environmental safety, ensuring that the transportation of these hazardous materials is conducted with the utmost care and adherence to regulations.

Given the inherent risks involved in the transportation of petroleum products, it becomes imperative for both operators and regulators to embrace and implement appropriate accident investigation procedures that are guided by comprehensive risk assessment principles. By doing so, they can gain a thorough understanding of the potential severe hazards associated with the inherently dangerous nature of petroleum products transported by road, and take proactive measures to prevent accidents and mitigate their consequences. (Zhang, 2016)

Accident investigation procedures serve as a crucial tool for unraveling the complex factors that contribute to accidents and incidents in the transportation of petroleum products. These procedures involve a systematic analysis of the events leading up to an accident, examining various aspects such as human factors, equipment failure, operational practices, and external influences. Through a meticulous examination of these factors, operators and regulators can identify the root causes of accidents, determine the contributing factors, and develop effective strategies to prevent their recurrence in the future.

Risk assessment principles play a pivotal role in guiding accident investigation procedures related to the transportation of petroleum products. Risk assessment involves evaluating the potential hazards and their associated likelihood of occurrence, as well as the potential consequences if an accident were to happen. This assessment helps in prioritizing the areas of highest risk and allocating appropriate resources and preventive measures to address them. By adopting risk assessment principles, operators and regulators can make informed decisions regarding safety measures, training programs, maintenance protocols, and emergency response plans, thus minimizing the likelihood of accidents and mitigating their potential impacts. (Ambisisi Ambituuni et al, 2015)

The dangerous nature of petroleum products necessitates a collaborative approach between operators and regulators. Operators must adopt a proactive stance by implementing robust safety protocols, investing in reliable and well-maintained transportation conditions, and providing comprehensive training to their personnel. Meanwhile, regulatory agencies need to ensure stringent compliance with safety regulations, conduct regular inspections and audits, and enforce penalties for non-compliance. Through mutual cooperation and adherence to appropriate accident investigation procedures guided by risk assessment principles, operators and regulators can work together to enhance the safety of petroleum product transportation, protecting both the public and the environment from potential hazards.

Risk assessment of transportation of hazardous materials such as petroleum products has attracted research attention during the last 20 years (Yang et al., 2010) especially in the

context of safe transportation using pipelines (Dziubinski et al., 2006) and road (Verter and Kara, 2001). For instance, in a report by Robert Ngwira in 2022, a fuel tanker belonging to Petroda Malawi Limited was involved in an accident along Chikwawa road near Milare Police Station in Blantyre. According to Ngwira, the cause of the accident was reckless driving as the driver lost control of the vehicle as said by an eye witness.

Due to the accident, the tanker started leaking fuel uncontrollably, releasing gallons of fuel to the environment hence exposing the environment to hazard as contamination of this fuel with the ground resulted in pollution which would affect the plant growth in the area. Nevertheless, contamination of this fuel with underground water would cause enormous effects to people as health problems including diarrhea may arise when contaminated water is used to drink.

According to Ngwira, looters were seen scrambling for the leaking fuel which was, at the time and still is currently in short supply in the country as motorists spend days at the pump stations in the country. These people tend to keep the fuel in their homes without necessarily knowing the storage conditions of petroleum products. This puts their lives at risk as these products are highly flammable, speaking of which a couple died after a jerrycan containing petrol caught fire in their house in Dedza. According to Dedza Police spokesperson, Beatrice Jefita, the incident occurred on July 27, 2023 at Kachule Village.

Problem statement

In recent years, the transportation of petroleum products, particularly petrol and diesel, by road has experienced a substantial increase in importance and has become a fundamental component of modern society's functioning. This mode of transportation plays a crucial role in supporting economic activities and providing essential energy resources that power various sectors and industries. However, it is essential to recognize that the transportation of petroleum products via road is not without its challenges and inherent risks, which can significantly jeopardize public safety and harm the environment.(Ambituuni et al., 2015a)

One of the primary risks associated with road transportation of petroleum products is the occurrence of accidents. Due to the flammable nature of these materials, any mishap during transportation can lead to explosions, fires, and severe damages. These accidents not only endanger the lives of individuals directly involved but also pose a significant threat to nearby communities and the general public. Additionally, accidents involving petroleum products can result in the release of toxic substances, which can contaminate soil, water sources, and ecosystems, causing long-term environmental damage.

Furthermore, the transportation of petroleum products by road has the potential to disrupt society on various levels. In the event of a major accident or spill, roads may be closed off, leading to traffic congestion, delays, and disruptions in the movement of goods and people. This can have adverse effects on the economy, hindering the timely delivery of essential goods and services. Moreover, the cleanup and recovery efforts following a petroleum-related incident can be time-consuming and costly, thereby impacting the affected communities and straining limited resources. (Verma, 2016)

To address these pressing concerns, there is a need for comprehensive risk assessment of road transportation of petroleum products. The objective of such research is to identify potential hazards associated with this mode of transportation, evaluate their impacts, and propose effective strategies for accident prevention and mitigation. By conducting a thorough analysis of the risks involved, it becomes possible to develop robust safety protocols, implement appropriate preventive measures, and establish emergency response plans.

The research aims to ensure the safe and sustainable transportation of these hazardous materials by minimizing the occurrence of accidents, reducing their potential consequences, and safeguarding public safety and the environment. It involves examining various aspects such as vehicle safety standards, driver training and qualifications, route planning, emergency response capabilities, and the implementation of advanced technologies and monitoring systems. These measures can help enhance the overall safety and reliability of

road transportation of petroleum products, mitigating the risks associated with this critical activity.

In conclusion, while road transportation of petroleum products is integral to our modern society, it is not without risks. The occurrence of accidents, potential environmental damage, and societal disruptions are significant concerns that necessitate comprehensive risk assessment and proactive measures. By identifying potential hazards, evaluating their impacts, and proposing effective prevention and mitigation strategies, we can ensure the safe and sustainable transportation of petroleum products, protecting public safety and the environment for present and future generations.

Main and specific Objectives

Main Objective

- To conduct risk assessment for the road transportation of petroleum products

Specific Objectives

- To identify potential hazards associated with road transportation of petroleum products
- To quantify safety risks
- To evaluate the environmental impact

Research questions

- What are the key factors and variables contributing to the risk profile of road transportation of petroleum products?
- What are the primary causes and underlying factors of accidents and incidents related to road transportation of petroleum products?
- What are the environmental consequences of spills and accidents involving petroleum products during road transportation, and how do these consequences vary based on factors such as product type, volume and location?

Significance of the Study

- Public Safety Enhancement: By identifying and analyzing the factors contributing to accidents and incidents during the road transportation of petroleum products, the study can lead to the development of effective safety protocols, regulations and preventive strategies. This can directly lead to reduced accident rates, fewer injuries, and fewer fatalities among drivers, emergency responders, and bystanders.
- Environmental Protection: The study's assessment of the environmental impact of accidents and spills can guide the implementation of measures to minimize contamination of soil, water bodies, and ecosystems. This contributes to safeguarding biodiversity, protecting water resources, and preserving natural habitats.
- Regulatory Framework Improvement: The research can shed light on the effectiveness of existing safety regulations and protocols. Policymakers and regulatory agencies can use the study's findings to strengthen or develop more robust safety standards for the transportation of hazardous materials

CHAPTER 2: LITERATURE REVIEW

Many accidents involving trucking petroleum products by road in many developing countries are associated with consequential effects of human safety and environment. Such accidents have exposed lack of accident risk management structure in developing countries like Nigeria, Zambia and Malawi, just to mention a few.

As said by Dare et al., 2009, many of these accidents involving petroleum product transportation, including petrol and diesel by road have caused disasters and losses to man and the environment in Nigeria. Such accidents have exposed lack of accident prevention and emergency management structures within the context of trucking petroleum product. With projected growth in energy and demand and the consistent failure of the pipeline and rail transport systems, it is evident that trucking petroleum products by road remains the most viable inland transport means. Therefore, there is a need to develop a management framework for truck tanker accident prevention.

In recent years, increasing attention has been devoted to different aspects related to hazmat transportation especially within the context of hazmat risk assessment. Yang et al., 2010 suggested a model for utilization of historic data for accident surveys. Fabiano et al, 2002 and Guo and Verma, 2010 suggested models for decision making strategies in dangerous good transport and choosing vehicle capacity to minimize risk respectively. Nevertheless, little attention has been given to developing risk assessment model for accident prevention in developing countries where the effectiveness of regulation for accident prevention and emergency preparedness and response is often constrained by limited regulatory resources(Ambituuni et al., 2015b)

Generally, a road accident involving dangerous goods can damage road conditions, community (for economic and environmental consequences of leakage), and humans. In relation to hazard for humans, road transport of dangerous goods creates risks for people present or road (users), and people along the routes (surrounding population resident). It is essential therefore to get information on frequency and consequences which a road accident involving dangerous goods, including petroleum products generate. Frequency and impacts

can depend on: the effects of an accident and its duration (Adler et al., 2013); category and dangerousness of goods transported (Amezaga et al, 2015); type of accident, primary or secondary crashes (Hong Yang et al, 2014); road typology(motorway, arterial, urban road, etc.); road sections, for example straight, curved, tunnel, bridge, etc. (Kinateder et al, 2015); surrounded areas crossed; pavement structure; speed.

A very important issue is relationships between traffic congestion and frequency/impact of road accident. Traffic congestion and road accidents are two important external costs of transports produced by road users with relevant impacts on road users and community. The reduction of their impacts is one of the primary objectives for transport policy makers.

Traffic congestion is an omnipresent phenomenon mainly during rush hour in densely-populated areas (Arnott and Small). Literature defines two traffic congestion types: recurrent, if depend on relevant flows and density of traffic; non-recurrent, when it is the result of external events such as an accident. Some authors have studied the problem of interrelationship between traffic congestion and road accident (Shefer, 1994). Other authors have defined risk assessment for dangerous goods carriage (Cassini, 1998).

Traffic congestion and road accidents are closely related by an inverse relationship which can pose a potential dilemma for transport policy makers (Shefer and Rietveld, 1997). (Shefer, 1994) has proposed an inverse relationship between congestion and road fatalities, in which volume over capacity ratio was used to measure the level of congestion. A further study by Shefer and Rietveld (1997) investigated the link between congestion and safety on highways. Starting from the hypothesis previously used, they compared fatality rates throughout the day, and found that during peak hours the fatality rate is lower than that at other times of the day. Due to data unavailability, they examined a proposed model, using a simulated dataset rather than real-world data. Quddus (2009) underlined that these studies tend to use an analytical approach and a weak proxy for traffic congestion, so as such, more robust empirical evidence, and a precise congestion measurement, are required.

However, collecting data for multiple year to describe the relationship between traffic congestion and road accidents is an expensive and time-consuming activity

Case Example: Petroleum Product Distribution in Nigeria

The downstream subsector of petroleum industry in Nigeria is characterized by a complex assortment of conditions and processes including refining, distribution, transportation and retailing of petroleum products. The industry supplies about 40 million litres of petroleum products per day to an estimated 170 million people across 36 states and Abuja (NNPC, 2012) mainly via trucking operations. In addition to government owned retailing company (Nigeria National Petroleum Corporation-Retail), there are 6 major marketers and over 10,200 independent marketers all involved in the transportation and distribution of petroleum products. In 2012, the Federal Road Safety Commission (FRSC) reported the involvement of over 5000 petroleum product tankers in daily haulage on Nigerian roads, accounting for approximately 95% of the country's petroleum products transport volume on the road system.

This transport system has been largely responsible for accidents and disasters that pose risks to human safety and environment (Dare et al, 2009). However, regulatory activities (including accident prevention, preparedness and response) have mainly been constrained due to inadequate funding. For instance, while the FRSC have safety requirements and guidelines for articulated lory(tankers/trailers) operations in Nigeria that covers registration, licensing and emergency preparedness their operations are not efficient (Oluwadiya et al, 2009). This calls for enhanced identification of accidents hotspots for effective regulatory resource prioritization and distribution as a risk management strategy. A risk assessment model is therefore required in light of the limited access to good quality data which has often contributed to research limitations in Nigeria (Anifowose et al, 2012). The highly

articulated, small but politically sensitive nature of truck tanker operators in Nigeria (Majekodunmi, 2013), also typifies a case where a framework is required for integrating accident cost analysis so that regulators can build a case to enforce good safety and environmental standards and also manage the risk perception of operators.

Negative impacts of oil tanker accidents on the environment

Air pollution

One of the major environmental impacts of oil tanker accident is air pollution. Oil tanker accident results to oil spillage which causes fire outbreak and release of hazardous substances. It may be regional or global in scale. The gaseous and particulate matter emissions from oil tanker accidents affect air quality. Toxic air pollutants from oil tanker accidents have resulted to the loss of lives and damaged health of few surviving victims of oil tanker accident.

Studies by Ordinioha and Brisibe (2013) has also shown that Toxic air pollutants are associated with cancer, cardiovascular, respiratory and neurological diseases. Carbon monoxide (CO) inhale affects bloodstream, reduces the availability of oxygen and is extremely harmful to public health.

Climate Change

In many Oil tanker accident occurrences several million tons of gases are released into the atmosphere. These include lead (Pb), Carbon monoxide (CO; not a pollutant), methane (CH_4), nitrogen oxide (NO), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), perfluorocarbons (PFCs), silicon tetrafluoride (SF_6), benzene and volatile components (BTX), heavy metals (zinc, chrome, copper and cadmium) and particulate matters (ash, dust). Although there is an ongoing debate to what extent these emissions are linked to climate change and the role of anthropogenic factors. But some of these gases, particularly nitrous oxide, participate in depleting the stratosphere ozone (O_3) layer which naturally screens the earth's surface from ultraviolet radiation. Some of these gases such as SO_2, NO_2, H_2S, NH_3, and CO produce organic acids resulting in acid rain. This acid rain precipitation has

detrimental effects on the built environment, reduces agricultural crop yields and forest decline. It is also relevant to underline that climate change gas a significant impact on transportation systems, particularly conditions.

Soil Quality and Destroyed Vegetation

The environmental impact of oil tanker accident on soil consists of soil erosion and soil contamination. It influences natural vegetation and result to deforestation in the area of occurrences. Many a times oil tanker falls into the ditch, farm lands, and natural vegetation resulting too many environmental consequences. Many animal species are becoming extinct due to burn from oil tanker spillage. Petroleum released to the soil move through the soil to the ground water. Individual compounds separate from original mixture, depending on the chemical properties of the compound. Some of these compounds evaporate into the air and others dissolve into the ground water and move away from the release area. Other compounds attach to particles in the soil and stay in the soil for a very long time, altering the soil properties and nitrifying bacteria present in the soil that helps in enhancing soil fertility, smothered economic trees and food crops, reducing their yield. Spillages from oil tanker accident also contribute to increased biodiversity loss and the destruction of vegetation including farmland.

Distortion of Urban Landscape and Agricultural Land

Oil tanker accident affects the urban landscape. Houses, farm lands and vehicles burnt as a result of oil tanker accident occurrences causes' significant environmental degradation and nuisance. The burnt properties especially vehicles are left on the road or along the road for a long time thereby causing environmental nuisance. These burnt properties affect quality of urban life by creating physical barriers, generating odor, reducing urban aesthetic and affecting the built heritage. It also destroys urban conditions such as high-tension wire, and economic trees which also serves as shade. Some of the environmental implications of oil

tanker accident include environmental nuisance. Damages such as urban conditions and vehicles constitute environmental nuisance and obstruction on the road. This obstruction often results to more accident.

Health Hazard

Oil tanker accidents have caused lots of health disaster. Many lives were roasted as a result of fire outbreak from oil tanker accident while the very few surviving one's health was damaged for life. Children, young and old were affected in this incidence. Many of the victims of oil tanker accident were burnt in the act of scooping up spilled petroleum after the tanker crashed when it caught fire. In Onitsha oil tanker ran into the Bus Park roasted lots of lives and properties. This is as a result of brake failure and loss of control by the driver. Collisions of moving oil tanker with bus and smaller vehicle on the high way also resulted to the loss of many lives. Indiscriminate and improper parking of oil tanker along the road especially at night, the use of hand set in the filing station during the discharge of fuel and the use of phones while driving when the oil tanker is close has also led to accident and fire outbreak and this also has burnt and damaged the life of many victims.

CHAPTER 3: METHODOLOGY

3.1.1 Sampling techniques

This research adopted a simple sampling technique called the random sampling technique. In this technique, a small population of tanker drivers was sampled randomly across different areas within the city. The sampled population was then interviewed in an approach to know their thoughts and opinion on why accidents involving fuel tankers occur at such an alarming rate. This research also contains a descriptive study of the risk factors and how they influenced the occurrence of tanker accidents.

3.1.2 Data collection

The study used both primary and secondary data. The primary data was collected through direct interviews with tanker drivers from oil marketing companies such as Total Energies, MERU, Energem, and Zagaf Transport among others. A random sampling technique was adopted in the interviews with the drivers. Their opinion on how most accidents involving tankers in the country was used to find out about the main causes of the accidents involving the tankers carrying petroleum products, mainly petrol and diesel.

Although I met a lot of resistance during data collection, some tanker drivers misunderstood the whole idea of interviewing them, as such some felt it was stupid and time wasting to contribute. Nevertheless, I still managed to interview 20 drivers from different transport companies including Zagaf, Energem, SIMSO and MERU. Just to mention a few.

According to the findings from these interviews, the main causes of these tanker accidents include negligence leading to careless driving, poor road conditions, (for instance, Chiweta in Rumphi- along Mzuzu- Karonga Road), Mechanical failure, for instance brake failure among others.

On negligence, according to Mr. James Mphoyo of Zagaf Transport, tanker drivers operate long hours of driving without adequate rest. In his words, during the cyclone Freddy, they could only get fuel from the Dar es Salaam because all Mozambique routes were closed. They could travel a distance of approximately 1099 kilometers to get to Blantyre from Dar es Salaam. This is a very long, tiresome journey, as such they could not get adequate sleep.

Operating under pressure as the fuel demand increased, these drivers were pushed to work as fast as possible. This leads to negligence as they could recklessly drive just to get to Blantyre as fast as possible. Tanzania to Blantyre takes at least 15 hours of driving, as such tiredness and lack of adequate sleep leads to this inattentive state.

Poor road conditions are another leading factor that contributes to increasing tanker accidents in Malawi. According to Mr. Madalitso Mbewe of MERU, places like Chiweta in Rumphi and Khwekhwelere along Chikwawa road are not so good for the operation of huge vehicles as tankers. In his remarks, Chiweta, which meanders along the hills and valleys in Rumphi is not a good road for trucks and vehicles altogether. Drivers need to be extremely careful when driving along this place. Speed of not more than 10km/hr. is recommended, but since these drivers work under pressure and due to tiredness, it becomes so difficult to duly cooperate, this may lead to accidents.

Mechanical failure, another factor that contributes to road accidents involving fuel tankers in Malawi. According to Mr. Lekeni Manyozo of Petroda, mechanical failure is a big problem in the transportation of fuel in Malawi. In his remarks, Tankers take long period in transit and as such, vehicle servicing becomes an issue. For instance, last year, a Petroda tanker was involved in an accident in Chikwawa as the driver lost control of the vehicle. The vehicle had brake failure problem; this made the driver to lose control which led to the accident. The tanker started leaking fuel uncontrollably and people were getting the diesel in plastic buckets, which puts their lives at risk of being exposed to fire hazard.

Table 1 below shows the outcomes of the interviews

Name of Driver	Cause of Accident	Company
Mr. James MPhoyo	Negligence	Zagaf Transport
Mr. Madalitso Mbewe	Poor road conditions	MERU
Mr. Lekeni Manyozo	Mechanical failure	Petroda
Mr. Joel Mphande	Lack of sleep	SIMSO Oil
Mr. Maliseni Phiri	Reckless driving	Ninkawa Transport
Mr. Mateyu Fatsani	Mechanical failure	Ninkawa Transport
Mr. Basikolo Lenadi	Negligence	Puma
Mr. Patson Mbewe	Negligence	Puma
Mr. Malikebu Banda	Mechanical failure	MERU
Mr. Malizani Petulo	Mechanical failure	MERU
Mr. Pemphero Banda	Poor road conditions	MERU
Mr. Matiyasi Ngozo	Negligence	Petroda
Mr. Masugzo Msiska	Negligence	SIMSO Oil
Mr. Emmanuel Mailosi	Negligence	Petroda
Mr. Pilirani Zoya	Poor road conditions	Energem
Mr. Brian Thakolambuzi	Poor road conditions	Energem
Mr. Abraham Theyu	Negligence	SIMSO Oil
Mr. Walusungu Mughogho	Mechanical Failure	SIMSO Oil
Mr. Brighton Mandala	Mechanical failure	Puma
Mr. Madalitso Mickson	Negligence	Petroda

This data was further summarized using a pie chart below.

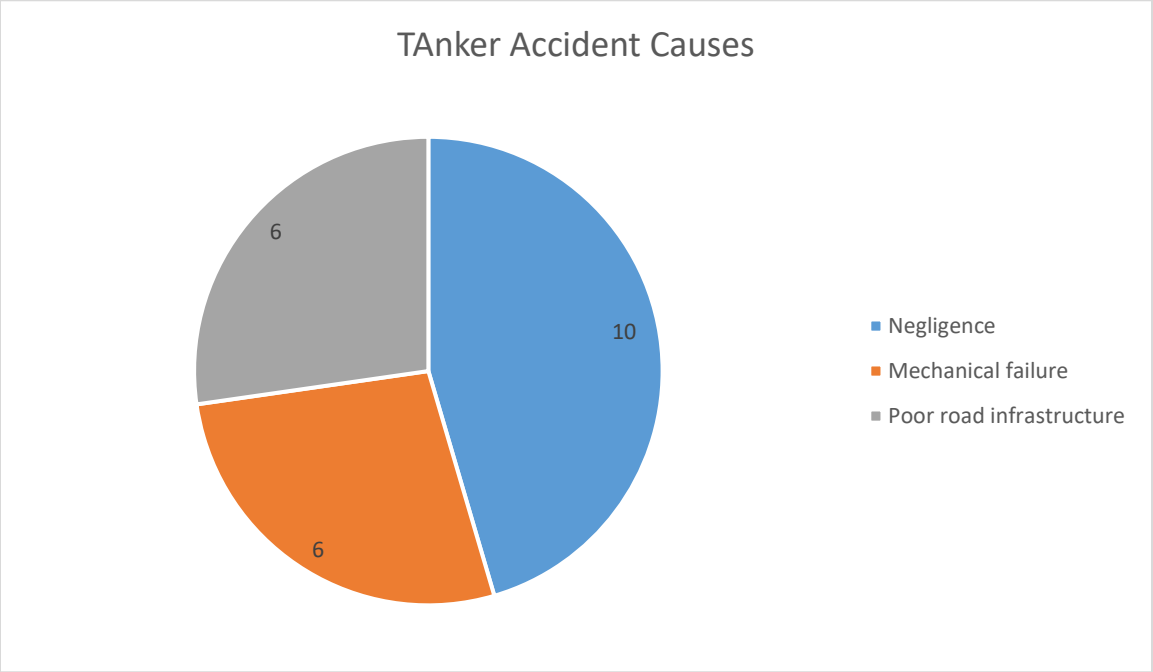


Figure 1. A pie chart showing causes of tanker accidents

Figure 1 is a pie chart which shows a summary of the main causal factors of petroleum tanker accidents according to a sample population of people that I managed to interview. In this chart, negligence which is a human factor is the major factor contributing to these accidents, dominating with a percentage of 45%. Mechanical failure and poor road conditions, which are non-human factors are the other factors contributing to the accidents involving petroleum tankers with a percentage of 27% each.

Secondary data was given out by NOCMA and MERA. National Oil Company of Malawi provided data on oil spills from the year 2020. And MERA, being the hub of all oil marketing companies provided data on accidents records from 2015 to 2019.

The second set of data was provided by the Malawi Energy Regulatory Authority. This data comprises accident report from 2016 to 2020.

3.1.3Data Analysis

On the data provided by NOCMA, I rearranged it into two incident types: minor oil spills at the depot and spills while in transit.

Table 2 shows oil spill incidents

Incident Type	Estimated No. of incidents Since 2020	Possible causes
Minor spills at The depot	15	• Human errors • Unsafe human behavior • Faulty fuel tankers
Fuel tanker incidents while in transit	8	• Inadequate fuel tanker maintenance • Poor driving • Poor road conditions

Table 2 shows oil spills data

The incidents at the depot do not have any effects on the environment as every single drop is taken care of and there is no chance for any environmental pollution. Incidents while in transit however, have enormous effects on the environment. Within the 8 incidents that happened during transit of petroleum products shipment, a case that happened near Milare police station in Blantyre in 2022, where a Petroda tanker leaked fuel after the driver lost control of the vehicle and swerved off into a bush along Chikwawa road. The driver failed to negotiate a corner as he was speeding. The tanker got damaged due to the accident, causing fuel to leak uncontrollably. It is reported that the about 40% leaked. This fuel seeped into the ground, causing enormous effects to the environment. Soil contamination, ecosystem destruction, as habitats were affected, are some of the consequences of this spill.

The other tragedy took place took place in Mwanza where a tanker carrying petroleum products overturned when the driver failed to control it due to brake failure. Due to this

problem, the driver failed to accelerate the tanker up the slope and ended up overturning. The tanker got damaged, leaking petrol uncontrollably. Fire later broke out. This accident happened weeks after another tanker leaked fuel uncontrollably in the same district. The accident happened at night when the tanker's brakes failed, making the driver lose control of the vehicle and it overturned, leaking petrol into the Mwanza riverbanks. People could find sand completely soaked in oil. Almost all the 35,000 litres of petrol that the vehicle was transporting leaked into the sands. This caused enormous environmental effects. Talking of water contamination into the Mwanza River, soil contamination as well as destruction of ecosystem.

The second dataset collected was accident report data from the Malawi Energy Regulatory Authority, MERA. This data was first cleaned and organized into a structured format then it was sorted and grouped according to years and the causal factors of the accidents. These factors were grouped into human factors, non-human factors and unknown factors.

Table 3 shows petroleum tanker accident reports from 2016 to 2020.

YEARS	NO. OF ACCIDENTS	NO. CAUSED BY HUMAN FACTORS	NO. CAUSED BY NON-HUMAN FACTORS	UNKNOWN FACTORS
2016	76	33	28	15
2017	58	26	23	9
2018	63	34	24	5
2019	70	35	23	12
2020	52	24	18	10

This data was further visualized into charts for different categories, including the total number of accidents, number caused by human factors, number caused by non-human factors and the unknown factors.

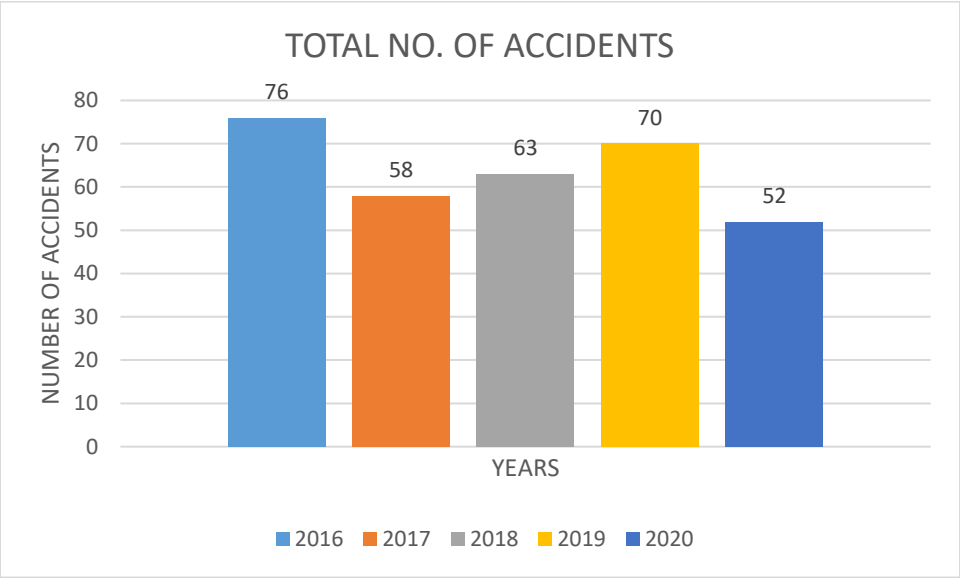


Figure 2. total number of accidents.

The number of accidents showed a general decrease from 2016 to 2020, indicating a positive trend in road safety. This could be true because of the introduction of stringent regulations regarding the transportation of goods and services including people. These regulations include introduction of alcohol detector techniques to prevent/minimize drinking while driving habits, construction and/or reconstruction of roads and provision of driver training and awareness campaigns regarding road safety. These regulations help in reducing or controlling road accidents, especially accidents involving the trucks that transport these hazmat materials.

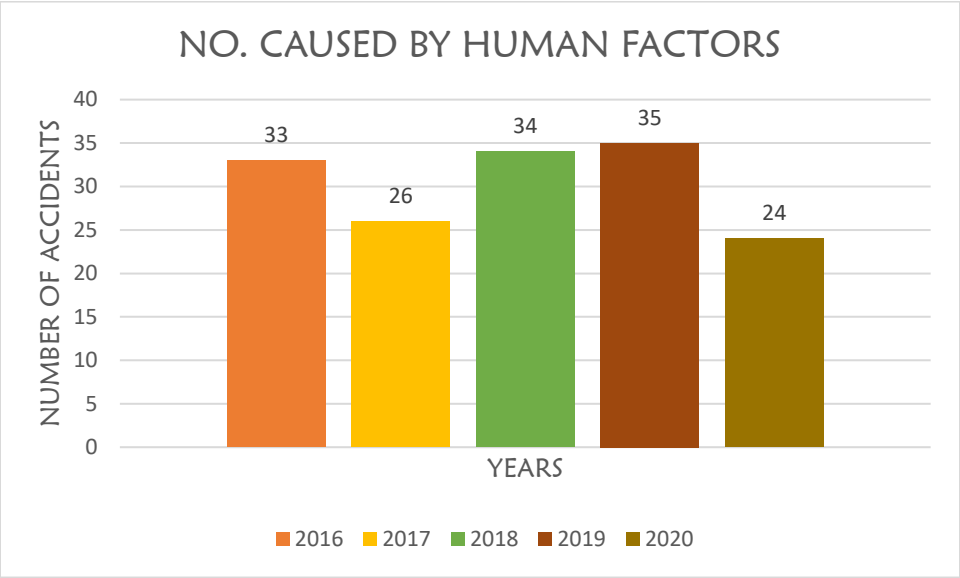


Figure 3. accidents caused by human factors

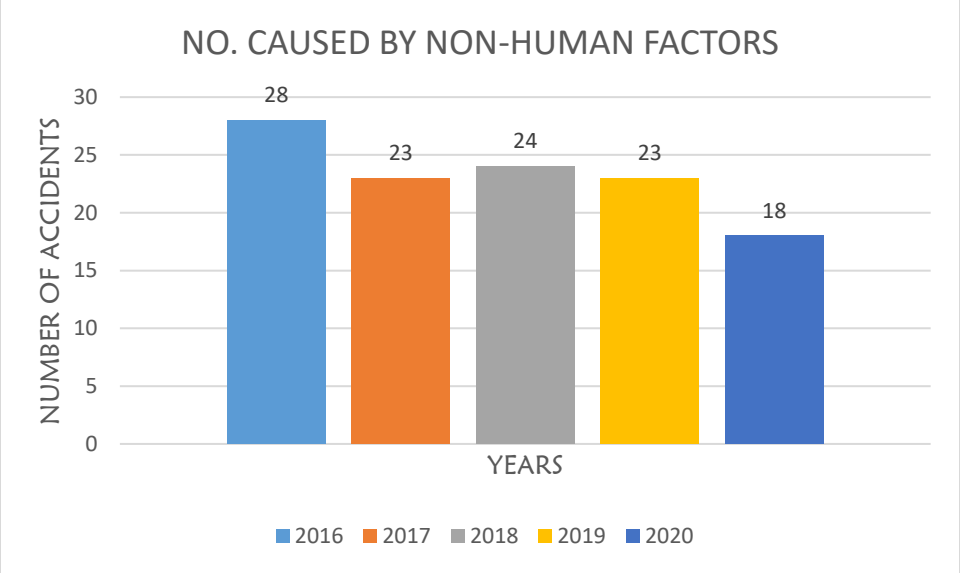


Figure 4. accidents caused by non-human factors

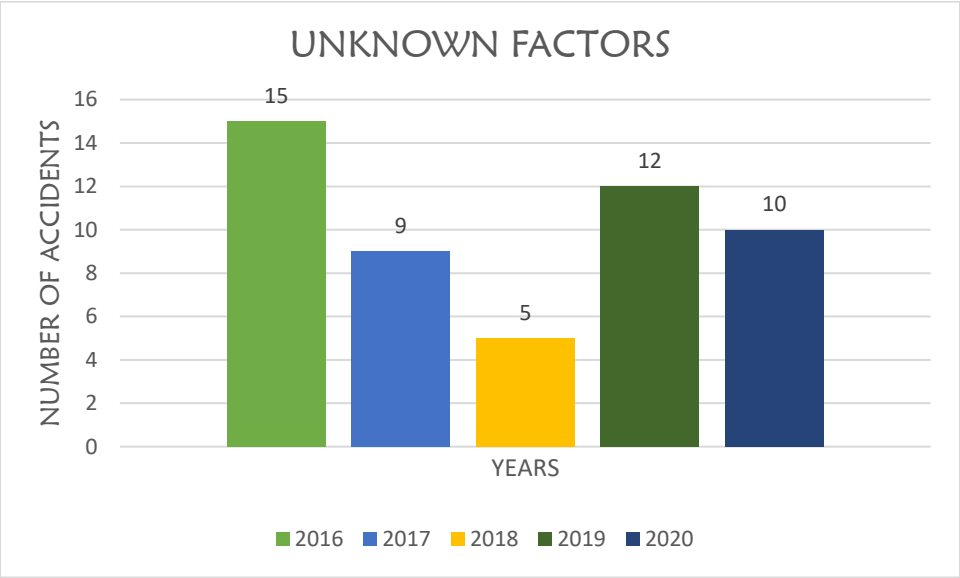


Figure 5. accidents caused by unknown factors

These charts indicate the trend of the accidents. From these charts, it was found out that human factors are the main contributing factors of accidents involving the transportation of petroleum products, with a percentage of 48%. Non-human factors including, poor road conditions and mechanical failure are the second in rank, holding a percentage of 36%. Unknown factors are the least of all with only 16%.

Figure 6 below generalizes this information.

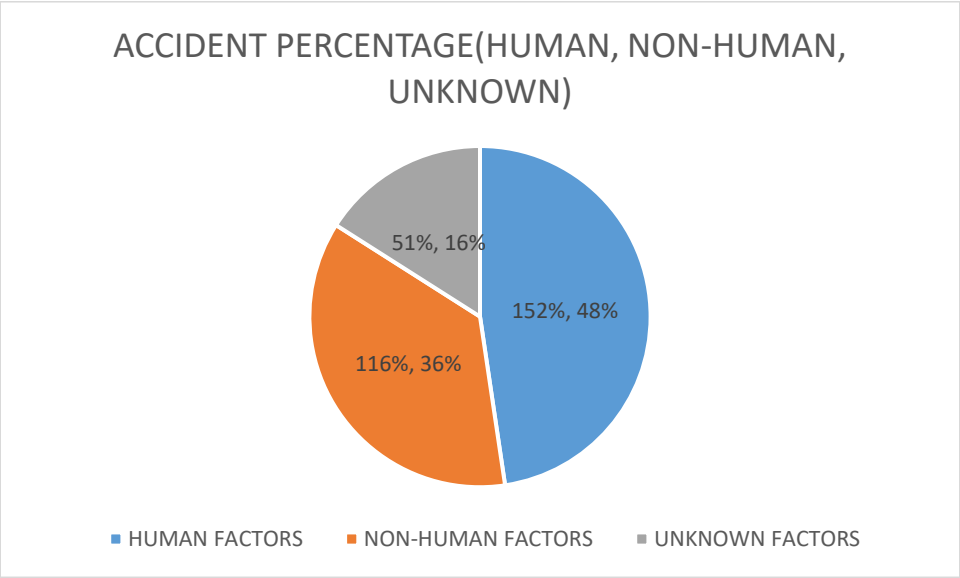


Figure 6. percentage distribution of causal factors

Using Microsoft excel I further analyzed the data by calculating the mean, median and standard deviation. By clicking the data tab on excel, then data analysis, I was able to calculate the mean, median and standard deviation of the data. The calculations are shown below

J	K	L	M	N
YEARS	NO. OF ACCIDENTS			
2016	76		*Column1*	
2017	58			
2018	63		Mean	63.8
2019	70		Standard E	4.247352
2020	52		Median	63
			Mode	#N/A
			Standard I	9.497368
			Sample Va	90.2
			Kurtosis	-1.21678
			Skewness	0.104825
			Range	24
			Minimum	52
			Maximum	76
			Sum	319
			Count	5

From this data, the mean, which is the average number of accidents from the class interval of 2016-2020, was found to be 63.8. The median number, which is the middle-year number was found to be 63 from 2018. As seen from the figure, there is no mode. This is because there are no repetitions, as mode by definition, is the most frequently occurring value in a distribution.

The standard deviation, which is a measure of how spread-out data values are around the mean, was found to be 9.497368. This is a good thing, because a higher standard deviation indicates a larger spread or variability of data points from the mean. In this case, this standard deviation suggests that are more widely dispersed or scattered around the mean. This shows that the accidents occurrence was declining from 2016 going to 2020.

CHAPTER 4: RESULTS AND DISCUSSIONS

The oil spill data provided by the National Oil Company of Malawi indicates the exposure of the environment to hazards. Some of the hazards brought about by the oil spillage include, chemical hazards as brought by the spill and infiltration of oil into the soil like in the Mwanza River case where the oil was found in sand in the Mwanza riverbank, Fire hazards as caused by the explosion after spillage.

Of the 23 cases of oil spills, 65.2% of the spills have no impact on the environment. They can therefore be regarded as safe spills. This is because they are well controlled within the NOCMA depots. 34.8% represents the incidents while in transit. These are associated with enormous risks including fire, water pollution, soil contamination among others.

On the accidents report data provided by the Malawi Energy Regulatory Authority, After deep analysis of the data, the hazards identified were accidents, which jeopardizes the health of people as well as their safety. After a closer analysis of the data, a particular trend was generated. The country recorded the highest number of accidents in 2016 which was 76. In 2017, the number dropped to 58. This decrease follows several factors. Some of which may be introduction of strict regulations, speed traps, alcohol detection techniques et cetera. In 2018, the number increased to 63. The reasons to this increase, would be that with time, people stopped taking the regulations so serious, as such the number of accidents increased. In 2019, the number increased further, six less to the number recorded in 2016. One of the reasons or this increase would be elections. During this time, there was very dense traffic, which may have contributed more to the probability of the accidents. In 2020, the number reduced again to 52. Stringent regulations, strong penalties may have been imposed to control these accidents. Driver training and awareness may have been provided as well. Generally, the trend shows a decrease in accidents involving petroleum tankers.

To conclude, human factors, including negligence are the main causal factors of the accidents involving petroleum tankers with a percentage of 48%. Non-human factors, including poor

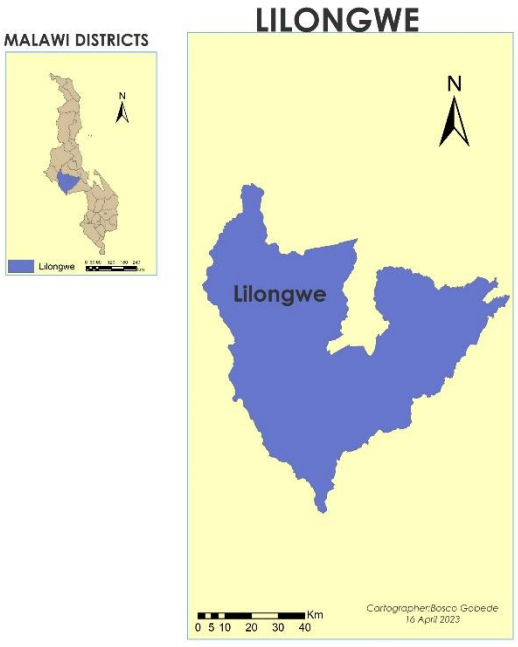
road conditions, mechanical failure (brake failure), are the next in rank with a percentage of 36%. The least of all are the unknown factors with a percentage of only 16%.

CHAPTER 5: STUDY AREA

5.1 Lilongwe City Location

Lilongwe, Malawi's capital, is located in the central region of Malawi. The city is on a latitude of 13.9669° S and a longitude of 33.7873 ° E and an elevation of 1050m (3440 ft) above sea level. It is one of the flat areas in Malawi with a smooth network of roads. Nevertheless, absence of dual carriageway in most of the roads in the city gives way to huge traffic, especially during rush hours. This gives way to accidents occurring frequently. Although the bypass road that extends from six miles, Bunda turn-off to the gateway mall was constructed to minimize traffic in the M1 road, tankers that deliver fuel to filling stations within the city still experience this problem of traffic jam. For instance, the Kaunda Road that extends from the gateway mall to Nsungwi, area 25, always possess huge traffic in the morning and evening.

5.2 Map of Lilongwe



CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

In conclusion, the research on the risk assessment of road transportation of petroleum products highlights the critical importance of identifying, evaluating, and managing the risks associated with this mode of transportation. The study systematically analyzed various hazards, including spills, leaks, fires and accidents, considering operational, technological, environmental, and human factors.

The research contributed to the development of a comprehensive risk management framework that integrated preventive and mitigative measures. These measures encompassed improved vehicle design, driver training programs, route optimization, emergency response planning, and regulatory enhancements.

The outcomes of this research hold significance for policymakers, industry stakeholders, and transportation companies involved in the road transportation of petroleum products. The findings provide valuable guidance for formulating effective risk management strategies, improving regulatory frameworks, and implementing safety measures to minimize the occurrence and impact of accidents and incidents.

By fostering a safer and more resilient transportation system for petroleum products, the research contributes to the protection of human life, the environment, and critical infrastructure. It underscores the importance of continuous monitoring, evaluation, and adaptation of risk management practices to ensure the safe and sustainable transportation of petroleum products on our road networks. Ultimately, the research aims to mitigate the risks associated with this crucial aspect of global energy supply and promote a safer and more resilient transportation system.

6.2 Recommendations

Based on this research, the following recommendations should be put forth:

1. Enhance Training and Awareness: This would be done by developing comprehensive training programs for drivers, logistics personnel, and emergency responders involved

in the transportation of petroleum products. These programs should focus on safe handling practices, emergency response procedures, and risk awareness to minimize human errors and improve preparedness.

2. Strengthen Regulatory Frameworks: Collaborate with regulatory bodies to review and strengthen existing regulations related to the transportation of petroleum products. Emphasize the enforcement of safety standards, including vehicle maintenance, driver qualifications, load securement, and spill prevention measures. Regular audits and inspections should be conducted to ensure compliance.
3. Employ Advanced Technologies: Explore the use of advanced technologies such as real-time monitoring systems, geographic information systems (GIS), and predictive analytics. These technologies can provide early warning systems for potential risks, enable effective route planning, and facilitate prompt response to emergencies.
4. Implement Risk Mitigation Measures: Develop and implement risk mitigation measures based on the identified hazards and their potential consequences. This may include improving vehicle design and safety features, implementing spill containment systems, and utilizing fire suppression systems. Additionally, establish protocols for incident reporting, investigation, and learning from past accidents to prevent their recurrence.
5. Foster Industry Collaboration: Encourage collaboration among stakeholders involved in the road transportation of petroleum products, including petroleum companies, transportation companies, regulatory bodies, and emergency response agencies. Foster information sharing, best practice sharing, and joint initiatives to address common risks and improve overall safety standards.
6. Promote Environmental Protection: Prioritize environmental protection by implementing measures to prevent and mitigate the environmental impact of potential spills or accidents. This may include the use of environmentally friendly containment materials, prompt cleanup procedures, and regular environmental monitoring.

By implementing these recommendations, the road transportation of petroleum products can be made safer and more resilient. These measures will contribute to minimizing risks,

protecting human life, safeguarding the environment, and maintaining the integrity of critical infrastructure.

6.3 Limitations of the project and its solutions

Every research has its ups and downs as there is always room for error and uncertainty especially when it comes to data collection. The research data was difficult to obtain especially the clinical data which was time-consuming as another factor that contributed to the delay of the project analysis and progress as such working under pressure was the way to handle all progress.

One of the challenges faced during this research project was the provision of data. As everyone would have guessed, the very first place to go to in the search for the data was the Malawi Road Traffic Directorate. I hoped this entity would provide me with the accident records involving tankers. Much to my surprise, it was found out that they do not go into much detail in terms of the accident reports. They only record the registration number of the vehicles involved in the accident, the nature of accident, are there any fatalities et cetera. Therefore, they directed me to the petroleum marketing companies including Total Energies, Ninkawa Transport, Zagaf Transport, just to mention a few.

Total Energies, one of the biggest oil marketing companies in Malawi was the first priority among the aforementioned companies. Nevertheless, just like Malawi Road Traffic Directorate, Total Energies after having a closer look at the data that I was seeking, told me they could not provide me with that kind of data either. Instead, they redirected me to the Malawi Energy Regulatory Authority (MERA), which is the hub of all the petroleum marketing companies.

Another challenge that was faced was caused by the delay in the response, and provision pf data by the officials from companies such as the National Oil Company of Malawi and the Malawi Energy Regulatory Authority. As much as these are busy entities, they contributed to a lot of time lost in the process of carrying out the research. This consumed a lot of time, contributing to the slow progress of the project. Due to these challenges, it made it more difficult to communicate with officials and personnel responsible for data provision as the

time for end of semester examinations approached hence the decision of choosing only a few entities as areas of focus for the project.

The other challenge encountered was the resistance from the drivers. In as much as this was a crucial topic, some of these drivers misunderstood the whole idea and felt they were being directly attacked. As such only a handful would be willing to interact. This led to a very slow progress in the data collection progress.

Despite all these challenges, the research was still carried out and had shown results that could be used for interpretation in other areas and decision making after data analysis.

6.4 Similarities and differences of implications of Research and other related studies

The research focuses specifically on evaluating the risks associated with transporting petroleum products via road. While there may be variations in the specific methodologies and contexts of different studies, there are some commonalities and differences when comparing this topic to related studies. Here are some similarities and differences:

6.4.1 Similarities:

Firstly, both the research topic and related studies likely employ a risk assessment approach to evaluate the potential hazards and vulnerabilities associated with transporting petroleum products. This typically involves identifying hazards, assessing their likelihood and potential consequences, and implementing mitigation measures to reduce risks.

Secondly, this research project is mainly centered at ensuring safety during the transportation of petroleum products. The related studies also lean towards the same objective. Therefore, both this research and related studies share a common concern for safety. They aim to identify potential risks, such as accidents, spills, or explosions, and develop strategies to minimize these risks. Safety considerations may encompass areas such as vehicle design, driver training, emergency response planning, and adherence to regulatory standards.

The other similarity of this research project with other related studies is to ensure the environment is always considered in every activity. Both the research topic and related studies likely address the environmental implications of transporting petroleum products. They may examine the potential for oil spills, contamination of soil and water bodies, air pollution, and the impact on ecosystems and wildlife. Assessing and mitigating these environmental risks is essential for sustainable transportation practices.

6.4.2 Differences

This topic differs with the other related studies on the transportation mode. The specific focus of the research topic on road transportation distinguishes it from related studies that may explore other transportation modes, such as pipeline, rail, or maritime transportation of petroleum products. Each mode presents unique risks and challenges, which necessitate distinct research approaches and mitigation strategies.

The second way how this research topic differs from other related studies is the scope of analysis. Related studies may have a broader scope, encompassing multiple aspects of petroleum transportation, while the research topic specifically hones in on risk assessment. Other studies might examine factors such as economic analysis, conditions planning, regulatory frameworks, or social impacts. The risk assessment of road transportation of petroleum products focuses primarily on evaluating and managing risks associated with this specific aspect of the supply chain.

Apart from that, this study differs from other related studies on the spatial and temporal context. Different studies may have variations in their spatial and temporal context. The research topic might focus on a particular region or country, examining the risk assessment specific to that area's road transportation conditions and environmental conditions. Related studies, on the other hand, may have a wider geographical scope or explore historical trends and future projections.

This study further differs from the other related studies on the methodologies and data Sources. While risk assessment methodologies will be common across studies, there may be differences in the specific approaches and data sources used. For instance, studies might employ different mathematical models, statistical analyses, or simulation techniques to assess risks. Additionally, data sources could include accident records, historical spill data, traffic data, environmental monitoring, or expert opinions, depending on the availability and context of the study.

By considering these similarities and differences, researchers can build upon existing knowledge and contribute to the field of risk assessment in the road transportation of petroleum products. This helps to improve safety practices, enhance environmental protection measures, and inform policy and decision-making processes in this domain.

6.5 Strength of research project

The research project of risk assessment of road transportation of petroleum products has several strengths, which make it a valuable and important area of study. One of the strengths of this project is to address safety and environmental concerns. Ensuring the safe transportation of petroleum products is of paramount importance due to the inherent risks associated with these materials. Since petroleum products are highly flammable, therefore there is always risk of fire and explosion hazards. In the event of transportation accident such as a collision or a tanker rupture, there is a significant risk of fire or explosion. These incidents can result in severe injuries, loss of life, and extensive property damage.

Accidental spills and leakages during transportation of petroleum products pose significant environmental and health risks. Spilled oil can contaminate soil, water bodies, and groundwater, leading to long-term ecological damage. Aquatic ecosystems, including marine life and coastal habitats, are particularly vulnerable to oil spills, as the toxic components of petroleum can suffocate and poison marine organisms. Contaminated water can as well impact human health, affecting drinking water supplies and potentially causing harm through exposure to toxic substances.

In the event of an oil spill or leakage, the surrounding land and wildlife can suffer severe consequences. Oil can contaminate soil, leading to long-term degradation and loss of fertility. Natural vegetation and habitats can be destroyed, impacting biodiversity and disrupting ecosystems. Wildlife, including birds, marine mammals, and fish, can be directly affected by oil spills, leading to habitat destruction, injury, and death.

This research would give an insight to the industry stakeholders, regulatory agencies, and transportation companies to work together to develop and implement best practices and standards. This includes investing in advanced technologies for monitoring, leak detection, and spill response, as well as promoting ongoing training and education for personnel involved in petroleum transportation. By prioritizing safety and environmental protection, the industry can minimize the risks associated with transporting petroleum products and ensure the well-being of both people and the environment.

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