DEVELOPING A SAFETY ASSESSMENT FRAMEWORK FOR THE TRANSPORTATION OF PETROLEUM PRODUCTS: A CASE STUDY OF THE NIGERIAN PETROLEUM DOWNSTREAM INDUSTRY

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# Developing a Safety Assessment Framework for the Transportation of Petroleum Products: A Case Study of the Nigerian Downstream Petroleum Industry


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**A thesis submitted in partial fulfilment of the requirements of the University of Wolverhampton for the degree of Doctor of Philosophy (PhD)**

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This work or any part thereof has not previously been presented in any form to the University or to any other body whether for the purposes of assessment, publication or for any other purpose (unless otherwise indicated). Save for any express acknowledgements, references and/or bibliographies cited in the work, and I can confirm that the intellectual content of the work is the result of my own efforts and of no other person.



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# ABSTRACT

In Nigeria, downstream transportation and distribution of petroleum products is mainly done using pipelines and tanker vehicles. However, the latter have been linked to serious accidents/incidents with substantial consequences on human safety and the environment. This project aims to develop a safety assessment framework for mitigating the impact of accidents and improve road safety during the transportation of petroleum products between a loading depot and retail stations using tankers. During this study, a review of the downstream sector of the oil and gas industry with respect to petroleum products transportation was carried out to identify key legislations and stakeholder interests within the context of accident mitigation and safety. A mixed research approach was adopted, using a questionnaire survey and semi-structured interviews for data collection. The questionnaire survey was used to investigate the problems of petroleum products transportation and distribution using road tankers from a tanker driver perspective, while semi-structured interviews were designed to elicit the opinions of professionals and elucidate their opinions and experiences in relation to the variables in this study. The results from the survey and the interviews conducted revealed gaps in the following areas related to the transportation of petroleum products: technologies, risk management, regulations, environmental management and training leading to the development of a Safety Assessment Framework (SAF) which constitutes the main contribution to knowledge. The developed framework integrates different components of safety to enhance the efficiency and reliability of transportation of petroleum products using tankers. This research would be of benefit to the Nigerian National Petroleum Corporation (NNPC) and its subsidiary the Petroleum Products and Marketing Company (PPMC) which oversees the transportation and distribution of petroleum products across the country. Also, the major oil marketers and the independent oil marketers which make up the freight transporters of the downstream oil and gas transport industry will benefit from this research. Concluding, this work may form a foundation for future research in the field of transport safety in Nigeria and Africa with regards to the transportation of petroleum products and other hazardous materials (HAZMATs).

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# DEDICATION

This thesis is dedicated to

My wife Francisca and my boys Daniel, David, Darwin and Darren.

To the memory of my mother, Late Mrs Annah Odeghe. Missed you so much!

# LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AHP………………… | Analytical Hierarchy Process |
| ALOHA……….. | Area Location and Hazardous Atmospheres |
| DOT ………… | Department of Transport |
| DPR…………………….. | Department of Petroleum Resources |
| FAHP………. | Fuzzy Analytical Hierarchy Process |
| FMEA………. | Failure Modes and Effects Analysis |
| FRSC ………….. | Federal Road Safety Commission |
| GIS……………. | Geographic Information System |
| GPS………… | Global Positioning System |
| GSM……… | Global Systems for Mobiles |
| HAZMAT | Hazardous Materials Transportation |
| IPMAN ………….. | Independent Petroleum Marketers Association of Nigeria |
| ITS ………… | Intelligent Transport Systems |
| JHA………… | Job Hazard Analysis |
| KRPC ………… | Kaduna Refinery and Petrochemicals Company |
| LOC……………. | Loss of Containment |

| | |
|---|---|
| MOMAN……… | Major Petroleum Marketers Association of Nigeria |
| NEMA………… | National Emergency Management Agency |
| NNPC | Nigeria National Petroleum Corporation |
| NOSDRA…….. | National Oil Spill Detection and Response Agency |
| PHAST………. | Process Hazard Analysis Software Tool |
| PHMSA………. | Pipelines and Hazardous Materials Safety Administration |
| PPMC | Petroleum Products Marketing Company of Nigeria |
| SFSD………. | State Fire Service Department |
| SRCFs……………… | Safety Risk Contributing Factors |
| VIO………………….. | Vehicle Inspection Officer |

# RESEARCH OUTPUT

Odogun, A., Georgakis, P. (2019) Transport Pollution: A Research of the Nigerian Transport Sector. *International Journal of Innovative Technology and Exploring Engineering* (IJITEE) ISSN: 2278-3075, Volume-8, Issue-11S, September 2019.

Odogun, A., Georgakis, P. (2020) Risk of Transporting Petroleum Products Using Tankers: A Nigerian Tanker Drivers Perspective. *International Journal of Innovative Technology and Exploring Engineering* (IJITEE). (Publication under Review).

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# 1 RESEARCH INTRODUCTION

## 1.1 Introduction

Road tankers has been the most common means of transporting petroleum products such as Premium Motor Spirit (PMS), Diesel and Kerosene from the oil depot to the various retail outlets across Nigeria. The number of road tankers used in transporting petroleum products in Nigeria has been on the increase owing to the fact that about 80 % of the country's petroleum products movement and distribution is done using road tankers (Obasanjo et al. 2014). Accidents involving road tankers transporting petroleum products are very fatal due to the flammability of the product. Apart from personal injuries and fatalities, road tanker accidents can result in environmental hazards like spill of cargo with severe financial consequences.

Recently, there have been increasing cases of road tanker accidents during the transportation of petroleum products in various countries including Nigeria. As such, human, vehicular, behavioural, mechanical, and environmental factors have been attributed to the causes of road tanker accidents. This research would investigate the causes of road tanker accidents by using questionnaires and interviews to elicit the views of tanker drivers and other stakeholders involved in the transportation of petroleum products. The aim of this research is to develop a safety assessment framework for the transportation of petroleum products to improve safety of operations from the perspective of technology, drivers' challenges, environment, risk management and safety, regulations and training.

This introductory chapter presents the research overview. It gives the research background, the justification and relevance of the research to the society as well as presenting the key research questions, its aim and objectives. Also presented in this chapter are the research design and an outline of the chapters developed in this thesis.

## 1.2 Background

Road tankers are very instrumental to the transportation and distribution of petroleum products worldwide. However, in recent times, an appreciable number of road tankers transporting petroleum products has been involved in accidents. These accidents have huge environmental, economic, health and safety as well as security implications on the economy, oil and gas transporters and the host communities. Tankers are designed to carry large amounts of fuel from state to state. Given the combustible nature of products being transported, fuel tanker trucks are built with safety in mind and their drivers are typically held to strict standards. Even at that, tanker accidents still occur, and they have disastrous consequences.

In Nigeria, about 80% of heavy truck accidents are due to loss of control (FRSC, 2013). In developed nations like the USA, UK and Germany, technology has played a big part in the transportation of hazardous materials including flammable substances like petroleum products. For instance, Intelligent Transport Systems (ITS) such as Electronic Stability Control (ESC), Active Steering or even further by integrated braking and steering has assisted positively to reduce accidents involving trucks (Kharrazi and Thomson, 2008).

## 1.3 Downstream Sector of the Nigeria Petroleum Industry

Nigeria is the second-biggest oil-rich country in Africa, after Libya. The country is estimated to hold 37 billion barrels of proven oil reserves, with an average daily output of about 2 million barrels per day. However, despite its rich resources, the Nigeria’s state-dominated oil industry is declining, afflicted by systemic corruption, starved of international investment, and hit hard by weak oil prices. Also, most of the crude oil from Nigeria fuel has to be refined outside the country because at the moment, the refineries in Nigeria are not functioning at full capacity to meet the needs of consumers of petroleum products. Figure 1 below shows Nigeria crude oil production in thousand barrels per day from 2011 to 2019. As shown in Figure 1, there is a steady decline in the yearly production of crude oil from 2011 and factors such as pipeline vandalism and equipment failure has been attributed to it.

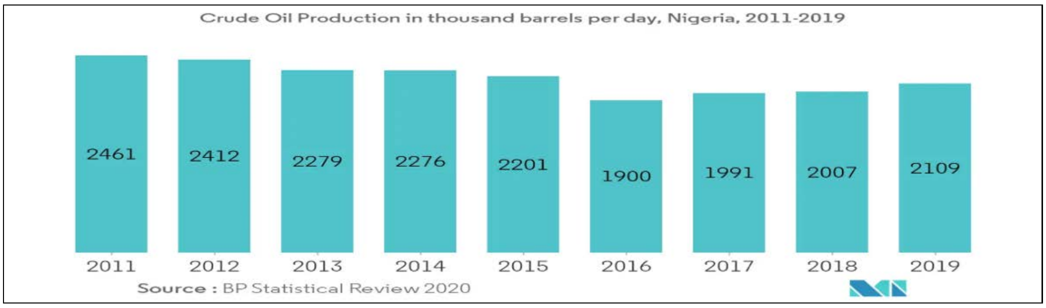



*Figure 1 Crude oil production in barrels per day, Nigeria, 2011-2019. Source: BP Statistical Review 2020*

The Nigerian National Petroleum Corporation (NNPC) is the driving force behind the economic development of Nigeria, providing fuel and feedstock for the nation's industrial facilities and meeting the energy needs of the individual customer and commercial enterprise (NNPC, 2014). The NNPC owns and operates an extensive network of refining and distribution facilities nationwide and is responsible for petroleum products distribution through its subsidiary known as the Pipelines and Products Marketing Company of Nigeria (PPMC). Petroleum products are the different types of fuels processed from crude petroleum which are used for power generation. They are extracted from crude petroleum from processing units by thermal cracking in the refineries. According to Rosenfeld and Feng (2011), the petroleum industry refines crude petroleum and processes natural gas into a multitude of products, and it is also involved in the distribution and marketing of petroleum-derived products. Examples of petroleum products are gasoline, kerosene (jet-fuels) diesel fuels, lubricants, paraffin wax and bitumen. Nigeria through the NNPC has four refineries with a total refining capacity of 445000bbl/d of crude oil (NNPC, 2015). Petroleum products are transported and distributed with the aid of pipelines from the processing plants to the loading depot, and by road tankers from the refineries and depot to the retail/filling stations. Petroleum products distribution is therefore concerned with the movement of refined petroleum from the refinery to the final consumers across various locations of delivery in the country (Ehinomen and Adepoju, 2012).

The Pipelines and Products Marketing Company of Nigeria (PPMC) is a subsidiary of the NNPC and it carries out the function of distribution of petroleum products through the 22 NNPC depots strategically located across the country. These depots were designed to receive finished petroleum products through the pipelines from the refineries for distribution to members of the public (NNPC, 2015). PPMC has been unable to fully meet this obligation for some years now as a result of factors like pipeline vandalism, insufficient production of petroleum products by the refineries, shut-down of the refineries and equipment failure. For this reason, petroleum products are now transported with road tankers from areas of the country where they are available to other areas to prevent products scarcity through a process known as “bridging”. The purpose of bridging is to ensure that products are transported by road from depots where they are available to other depots to ensure the depots’ sustainability. According to NNPC (2014) bridging also ensures uniform pricing of petroleum products in all parts of the country. Figure 2 shows the different stages in the movement of petroleum products from exploration to the marketing stages using road tankers until it gets to the petrol station which is the destination of the road tanker. At the petrol stations, products are offloaded and stored in underground tanks from where it is being sold to consumers through pumps. The petrol stations are either operated by private owners or major oil marketing companies such as Shell, Total, Texaco, Agip and Mobil. The major oil companies maintain their own fleet of road tankers for the transportation and distribution of petroleum products across Nigeria.

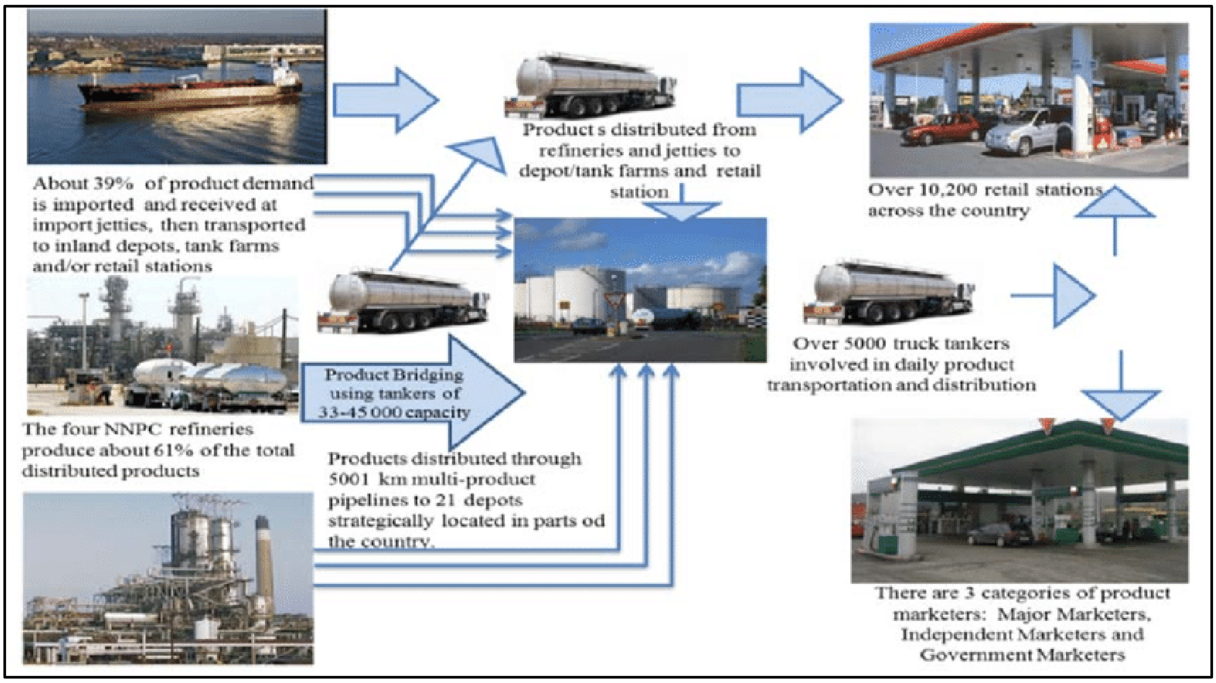



*Figure 2 Downstream structure of the petroleum industry. Adapted from Ambituuni (2016)*

Due to the deplorable state of the Nigerian roads, the transportation of petroleum products using road tankers has become very risky, unsafe and expensive, but it has become the only means through which products can be transported around the country presently pending the restoration of the use of pipelines. According to Anyadiegwu (2015), safety is a very important factor that should be considered when discussing the movement of petroleum products from the loading depots to retail stations across Nigeria.

## 1.4 Challenges of the Downstream Transportation of Petroleum Products

The transport industry especially the road sector in Nigeria has been faced with various problems and challenges that are threatening the performance of the industry (Onakala and Olajide, 2020). These problems include poorly maintained roads, safety and security concerns, high accident rates and increasing operational cost (Ambituuni et al., 2014). Other challenges faced by the downstream sector of the petroleum industry include lack of maintenance of the refineries resulting in low refining activities for the domestic market, pipeline vandalism, poor maintenance of pipelines and depots, poor transportation infrastructure for the physical distribution of petroleum products to end-users and issues with the petroleum products supply chain such as perennial shortages of products and the antecedent long queues at retail stations. Other challenges include: product diversion, product adulteration, abnormal product subsidy, underutilized refineries, refinery sabotage, product theft, corruption, and sharp practices in retail outlets across the country (Adiele, (2020); Ambituuni et al., (2014); Gonzalez, (2016); Osuala, (2013) & Chigbu et al., 2016).

A study by Obasanjo *et al* (2014) to investigate roads haulage constraints in the transportation of petroleum products in Nigeria was aimed at assessing the efficiency of road haulage in the distribution of petroleum products in Nigeria. The study employed a systematic sampling method to collect primary data from truck drivers. Analysis of the data was done using descriptive statistics and the Kruskal-Wallis's methods. The result shows that delay at police and military checkpoints is the main constraint of the distribution system; this was followed by mechanical problems of vehicles and bad roads. However, the study fails to address the critical issue of tanker accidents and the cost of those accidents to the operators and the Nigerian economy.

Amponsah & Opei (2014) conducted a study aimed at exploring the supply chain challenges in the downstream petroleum sector in Ghana. The study adopted a mixed method approach, and data for the study were collected from key players in the downstream petroleum sector through in-depth interviews and a questionnaire. The study reveals that government interference in activities of key actors, inability of government to pay under recoveries, government indebtedness to actors, inadequate infrastructure and inability of Tema oil refinery (TOR) to refining crude regularly as some key challenges that impacted the effective and efficient supply chain process. The study recommended the Government of Ghana to inject capital for infrastructural development of the sector as well as wean off its interference in the activities of actors. In this case, key national players like the Bulk Oil Storage and Transportation (BOST) should be given autonomous status.

In Gambia, Manneh (2020) conducted a study aimed at exploring the perspectives of retail petroleum marketing as well as challenges of petroleum import, storage and sales in the Gambia's downstream petroleum sector. A qualitative method was adopted for the study through in-depth interviews in a semi-questionnaire format. The study discovered that oil marketing companies (OMCs) downstream marketing strategies, programs and activities shifted from undifferentiated commodity imported refinery products marketing (old/previous marketing scenario) to branded value added services differentiated petroleum products (present marketing scenario) marketing owing to increase in both downstream energy market liberalization and market competition. The study also revealed that industry players face many challenges ranging from inadequate legislation, government interference, limited fuel terminal tanks, supply chain and other operational difficulties, high import duties and lack of subsidy on imported petroleum products. The study recommends that OMCs should develop and implement marketing strategies, programs and activities in line with product differentiation, branding and value-added services. The study equally recommends that the stakeholders in the industry should work on the amendments of downstream petroleum legislation, expand the fuel terminal tank storage facility, adopt and enforce national downstream petroleum quality standard in the daily operations and work towards realizing full deregulation in the sector.

The impact of these problems is enormous and include; loss of life and property, increase insurance cost, waste of time and man-hour, colossal loss that can lead to the collapse of the haulage company, increase in freight rates, destruction of the road infrastructure and increase in cost of road and vehicle maintenance (Farah, 2016). In terms of financial loss to Nigeria, the Federal Road Safety Commission (FRSC, 2010) says the problem of accidents involving road tankers in Nigeria is costing the nation a lot of resources. For instance, Olagunju (2011) reported that from January 2007 to June 2010, not less than 4,107 tankers were involved in road traffic accidents in Nigeria causing the death of 4,076 people and 12,994 sustaining injuries of varying degrees, with accompanying loss of property.

## 1.5 Road Crash Statistics of Heavy Goods Vehicles in Nigeria (2007 - 2017)

Table 1 gives a summary for road crashes involving heavy good vehicle in Nigeria from 2007 – 2017. From the table, there was a steady increase in the number of crashes from 2008 until 2013. From 2014 – 2018, we noticed that the rate of accidents started to decrease which implies a positive impact of the safety measures put in place. Also, Table 2 shows the cost of 116 tankers that were involved in road crashes in the first quarter of 2018 in Nigeria. The economic cost for the 116 tankers involved in road crashes was N7.157.2 billion.

Note that the total cost does not include the following:

- People killed
- Cost of treatment for people injured
- Roads and road infrastructure damaged
- Environmental impacts that will require mitigation
- Other collateral damages (farm lands, houses, settlements displaced, other vehicles in collision with, other property etc.

*Table 1 Source: FRSC Road Crash data 2007-2017*

| Year | Number of trailers involved | Number of tankers involved | Total RTC | Total persons killed | Total persons injured | Total casualty |
|---|---|---|---|---|---|---|
| **2007** | 703 | 273 | 607 | 805 | 269 | 1074 |
| **2008** | 1192 | 463 | 1129 | 1121 | 3891 | 5112 |
| **2009** | 1272 | 495 | 1213 | 1085 | 3714 | 4799 |
| **2010** | 1186 | 461 | 968 | 965 | 3220 | 4185 |
| **2011** | 464 | 180 | 1188 | 1090 | 4117 | 5207 |
| **2012** | 462 | 179 | 1194 | 1097 | 3935 | 5032 |
| **2013** | 1180 | 315 | 1222 | 1178 | 4006 | 5184 |
| **2014** | 727 | 271 | 934 | 1079 | 3206 | 4285 |
| **2015** | 761 | 331 | 876 | 979 | 3048 | 4027 |
| **2016** | 657 | 359 | 872 | 910 | 3516 | 4426 |
| **2017** | 624 | 308 | 779 | 737 | 2622 | 3359 |

*Table 2 Economic cost of tanker crashes Q1, 2018. Source: FRSC Reports*

| No of RTC involving tankers | No of tankers involved | Cost of tankers involved in RTC |
|---|---|---|
| **1120** | 116 | Head @ = N 50M<br>Trailer @ = N 7M<br>Load @ = N 4.7M<br>Total @ = N 61.7M<br>61700000 x116 vehicles = N 7.2B |

## 1.6 Selected Incidents Involving Petroleum Tankers in Nigeria

This section presents some selected accidents involving tankers transporting petroleum products in Nigeria in order to showcase why this research is very important. The aim of this research is to develop a safety framework that would be used to mitigate accidents involving road tankers transporting petroleum products in Nigeria. Most accidents that occur in Nigeria involving petroleum tankers have been very fatal due to the nature of the cargo the vehicle is transporting which in most cases results in fire explosion. Most times, the people in the community where a tanker accident occur would want to scoop the product either for sale or for personal consumption and this have normally resulted in fire explosion claiming lives, destroying properties with various environmental damages. In Table 3, Merem *et al.* (2018) presents some selected Incidents of fuel tanker disaster in Nigeria covering a period of ten years (2008-2018).

*Table 3 Selected Incidents of Fuel Tanker Disaster in Nigeria 2008-2018. Source: Merem et al., (2018)*

| Date | Incident | Underlying cause of accidents | Location |
|---|---|---|---|
| **10th June, 2008** | About six cars were burnt in a fuel tanker explosion incident that took place at 3rd mainland bridge. | Tanker crashed into other vehicles due to brake failure. | 3rd Mainland Bridge, Lagos. |
| **11th October, 2009** | More than 70 people died when a fuel tanker exploded after collision with a pylon. | Fuel tanker was attempting to cross large potholes on the Enugu-Onitsha highway when it toppled over, spilling fuel across the road. | Onitsha (outskirt), Anambra State. |
| **5th November, 2010** | About 400 persons died and 150 vehicles destroyed in a fuel tanker incident. | Brake failure and tanker crashed into other vehicles causing multiple accidents. | Ibadan-Ife Expressway, 280 km to Lagos. |
| **12th July, 2012** | About 121 persons died and 75 injured in a fuel tanker incident. | People scooping fuel from a crashed tanker which exploded and killed almost all the people at the scene. | Okosia, River State. |
| **5th April, 2013** | About 30 persons died and a number of vehicles destroyed in a fuel tanker incident. | Tanker truck and other vehicles were trying to overtake each other on the road resulting in collision. | Benin-Shagamu Expressway. |
| **2nd April, 2014** | 2 deaths and 4 human injuries were recorded when a fuel tanker hit another vehicle while trying to overtake. | Fuel tanker collided with another vehicle while trying to overtake. | Ovia North East LGA, Edo State. |
| **31st May, 2015** | About 60 persons died and many others injured in a fuel tanker incident. | The driver of the fuel tanker lost control and ran into a big pothole. | Upper Iweka Junction Onitsha, Anambra State. |
| **27th June, 2018** | About 10 persons died and many others injured in a fuel tanker explosion. | Brake failure causing petrol tanker to crash into another vehicle resulting in explosion. | Lagos-Ibadan Expressway. |

## 1.7 Research Aim

The aim of this research is to develop a Safety Assessment Framework (SAF) for accident mitigation that would promote road safety during road tanker transportation of petroleum products.

## 1.8 Research Objectives

The above aim would be achieved through the following objectives:

1. To perform a literature review on the Nigerian downstream petroleum industry.
2. To investigate the causes of road accidents involving tankers transporting petroleum products in Nigeria.
3. To investigate the challenges faced by stakeholders across the value chain involved in the transportation of petroleum products.
4. To evaluate the suitability of measures that can be implemented for the mitigation of tanker transportation accidents.
5. To develop a framework for road safety during Hazmat transportation considering safety legislation and standards for tanker operations in Nigeria.
6. To evaluate the developed framework and use it as a guideline for the mitigation of accidents during the transportation of petroleum products using road tankers in Nigeria thereby promoting road safety.

## 1.9 Research Questions

This research seeks to address some fundamental questions as listed below to achieve the objectives of this research:

1. What is the status of hazmat transportation globally, and in Nigeria particularly?

2. What are the contributory factors to the causes of accidents during the transportation of petroleum products in Nigeria?
3. What challenges do tanker drivers face in the downstream sector of the petroleum transport industry?
4. What measures could be implemented to mitigate tanker transportation accidents?
5. What is the perception of drivers toward training as it relates to petroleum products transportation?
6. What possible benefits could the Nigerian oil and gas transport sector achieved by implementing the safety assessment framework?

*Table 4 Linking table of research objectives, questions, and chapters (RO= research objective, RQ= research question)*

| Objectives Number | Research Objectives | Research Question Number | Research Question | Chapters | Method of Analysis |
|---|---|---|---|---|---|
| **RO1** | To perform a literature review on the Nigerian downstream petroleum industry. | RQ1 | What is the status of hazmat transportation globally? In Nigeria? | 1 | Literature review |
| **RO2** | To investigate the causes of accidents involving road tankers transporting petroleum products in Nigeria. | RQ2 | What are the contributory factors to the causes of accidents during the transportation of petroleum products in Nigeria? | 1 | Literature review & Quantitative survey |

| | | | | | |
|---|---|---|---|---|---|
| **RO3** | To investigate the challenges faced by stakeholders across the value chain involved in the transportation of petroleum products. | RQ3 | What are the challenges faced by the downstream petroleum transportation sector in Nigeria? | 2 | Quantitative survey |
| **RO4** | To evaluate the suitability of measures that can be implemented for the mitigation of tanker transportation accidents. | RQ4 | What challenges do tanker drivers face in the petroleum downstream industry in Nigeria? | 5 &6 | Quantitative survey |
| **RO5** | To develop a framework for road safety during Hazmat transportation considering safety legislation and standards for tanker operations in Nigeria. | RQ5 | What are the views of drivers towards technology? | 2 | Mixed research methods. |
| **RO6** | To use the developed framework as a guideline for the mitigation of accident during the transportation of petroleum products in Nigeria thereby promoting road safety. | RQ6 | What are the possible benefits for the Nigerian oil and gas transport sector by implementing the developed safety framework? | 2 | Interviews. |

## 1.10 Outline Methodology

The first objective would be achieved by carrying out a literature review of the Nigerian downstream oil and gas sector as it relates to the transportation and distribution of petroleum products in Nigeria. The literature review presents an overview of the transportation of petroleum products using road tankers from the storage depots to the retail outlets.

Then subsequently, the research adopted a mixed methods approach through the combined use of quantitative and qualitative strategies to investigate the causes of road tanker accidents during the transportation of petroleum products in Nigeria to achieve the second objective.

The third objective would be achieved by conducting a qualitative study through a semi-structured interview to seek the opinions of different stakeholders and experts across the value chain regarding the challenges they face during tanker transportation of petroleum products.

The fourth objective would be achieved by carrying out a feasibility study to evaluate and understand which measures can be implemented to prevent accidents on the road during petroleum products transportation. This would be achieved through a semi structured interview with transport experts. A review of the success of similar measures in other parts of the world would also be carried out.

The fifth objective would be achieved by developing a framework based on the results from the analysis of both the survey and interviews, and linking together all the elements that would contribute to the safety of tanker transportation. Additional elements of the framework will include safety legislation and standards for tanker transportation in Nigeria.

Finally, the framework would be evaluated through interviews and Focus Group discussion to evaluate and determine the acceptability of the proposed framework that would be implemented to enhance road safety for the oil tankers which is the sixth objective, and this conclude the research study.

## 1.11 Research Scope and Limitations

The scope of this research study is to develop a safety assessment framework for Hazardous Materials (HazMat) transportation using tankers in order for stakeholders to select and deploy measures to mitigate accidents and promote safety on the road. Like any research, the limitations are an important part as this identifies the scope and highlights the future work. For this research the limitations were:

- Hazardous materials are made up of nine classes, however, considering the volume of work that would be required to develop a framework for each class of HazMat, the limited time and the resources available to the researcher, the researcher has decided to consider only one class of the hazardous materials. However, the transferability of the framework to other classes of hazmat has been considered during its design and implementation.
- Lack of adequate data and information relating to tanker transportation.
- Financial constraints as researcher have to travel to Nigeria for data collection. Three oil depot was visited by the researcher for the administration of questionnaires to tanker drivers. Further research should include visiting more oil depots.
- The lack of hazmat transportation projects in Nigeria meant the interviews was conducted with a limited number as the population of Hazmat transportation experts in the country is very limited.
- Impact of Covid 19 pandemic meant that researcher has limited access to institutions library and use of school laboratory for research purpose.

## 1.12 Contributions to Knowledge

- The main contribution of this research would be to develop a safety framework for accident mitigation for road tankers during the transportation of petroleum products and other hazardous materials.
- Providing information flow between stakeholders within the freight transportation industries and technology consultants for the provision of adequate technological solutions for tanker accidents.
- This research would add to the body of work on the transportation of petroleum products in the Nigerian oil and gas sector. This study can be used as a foundation for future studies and research on Hazmat transportation.
- This study would promote safety awareness among depot operators at the loading stages of petroleum products all through to the offloading of products at retail outlets.
- It is also envisaged that the framework that will be developed as part of this research may form a foundation for future directions in terms of training guidelines and initiatives of oil tanker drivers in Nigeria. There is limited research in Nigeria that investigated the challenges faced by tanker drivers to develop a safety framework.
- The research would be of benefit to the Nigerian National Petroleum Corporation (NNPC) and its subsidiary the Petroleum Products and Marketing Company (PPMC) which oversees the transport and distribution of petroleum products across the country.
- The public would also benefit from this research because the framework that would be developed could be used by the government and different stakeholders to create awareness that would assist to improve transport safety and risk management.

- The framework developed from this study integrated different components of safety to enhance the safety of tankers on the road and make distribution of petroleum products in Nigeria safe, efficient and reliable.

## 1.13 Thesis Structure

The flow of the thesis was made logically so that the reader can flow along while gaining insight and understanding into first: Why the research was done, how the objectives and research questions were achieved and how the framework and conclusions were constructed. The layout is in a logical sequence commencing with the introduction of a chapter and ending with the summary of the chapter.

**Chapter 1**: This chapter gives a general introduction to the thesis and comprises of the background study. It reviews the Nigerian downstream petroleum industry and the challenges faced by the sector during the transportation of petroleum products. In this chapter, the research questions, aims and objectives, scope and limitations as well as the research contribution to knowledge were presented. This chapter concludes with the organisation of the thesis and a summary of the chapter.

**Chapters 2**: This contains the literature review conducted during this research. It discusses the theoretical concepts that underpin the research. The causes of road tanker accidents, related works in Hazmat transportation and risk management frameworks for the transportation of hazardous materials were reviewed in this chapter. Also, global standards and regulations for transporting HazMat’s were reviewed.

**Chapter 3**: This chapter presents the conceptual framework for this research. This chapter discusses how the different variables that make up this study were linked to each other. It then goes further to present a conceptual framework for the research.

**Chapter 4**. This chapter discusses the methodological approach and methods used to carry out the research. It also discusses the particular reasons why the mixed method approach was embraced.

**Chapter 5**: This chapter presents the findings of the quantitative data analysis which was carried out. During the field survey, data were collected using questionnaires from truck drivers at three oil depots. The data collected were analysed in this chapter using, frequency distribution tables, bar charts, and other statistical methods. The challenges faced by tanker drivers during petroleum products transportation and the factors that contribute to tanker road accidents were derived from the primary data and analysed in this chapter.

**Chapter 6:** This chapter presents the findings of the qualitative data analysis which was undertaken by using thematic content analysis to investigate the problems of tanker transportation of petroleum products in Nigeria.

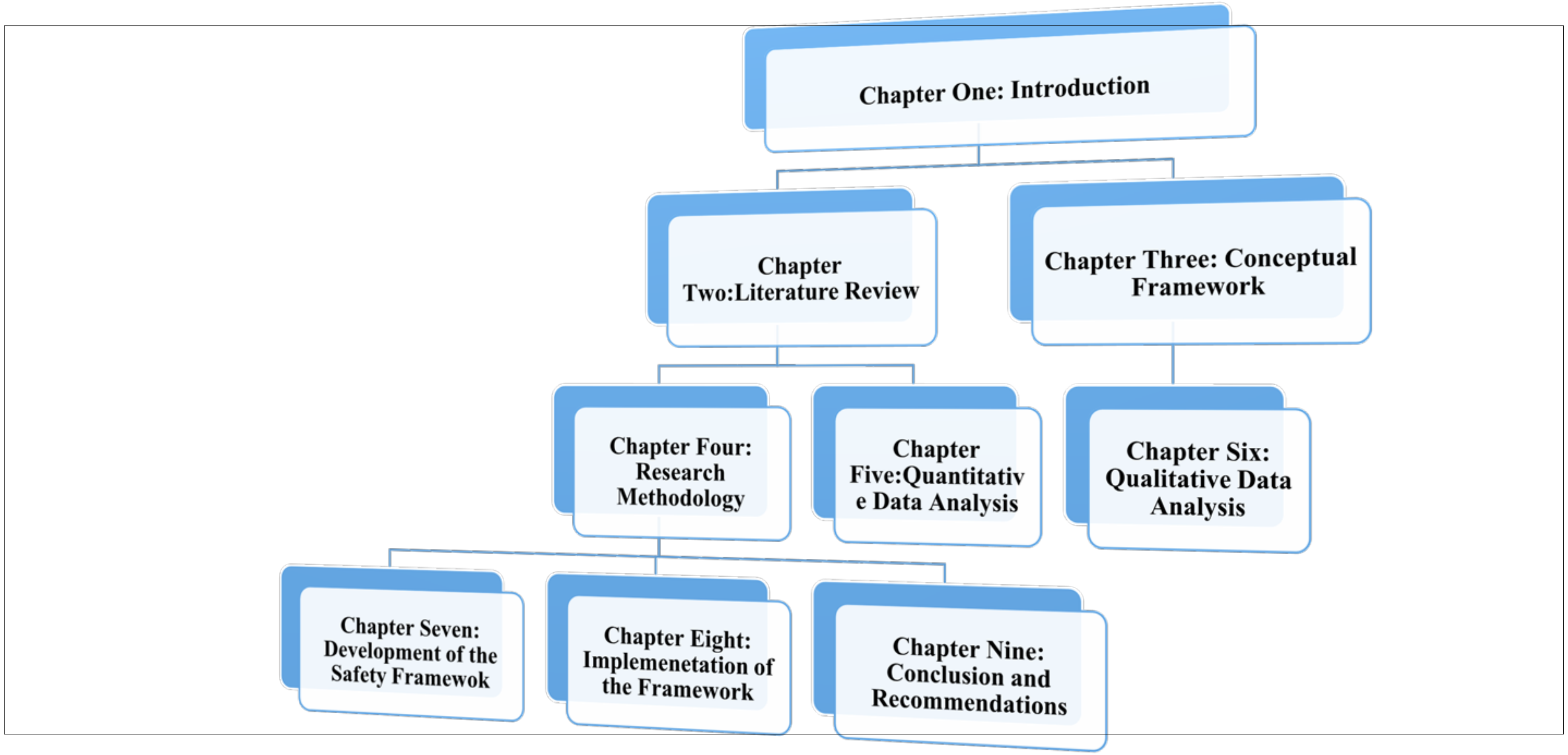
**Chapter 7:** This chapter presents the framework development for this research and the way the different components interact with each other to realise the aim and objectives of the research.

**Chapter 8:** This chapter discusses how the framework developed from this research would be implemented in the petroleum industry.

**Chapter 9**: This chapter presents the findings, conclusions, and recommendations of the research, outlining the key contributions, and limitations, making recommendations for hazmat transportation and proposing recommendations for future research development.

The structure of this research thesis and the organization of the chapters is illustrated in the form of a diagram as shown in Figure 3.

*Figure 3 Structure of the thesis and organisation of chapters*



## 1.14 Summary of Chapter One

This chapter has presented an overview of the thesis with discussions centered on the background to the research which aims to develop a Safety Assessment Framework (SAF) for accident mitigation during road tanker transportation of petroleum products in Nigeria. This was then followed by the research aims and objectives as well as the research questions. Further to this, the scope and limitations of the study as well as the contribution to knowledge were discussed. Finally, a summary of how the research thesis was structured and organised was presented in the form of a diagram. The next chapter of this thesis will subsequently consist of the literature review that will form the foundation of the research methodology in order to gather primary empirical data for this research. Findings from the empirical data would be used to propose strategies for the development of SAF for the mitigation of accidents involving road tankers in the downstream sector of the oil and gas industry.

# 2 LITERATURE REVIEW

## 2.1 Introduction

This chapter begins with the theoretical framework for this research to set the stage for the conceptual framework that would be developed in chapter three. This chapter reviews the Hazardous materials transportation (HAZMATs). In this chapter, the causes of accidents were reviewed with focus on accidents involving road tankers transporting flammable hazardous materials such as petroleum products. The risk management frameworks in the transportation of hazardous materials which is the main focus of this research was reviewed. A review of the regulations for transporting hazardous materials from a global perspective was reviewed along with the environmental impact of hazardous materials transportation. The aim of this research is to develop a safety framework for the transportation of hazardous materials with focus on tanker transportation of petroleum products. In this research, hazardous materials (HAZMAT) would be used to describe petroleum products. Hence, the study would focus on the transportation of petroleum products which is a class 3 hazmat according to the hazardous materials classification.

## 2.2 Literature Search

During a literature review, researchers use inclusion and exclusion criteria to describe their strategies for the review process. The application of inclusion and exclusion criteria is crucial, as it assist the researcher to narrow down the literature search and review process, thereby, making it less complicated (Torres-Carrión *et al*., 2018). Also in this study, the researcher adopted the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) model by first identifying a list of materials which were sourced from different scientific journal databases. After identifying the various items that would be used for the research, the next stage is the screening process in order to select the most relevant items to be included in the study (Page et al., 2021).  The databases used to search for materials for this study include: google scholar, library resources, conference proceedings, books, journal articles, electronic databases, official reports from government agencies and online materials in order to have a broad knowledge of the subject area. The keywords explored during the literature search for this study include: risk management frameworks, risk assessment, petrol tanker accidents, accidents prevention, tanker drivers, oil loading depots, petrol stations, HazMat transportation, environment, fire disaster, road accidents, petroleum products and road safety.

*Table 5 PRISMA Model for Literature Search (Adopted from Page et al., 2021).*

| **Steps** | **Methods** |
|---|---|
| Identifying | Identify a list of materials that would be used for the study. |
| Screening | From the identified material, select those that are relevant to the study. |
| Included | Include only items that are suitable for the study. |

The next session will discuss the theoretical framework for this research.

## 2.3 Theoretical Framework

In the context of Occupational Health and Safety (OHS), one of the most important aspects is the analysis and prevention of accidents. In terms of OHS, an accident might be defined as an unexpected event with undesirable outcomes that results directly or indirectly from human activity and not from natural events or disasters (OHS Body of Knowledge, 2012). The goal of safety management is to eliminate accidents or at least to reduce the number of workplace accidents. In order to achieve this goal, it is important to study the mechanisms causing accidents to happen. The most popular theories of accident causation are the Domino theory, the human factors theory, the accident/incident theory, the epidemiological theory, the systems theory, the combination theory, the Bow-tie accident theory, and the behavioural theory.

## 2.4 Domino Theory of Accident Causation

Heinrich (1931) pioneered the emergence of what is known as the Domino theory of accident causation after his study of the reports of 75,000 industrial accidents in late 1920s. Heinrich's conclusion and findings are that;

1. Acts that are unsafe by co- workers cause 88% of industrial accidents.

2. unsafe conditions are responsible for 10% of industrial accidents, and

3. Unavoidable circumstances are responsible for 2% of industrial accidents.

From his study, Heinrich came up with the Axioms of industrial safety and his theory of accident causation popularly known as the Domino theory as shown in Figure 4. Heinrich Axioms of industrial safety are summarised as follows:

- Injury is a product of a completed series of factors, one of which is the accident itself,
- An accident can take place only from an unsafe act by a person and/or a physical or mechanical occurrence,
- Unsafe behaviour by people is the cause of most accidents,

- An accident or injury does not occur immediately after an unsafe act by a person or an unsafe condition.
- The reasons why people commit unsafe acts can provide helpful guides in selecting corrective accident actions
- The severity of an accident is largely fortuitous, and the accident that caused it is largely preventable.
- The best accident prevention techniques are analogous with the best quality and productivity methods.
- Management should assume responsibility for safety, because it is in the best position to get results.
- The supervisor is the key person in the prevention of accidents
- In addition to the direct costs of an accident e.g., compensation, liability claims, medical costs etc., there are also hidden and indirect costs.

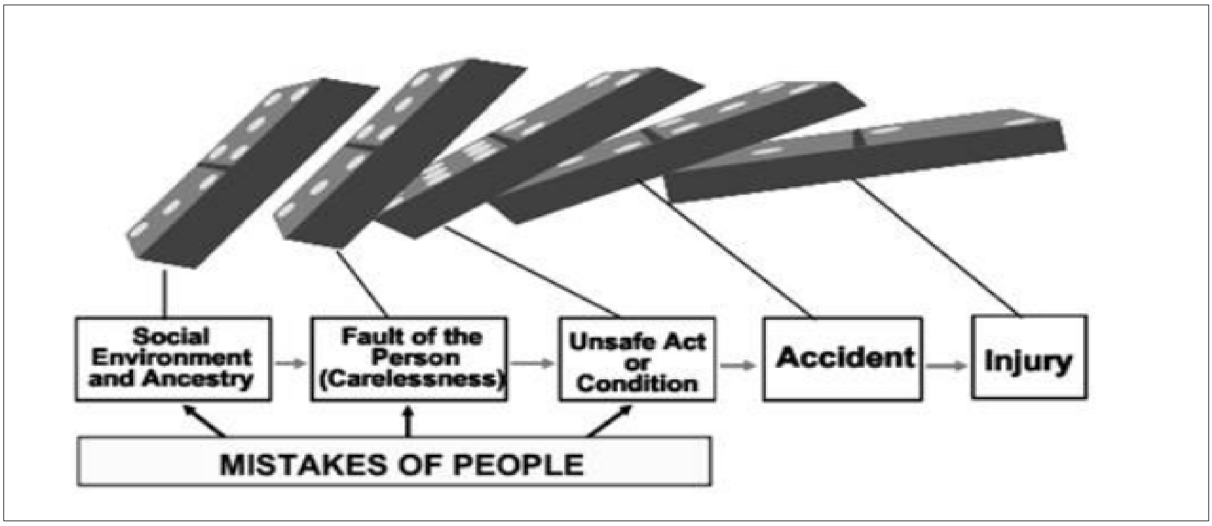



*Figure 4 Heinrich's domino model of accident causation. Source: Carrillo-Castrillo, et al. (2013).*

According to Moliero et al (2008), Heinreich's domino theory lays more emphasis on the human error in the causation of accidents. Other factors are structural factors like production and quality techniques and technological factors like physical and mechanical constraints. Furthermore, there are two central points in the domino theory of accident causation:

1. Injuries are caused by the action of preceding factors.
2. Removal of the central factor negates the action of the preceding factors and thus, prevents accidents and injuries.

Heinrich’s model is time-efficient and useful for investigating accident causes. However, it has certain disadvantages in terms of reliability and validity. First of all, there is one key reliability weakness – the assumption of linear relationship between three categories of accident causes. In more complex situations this assumption does not hold (Manuele, 2003). Secondly, the domino model does not account for the influence of external factors which represents a validity threat. The domino model might therefore be not applicable for devising accident prevention strategies due to these weaknesses. However, for simpler processes that have low dependence on external factors the domino model might be the most efficient approach. In order to overcome validity weaknesses, McLoughlin suggested adding a sixth domino to Heinrich’s model (HSM, 2010). McLoughlin stated that “external factors” domino should be added in the beginning of the chain. The suggested change allows accounting for global factors such as recession and economic changes in the context of OHS strategy (HSM, 2010).

## 2.5 The Bow-Tie Accident Model

The bow-tie model is also called the cause-consequence diagram. It was initially developed by Shell for the purposes of risk assessment (Hale et al., 2007). The model has a central point (undesirable event), with the events and circumstances preceding the undesirable event shown on the left hand, and various scenarios and consequences of the undesired event shown on the right hand. Figure 5 illustrates the bow-tie model. This model shares the understanding of accidents causation with the Swiss Cheese model (Hale et al., 2007). The bow-tie model belongs to complex linear models as it reflects the combinations of various accident causes and consequences of critical events. The key concepts of the model are hazards (acting on the left hand), consequences (acting on the right hand) and top events (central points of bow-tie chart). It should be noted that top events in this model are events with significant potential for unwanted consequences (Ferdous, 2011). The purpose of safety management in this context is to create barriers in order to prevent the emergence of negative consequences after top events, or to prevent top events (Ferdous, 2011).

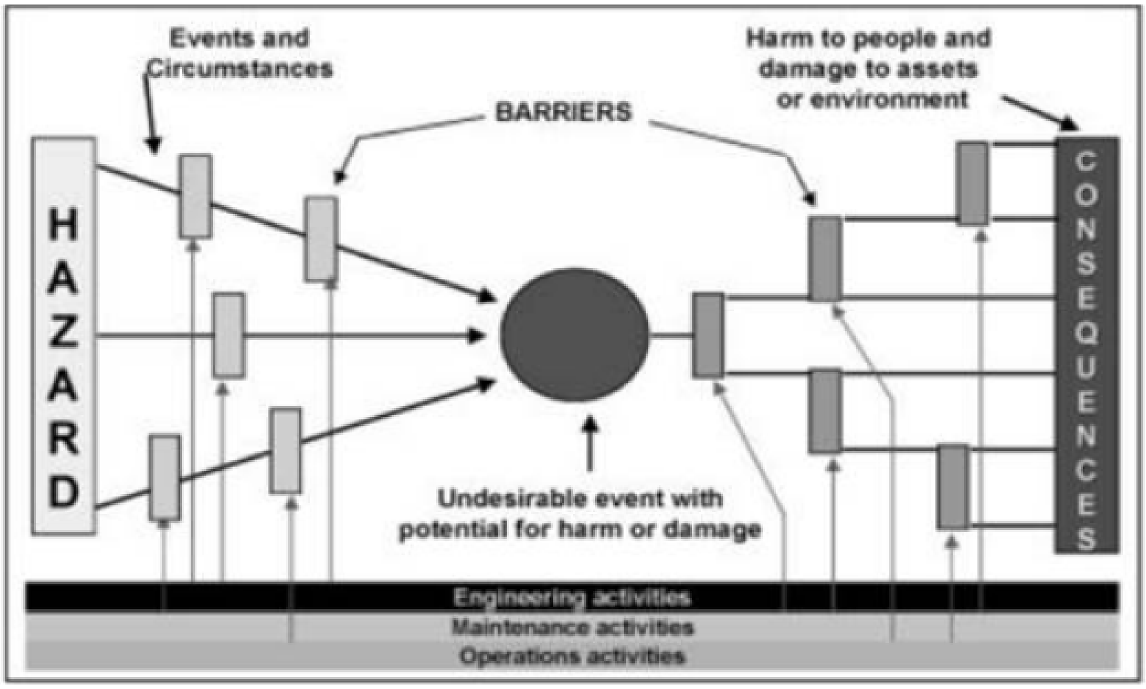



*Figure 5 Bow-tie accident causation model (Channing, 2013)*

The Bow-Tie model as shown in Figure 5 has several advantages in the context of OHS analysis and accident prevention. This model combines the analysis of accident causation and risk assessment scenarios. Furthermore, it can be used for devising control measures aimed at preventing undesirable events, and for addressing the consequences of undesirable events by introducing recovery measures (Manuele, 2003). However, the bow-tie model has a significant limitation in terms of validity as the model treats accidents separately. Common factors influencing the whole work process might be missed using such approach. Furthermore, the model is generic so the specific causes, top events and effects should be determined individually for every particular case. If some critical accident causes or top events are missed, the reliability of the model will be weakened. At the same time, the bow-tie model is well-applicable at the departmental and organizational level, since it accounts for multiple causes and multiple accident scenarios (Ale, 2009).

## 2.6 Human Factors Theory of Accident Causation

The Human factors theory of accident causation as shown in Figure 6 is when a worker is distracted by factors that are either internal or external. The distracting factors influences are temporary and not permanent. Therefore, if care is taken to eliminate the distracting factors, there is a possibility of preventing accidents. The human factors theory of accident causation consists of three broad factors that lead to human error:

- Overload
- Inappropriate response
- Inappropriate activities

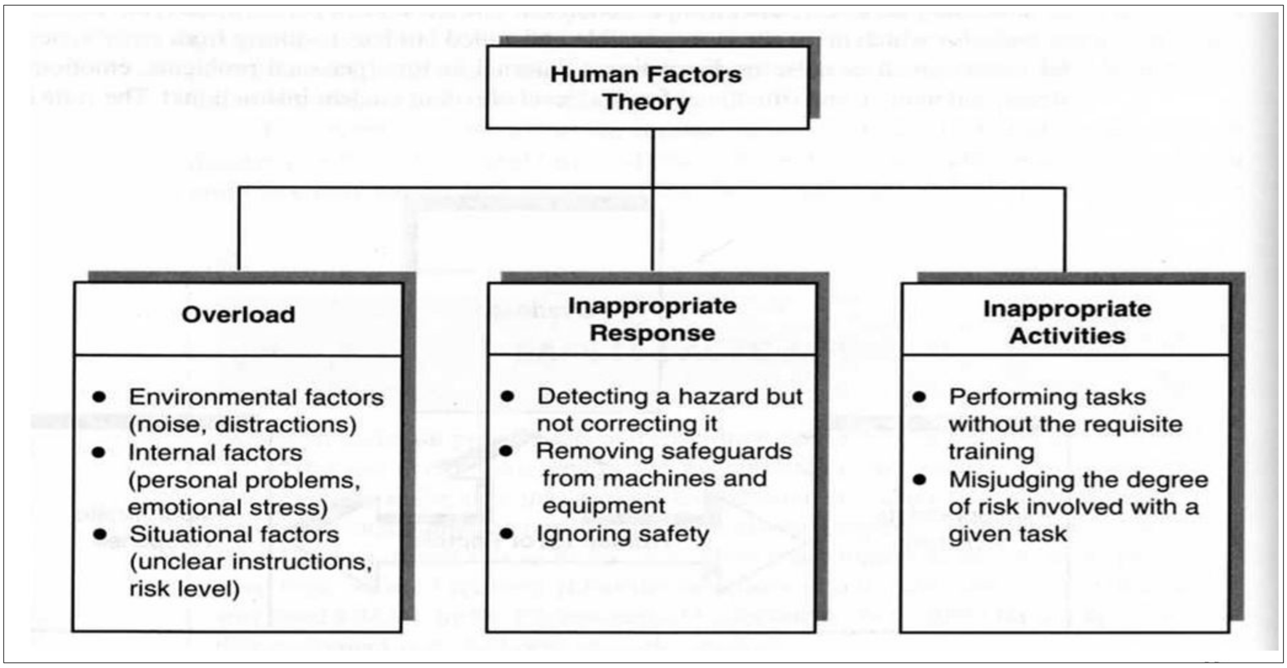



*Figure 6 Human factor theory of accident causation. Source: Adopted from Moleiro, 2008*

## 2.7 Accident/Incident Theory of Accident Causation

The accident/incident model of accident causation suggests that human error normally arises from three multidimensional factors of overload, ergonomic traps and a decision to err. These factors lead to an accident under the Accident/incident model as shown in Figure 7.

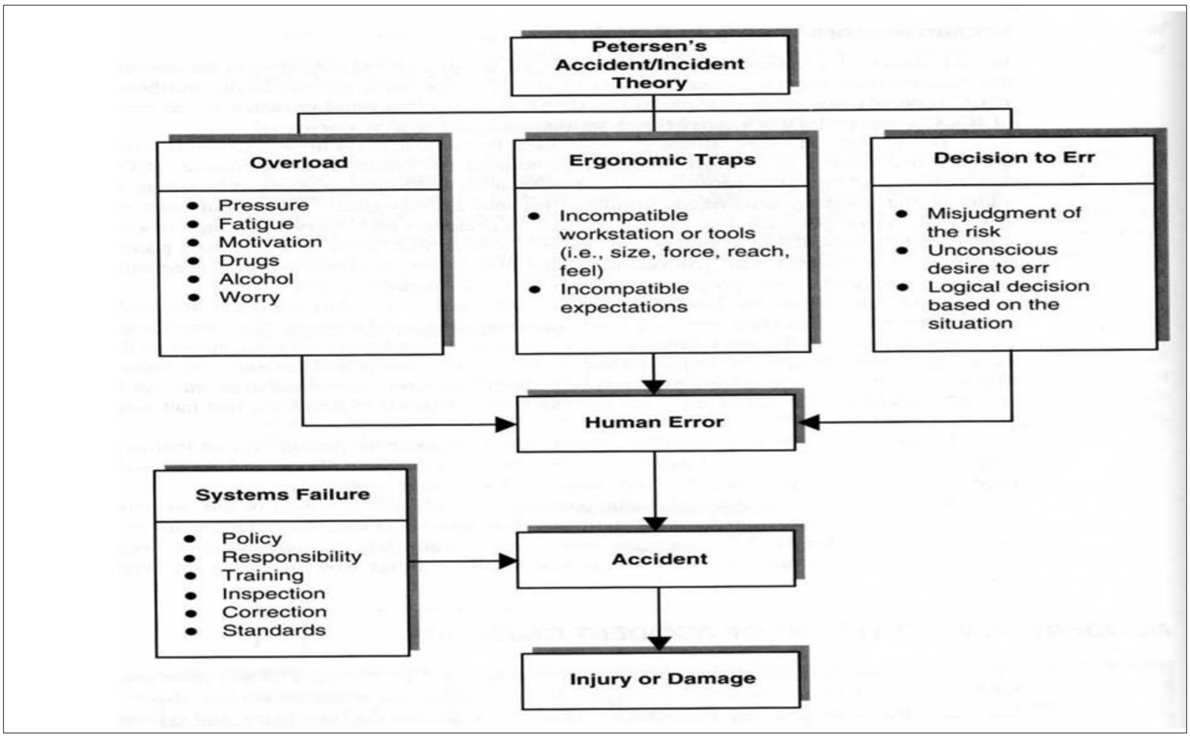



*Figure 7 Accident/incident model. Source: Adopted from Moleiro, 2008*

The model postulates that even as a person interacts with a machine within an environment, three activities take place between the system and the tasks to be executed. Each time a task is performed, risk exists that accident may occur. Sometimes the risks are great and at other times the risk are small.

## 2.8 Epidemiological Model

One of the distinct theoretical areas of research on road traffic accidents is built around the concept of the epidemiological model. According to Dart and Mackenzie (1981) and Badejo (2011), the epidemiological model originated from medical research, where it is a study of causal relationships between environmental factors and disease. This was later widely used in the analysis of non-disease injury and fatality due to road traffic accident. It was premised on three variables of the host, the agent and the environment as illustrated in Figure 8.

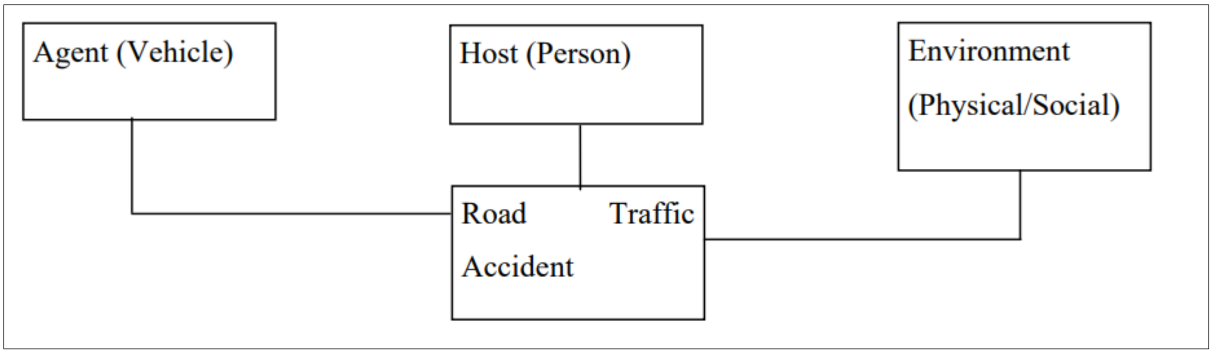



*Figure 8 Epidemiological model of road traffic accident Source: Schram, (1970)*

Under this model, the host is the person, the agent is the vehicle, and the environment is the physical and social factors. It is the interactions that take place between these variables that result in an accident.

Drawing from the work of Badejo (2011), road traffic accident phases are captured at three levels of occurrence, these are;

- The pre-crash phase: This is also called the accident-avoidance stage, and it is made up of all accident causation factors of the vehicle, environment, road users and all measures taken to prevent the accident from happening.
- The crash phase: This is the accident's occurrence stage and is known as the injury prevention stage. The outcome of the accident and the circumstances of its occurrence in terms of time and location are included in this phase.
- The post-crash phase: At this phase, accidents consequences are assessed and evaluated to achieve severity reduction. It involves saving lives and reducing the number going

to hospital and prevention of disabilities. Nigeria is in this stage in its accident management level, as efforts are largely concentrated in managing accidents rather than actual prevention due to failure to enforce traffic rules and regulations.

## 2.9 Systems Theory of Accident Causation

A system is a group of constantly interacting and interrelated components that form a unified and complete whole. It is a situation where an accident occurs in a system that comprises three components of host, agency and environment. Thus, the main components of the systems model are the person/machine/environment, information, decisions, risks, and the task to be performed. Each of these components has a certain level of bearing on the probability that an accident will either occur or not.

## 2.10 Combination Theory

On combination theory, Moliero (2008) postulated that one given model might not be fully adequate in explaining why accidents occur, because for some accidents, one given model may be adequate while for some others, a combination of models may be required. The combination theory is therefore a postulation that, the explanation for the actual cause of an accident may be achieved through a combination of several different models. 3.2.7

## 2.11 Behavioural Theory

This is often referred to as behaviour-based safety (BBS) and it is the application of behavioural theories from the field of psychology to the field of occupational safety. The theories are applied in situations where certain types of human behaviours are desired and others are avoided. Positive measures like incentives and rewards are used to encourage the desired behaviours and to discourage unsafe actions (Moliero, 2008). The prominent proponents of the behaviour theories are Geller (2000) Fern and Alzamora (1999).

According to Hossenian and Torghabeh (2012) and Rau et al., (2018) personality factors and safety attitudes have been proved effective in predicting accidents in traffic and the workplace. The study was aimed to explore the effect of personality factors and safety attitudes in elevator accidents using the structural equation model. The study suggested that conscientiousness could predict compliant safety behaviour both directly and indirectly through safety attitude and could predict proactive safety behaviour. The study further suggests that recruiters should choose elevator workers who are conscientious, agreeable and of low trait anxiety. Also, the study recommends that safety trainings for elevator workers should focus on culturing their safety attitude.

Also, accident causation theory explains the possible causation mechanisms of accidents, and unsafe behaviour is a major component of such causes (Guo and Gong, 2020). Similarly, Meng et al., (2019) proposed that most accidents are triggered predominantly by human-related hazards and unsafe behaviour was identified as one of the direct causes of accidents. Guo and Gong (2020), summarised the main points in the behavioural theory of accident causation in four aspects:

- Psychological factors
- Organisational and management factors
- Environmental factors
- Comprehensive factors.

## 2.12 Definition of Hazardous Materials (HAZMAT)

According to the U.S Department of Transportation (DOT) hazardous materials are products or articles or substances that are capable of posing a significant risk to health, safety or property when transported by air, rail, ground or sea. Ming-Wei and Ming Ying (2014) defined hazardous materials as solids, liquids or gases that are very easy to cause personal casualty and property damage which therefore need special protection during the process of transport, handling and storage including material that are explosive, flammable, bio hazardous, corrosive and radioactive. The US Environmental Protection Agency (EPA) defined a hazardous material as any substance that could cause a severe health hazard to humans as a result of a short-term exposure during an accident or emergency. Ma et al (2020) described hazardous materials as those substances and articles with explosive, inflammable, toxic, infectious, corrosive, and other dangerous characteristics that are liable to cause human casualties, property damage, or environmental pollution in the course of production, management, transportation, storage, use, and disposal, which is required special protection. These accidents or emergencies are called HAZMAT (Hazardous Materials) incidents and they can occur at any time during manufacture, transportation, storage, use, or disposal of a substance (Ma et al., 2020). HAZMATS are used as fuels for our cars and trucks, heats and cools our homes and offices, used in farming and medical applications, as well as manufacturing, mining and other industries (Uday and Jigisha, 2014).

## 2.13 Risks Associated with Distribution of Petroleum Products by Road

The increased risk associated to HAZMAT transportation incidents has raised the awareness of industries, government and academia (Ditta et al., 2019). It is estimated that four billion tons of hazardous materials are transported worldwide every year. In China alone, over one billion tons of hazardous materials are transported by road every year. There are about 11,600 enterprises, about 32 million people involved, and more than 360,000 vehicles engaged in the road transport of hazardous materials (Ma et al., 2020). In 2009 there were 14,816 HAZMAT incidents by different transportation modes, whereas the estimate for 2012 was 17,459, which resulted in 7 fatalities, 152 injuries and $68,045,434 in damages (USDOT).

In Nigeria, the transportation and distribution of petroleum products by road using tankers is overlaid by complexity of multiple players, multiple regulators, product with varying volatility, multiple hazards and multiple transport routes. However, the current regulation of trucking downstream operations appears to be fragmented and not effective as evident in the number of petrol tanker related accidents recorded in Nigeria (Ambituuni *et al*. 2015). For this reason, there is need for a comprehensive risk management approach to enhance regulatory programs and also assist individual companies in developing tailored approaches to achieve cost-effective risk reduction beyond the regulations (Ambituuni *et al*. 2015).

In the wrong hands (Fan, Chiang & Russell, 2015), hazmat can pose a significant security threat, particularly those that can be used as weapons of mass destruction. Addressing this security threat is vital to the safety of human lives and the environment and also the security of the economy (DOT & PHMSA). For this reason, Hazmat transportation problems should be evaluated by incorporating economic, social, and environmental conditions simultaneously (Bula et al. 2018). Also, because Hazmat transportation accidents can have impact on human and the environment, it is therefore important to ensure a more efficient transport system with low accident rates by developing a hazmat network optimization (Sun *et al*. 2018).

## 2.14 Classification of Hazardous Materials

According to the United Nations (2013), hazardous materials are being classified into nine groups according to their physical, chemical and nuclear properties as shown in the table below. The nine classes are: explosives and pyrotechnics, gases, flammable and combustible liquids, flammable, combustible and dangerous-when-wet solids, oxidizers and organic peroxides, poisonous and infectious materials, radioactive materials, corrosive materials (acidic or basic) and miscellaneous dangerous goods such as hazardous waste. Table 6 below summarizes the nine classes of hazardous materials.

| DOT Hazard Class | Hazardous Material Example |
|---|---|
| **Class 1: Explosive** | Dynamite |
| **Class 2:**<br>**Division 2.1: Flammable gas**<br>**Division 2.2: Non-Flammable gas**<br>**Division 2.3: Poison/toxic gas** | <br>Hydrogen, Propane<br>Nitrogen<br>Fluorine |
| **Class 3: Flammable liquids** | Gasoline, Xylene, ethanol |
| **Class 4:**<br>**Division 4.1: Flammable solid**<br>**Division 4.2: Spontaneously combustible**<br>**Division 4.3: Dangerous when wet** | <br>Ammonium picrate<br>White phosphorus<br>Sodium metal |
| **Class 5:**<br>**Division 5.1: Oxidizer**<br>**Division 5.2: Organic peroxide** | <br>Ammonium nitrate<br>Methyl, ethyl, Ketone, peroxide |
| **Class 6:**<br>**Division 6.1: Poison**<br>**Division 6.2: Infectious substances** | <br>Potassium cyanide<br>Anthrax |
| **Class 7: Radioactive** | Radioactive labelled chemicals |
| **Class 8: Corrosives** | Formaldehyde |
| **Class 9: Miscellaneous** | Dry ice, Lithium, Batteries |

*Table 6 Classification of Hazardous Materials (HAZMATs)*

## 2.15 Transportation of Hazardous Materials (HAZMAT)

The transportation of hazardous materials (Hazmat) is a growing problem worldwide due to the increasing transported volumes. In fact, as a consequence of industrial development, huge quantities of Hazmat are produced yearly and obviously they have to be transported {(Ditta et al. (2019); Leonelli et al. (2000)}. Hazardous materials transportation is an important part of the life cycle, which often goes through town or areas of the crowd, and in the event of an accident, heavy casualties may occur, leading to severe pollution of the environment for a long time with huge economic losses (Ma et al. 2020). As a matter of fact, when considering the transportation of HAZMAT, attention is always focused on the “accident-induced” releases, since the kinetic energy of moving vehicles has the potential to cause the rupture of the vessel resulting in a relevant loss of containment as a consequence of the accident (Bonvicini et al. 2007). Uday & Jigisha (2011) described transportation by Hazmat truck as a moving point source of risk due to the pervasiveness of the materials they transport. They maintained that the loss of containment (LOC) occurs when the moving truck meets with an accident either due to collision or due to non-collision related incidents such as over-turning etc. Similarly, Ambituuni et al. (2015) mentioned that the transportation of petroleum products by road has given rise to numerous accidental releases of hazardous materials into the environment and such releases because of their chemical properties, volume upon loss of containment (LOC), sensitivity of host environment and proximity of human presence have safety and environmental consequences. In most developing countries including Nigeria, most towns and villages are situated very close to major roads serving as key transport corridors thereby increasing accident vulnerability and increased risk to such communities (Fabiano et al., 2002; Anifowose et al., 2011).

Tankers and other trucks provide important freight transport services across Nigeria. Tankers are used to move petroleum products from refineries, oil depots and tanks from different locations to various destinations in the country as shown in Figure 9. Inter-urban vehicles facilitate transportation of consumer goods to markets, shopping centres, warehouses, raw materials to factories and petroleum products to various filling stations all within an urban area. With this in mind, the safety standard for tankers and drivers transporting petroleum products must be very high in other to gain public trust from a safety point of view (Aderibigbe, 2017)

*Figure 9 A petrol tanker going through a bed on a long road.*

Petroleum transportation systems (PTSs) involve many methods to ensure that petroleum and its refined products reach the final customers through connections between different industry supply chains (Alghanmi, 2018). In enhancing the operational practices of these systems, several technologies have been incorporated in order to enhance safety and reliability (McCoy, 2008). As a result, modern PTSs are becoming more and more oriented towards the safety of the environment, humanity, and equipment, while ensuring the safe delivery of products to various destinations within the supply chain (Alghanmi, 2018).

Also, the transportation of HAZMAT is strictly associated with safety, security and environmental concerns. For this reason, hazmat transportation needs to be treated separately from classical transportation problems. The application of technology has contributed significantly to road safety as well as mitigating the impacts of road accidents. For instance, computer programmes such as ALOHA (Area Location of Hazardous Atmosphere) and PHAST (Process Hazard Analysis Software Tool) have gained recognition in the modelling and simulation of the scenario of an accident involving a liquified petroleum gas (LPG) truck tanker in India (Bahira et al., 2016). Bhagat et al., (2018) reviewed various techniques for secured transportation using GSM & GPS technologies. Through a GSM module, the location of tanker, speed and lock status is sent to the owner at regular interval which helps in monitoring the tanker (Bhagat et al., 2018).

In the U.S.A, the Pipeline and Hazardous Materials Safety Administration (PHMSA) is a risk management body under the U.S. Department of transportation. This body was established by the Hazardous materials Transportation Act of 1974 and operates a hazardous material regulatory system that is prevention-oriented and focused on identifying a hazard and reducing the probability and magnitude of a hazardous material incident. In the event of an incident, PHMSA, through its planning and training grants provides funds to state and local emergency preparedness and emergency response organizations for planning and training directed towards mitigation of the consequences associated with hazardous material incidents.

According to Pezzullo & Fillippo (2009), in hazmat road transportation, the “where (it happens) and who” (has to handle it immediately) of emergencies and critical incidents are the two big unanswered questions. Thus, it very necessary to have an accurate understanding of the main safety processes and criticalities underlying the operational activity in the hazmat logistics so as to implement adequate preventive measures (Pezzullo & Fillippo, 2009).

Nigeria has three refineries that refines its crude oil into other petroleum products like petrol, kerosene, diesel, liquefied petroleum gas (LPG). These various petroleum products are in high demand in Nigeria such that the three local refineries cannot refine enough quantity for the demand of consumers. As such, refined petroleum products are imported from other countries to meet the high demands of consumers because the current refineries in Nigeria are functioning poorly due to age, poor maintenance, weak governance and vandalization of the pipelines supplying crude oil to the refineries, which have affected their production capacities (Udonne and Akinyemi, 2018).

## 2.16 Stakeholders in Transportation of Petroleum Products in Nigeria

The responsibility of distributing petroleum products in Nigeria rest on the Petroleum Product Marketing Company of Nigeria (PPMC) (see chapter one) which is also a subsidiary of the Nigerian National Petroleum Corporation (NNPC). The NNPC oversees all oil activities in Nigeria from the upstream sector which include the exploration of the oil to the downstream sector which include refining of the crude, distribution and marketing of the petroleum products (NNPC 2006). In the US, the department of transportation’s (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA) is responsible for the safe and secure transportation of hazardous materials (hazmat). The Nigerian National Petroleum Corporation (NNPC), its subsidiary the Petroleum Products and Marketing Company (PPMC) and the Department of Petroleum Resources (DPR) are the top players in the downstream petroleum activities as shown in Figure 10.

A study was conducted by Floden & Woxenius (2021) aimed at identifying and mapping the stakeholders of dangerous goods transport by land modes and analyse their interest and relationships between them in order to increase transport safety. The study adopted both literature review, interviews and workshops approach, including actors commercially involved in transport, and rescue services, policy makers, regulating authorities, municipalities and citizens. The results from the study shows that not only the traditional transport actors, but also societal actors largely influence transport of dangerous goods.

In Nigeria, there are several different stakeholders that have an interest in the reduction of dangerous goods transportation risk, both to the population and to the environment. They include:

- The general public who are exposed to the risks from the transportation of petroleum products;
- Government agencies charged with the responsibility for public safety;
- Industry, which comprise dangerous goods producers, carriers and consumers.

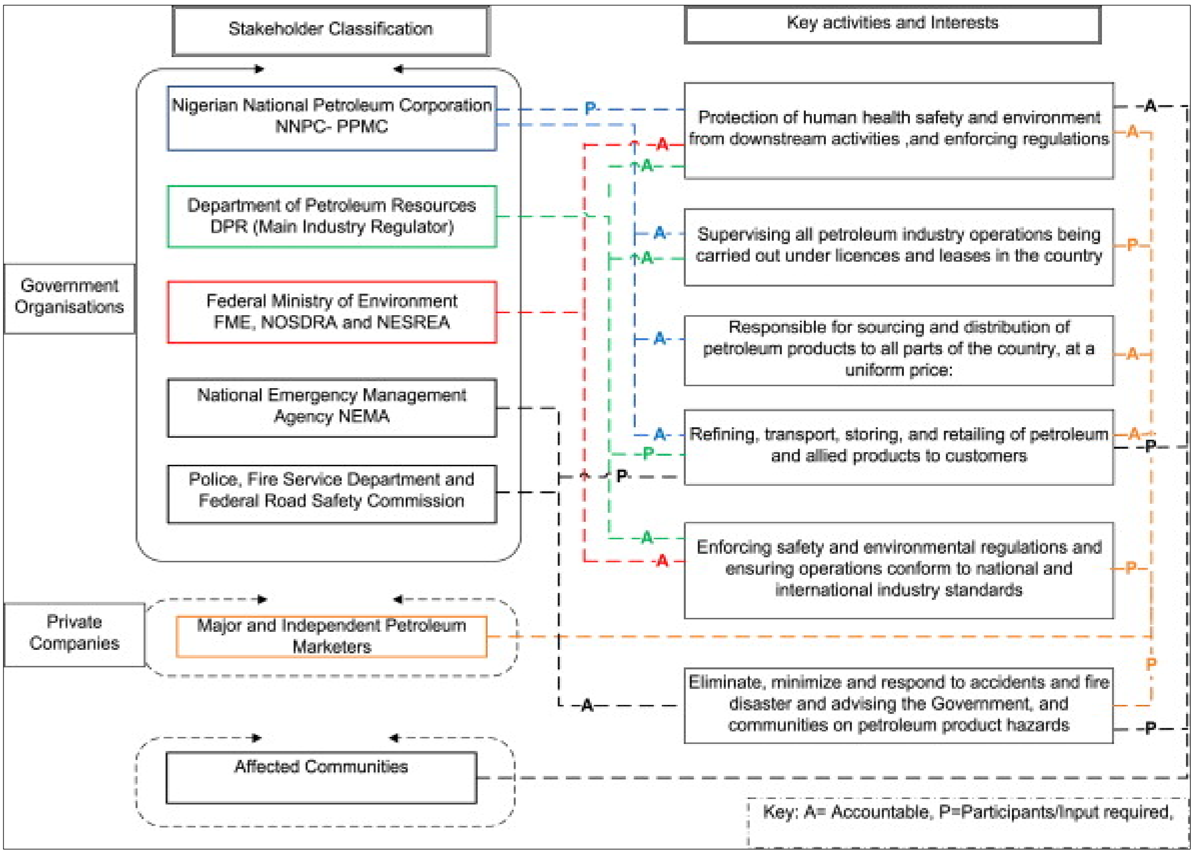



*Figure 10 Downstream stakeholder structure. Source: (Ambituuni et al. 2014)*

## 2.17 Causes of Road Tanker Accidents

The second objective of this research is to investigate the causes of tanker accidents during the transportation of petroleum products. In chapter one of this thesis, an overview of the downstream petroleum industry was presented with focus on petroleum products transportation using tankers. The aim of this research is to develop a safety assessment framework for the transportation of petroleum products in Nigeria. The framework would be used by oil transporters to mitigate accidents involving tankers and also to promote the safety of tankers transporting and distributing petroleum products across the country. This section will therefore review the causes of hazmat accidents involving tankers during the transportation of petroleum products including other class 3 flammable substances.

Most previous studies that analysed the factors responsible for Hazmat transportation accidents used a statistical method and most of the researchers largely confined themselves to the collection, analysis, and interpretation of data derived from accident reports or an accident database (Zhao et al. 2012). For instance, Oggero et al. (2006) studied 1932 accidents that occurred during the transport of Hazmat by road and rail from the beginning of the 20th century to July 2004, and concluded that the following major factors were responsible for the accidents:

- external factors such as the weather,
- human factors such as operator error, and
- mechanical failures.

According to Oggero et al. (2006) the training of professionals involved in transportation seems to be of major importance among the diverse measures taken to improve the situation of hazmat accident.

In another study, Al-Masaeid (1996) performed a study to investigate the causes of fuel tanker accidents and their relationship to drivers, roadway and tanker characteristics. During the study, 730 fuel tanker drivers were randomly selected to complete a questionnaire at Zerqa Refinery site, Jordan. The study examined data on causes and locations of tanker accidents, drivers' characteristics and tanker related issues. The results revealed that 88%, 40%, and 7% of tanker accidents were caused by human errors, geometric deficiency and highway defects, and tanker defects respectively. The results from the analysis also revealed that driver characteristics such as age and health conditions had a significant influence on tanker accidents and that most of the tanker accidents occurred on horizontal and vertical curves. Also, regular tanker maintenance and repair had a significant influence on tanker accident occurrences. Restrictions on age and health condition of tanker of tanker drivers, improvement of tanker route alignment, and regular tanker maintenance and repair would be a successful accident mitigation measure.

According to Shen *et. al.,* (2014) human-related errors (73.8%) and vehicle-related defects (19.6%) are the primary reasons for hazmat tanker crashes in China. The study revealed that the main accident types were rollover (29.10%), run-off-the-road (16.67%), and rear-end collisions (13.28%), with a high likelihood of a large spill occurring. Also, a study by Akpoghomeh (2012), reports that human causative factors accounted for 73% of traffic accidents in Nigeria, while technical factors accounted for 20% of the causes. Speed violation, dangerous driving and loss of control, contributed 60% of the human causative factors.

Ewbank *et al*. (2019) performed a study to investigate the circumstances, causes, and health effects of oil tanker truck disasters that occurred from 1997 to 2017. The study adopted a systematic review using PRISMA criteria to better understand the public health concerns and identify prevention targets. The results from the study reveals scooping - the practice of collecting spilled oil from disabled tanker trucks for use or resale was largely attributed to the disasters. Using the Haddon matrix, potential targets for future disaster prevention were identified. In Nigeria, many of the fire explosion that accompanied a tanker accident has been attributed to scooping of products (Ewbank *et al*. 2019).

Singh (2017) identified drivers' fault as the single most important factor responsible for accidents. In the study, drivers' fault accounted for 78% of total accidents, 76.5% of total injuries and 73.7% of total fatalities in 2013. Within the category of drivers' fault, accidents caused due to exceeding lawful speed accounted for a high share of 55.6%. As a share of total accidents and deaths due to drivers' fault, intake of alcohol and drugs accounted for 5.3% and 6.4%, respectively. As a share of total road accidents and deaths, overloading / overcrowding of vehicles accounted for 19.6% and 22.8%, respectively. The analysis by Akpoghomeh (2012) & Sigh (2017) did not distinguish the causes according to types of vehicles or traffic characteristics.

In a study, Zhao *et al*. (2012) applied Bayesian networks to prioritize the factors that influence hazardous material (Hazmat) transportation accidents. The Bayesian network structure was built based on expert knowledge using Dempster–Shafer evidence theory, and the structure was modified based on a test for conditional independence. During the study, 94 cases of Chinese Hazmat transportation accidents were collected and analysed to compute the posterior probability of each factor using the expectation–maximization learning algorithm. The result from the study shows that the three most influential factors in Hazmat transportation accidents were human factors, the transport vehicle and facilities, and packing and loading of the Hazmat. These findings provide an empirically supported theoretical basis for Hazmat transportation corporations to take corrective and preventative measures to reduce the risk of accidents (Zhao *et al*. 2012).

In India, petroleum companies recorded 1635 transport accidents in a period of 5 years. A study by Gangadhari, (2020) to access the root causes behind the accidents to identify the actual damage caused by the accidents revealed fuel releases, spillage, fire and explosions as the major accidents occurring. The study also indicated drivers' negligence, road conditions and equipment failure as the main reasons behind the accidents. The study thereafter used the analysis of accidents reports and inputs from experts to make suggestions to prevent accidents in the industry.

Elshamly *et. al*., (2017) performed a study to identify truck driver's behaviour and its influence on crash involvement in Egypt. The study adopted a quantitative approach by administering questionnaires to truck drivers. The results of the study showed that fatigue in terms of driving hours (continuous and total) and lack of sleep, drug use during driving, and driver obesity are the most influencing factors on the occurrence of truck accidents in Egypt, thus revealing a strong relationship between driver fatigue, obesity and crash involvement. Similarly, Liu *et al.*, (2018) conducted a study to investigate the risk factors contributing to extremely serious accidents in China. The study revealed that fatigue was significantly associated with serious road accidents. Also, Poku-Boansi *et al.*, (2018) described the long periods of driving without proper rest routine or replacement drivers as a major factor responsible for drivers' fatigue.

Maqbool *et al.*, (2019) and Bun (2012) are of the opinion that lack of effective road design and maintenance are among the main factors that contribute to road accidents which also agrees with the results of a study conducted by Isa and Siyan (2016) to analyse the factors responsible for road traffic accidents along the Kano-Kaduna-Abuja dual carriage road. In that study, lack of routine repairs, maintenance and the existence of potholes are responsible for crashes on the highway.

A study conducted by Malin *et. al.*, (2019) to investigate the relative accident risk of different road weather conditions shows that relative accident risks were increased for poor road weather conditions and even highest for icy rain and very slippery road conditions. The study further revealed that the risk in poor weather and road conditions was higher on motorways compared to two-lane and multiple-lane roads. Still on the risk factor of severe weather conditions, Chakrabarty and Gupta (2013) are of the opinion that the task associated with driving becomes more complex when there are poor visibility conditions such as rain, fog, or snow as these create several additional demands on the driver making his ability to collect and process information very challenging.

Olawole and Olapoju (2018) conducted a study to examine spatial patterns and possible determinants of tanker accidents in Nigeria using geographically weighted regression techniques. The study sourced secondary data on tanker accidents for the year 2007 to 2010 and other relevant data from the databases of the Federal Road Safety Commissions of Nigeria (FRSC) and National Bureau of Statistics (NBS). The findings from the study shows that tanker accidents vary by state and also revealed an upward trend in the occurrence of tanker accidents. The study concluded by recommending strategies for the avoidance of tanker accidents in Nigeria.

Qureshi *et. al* (2020) conducted a study to investigate the 2017 Ahmedpur Sharqia oil tanker explosion and fire incident in Pakistan which claims 219 lives and seen by many as one of the biggest road transportation disasters in history. The investigation follows a holistic approach that examines the whole system including driver management, vehicle design, road design, and police management of the spillage scene. The analysis shows that although the first cause was driver dozing off behind the wheel, however, it was a complete system failure which created a domino effect. The investigations revealed that there were serious lapses in the design and fabrication of the vessel and truck in violation of UN-ADR safety standards and Pakistan's OGRA-RT standards and no proper safety protocols were followed for driver workload and shift management by Shell Pakistan Limited and its contractors. The technological failures may refer mainly to parcels with mechanical or technological elements that ensure containment and the transport safety. For instance, the tank trucks (or tank containers) have technological systems as temperature and/or pressure sensors (working for monitoring systems to check the state of hazardous material during the transport), and mechanical components (as vapor vents, man holes and covers, discharging valves, safety valves, and so on). Usually these are standard elements which comply with technical codes, and whose reliability could be considered as an input data (Conca *et al*. 2016). The investigation also shows mismanagement of the post-crash scenario by local law enforcement agencies. The study concluded by providing crucial lessons on the domino nature of such disasters.

According to Manzoor (2020) tanker drivers who are not trained and experienced could pose a significant problem in the HAZMAT transportation industry and this could lead to road accidents and improper emergency responses due to drivers' error. A study performed by Kircher *et al*., (2020) on the effects of training on truck-tanker drivers' interaction with cyclists in a right turn shows that drivers behaviour changed after receiving training, resulting in a better speed management and a more intensive monitoring of the cyclists. The study also revealed that driver training can possibly be one contributor to an increase in road safety in urban areas.

Aderibigbe (2017) conducted a study to identify the root cause of a Bridger Receipt Vehicles (BRV), related accident which happened along the Lagos airport road in Nigeria, close to the jet fuel storage depots, creating a potential for huge fire disaster. Using the fishbone diagram and a detailed root cause analysis, the study revealed that driving under the influence of alcohol and the prevailing operational challenges played a major role in the series of events that led to the accident. In this case, the driving under the influence of alcohol was the root cause of the accident, although other factors like potholes on the road also contributed to it. The accident could have been avoided if the driver of the truck was not drunk such that he would have been able to avoid the potholes that led to the truck rolling over.

## 2.18 Hazards Posed by Road Tanker Transportation of Petroleum Products.

Every country in the world hauls a variety of cargo using tankers. Tanker vehicles transport large quantities of liquid or gas, including oil, water, gasoline, septic tank contents, and chemicals. Light-duty tanker trucks can carry as much as 3,000 gallons of liquid. On the other hand, heavy tanker trucks can carry even higher volumes. There is no doubt that these trucks provide a vital service for many businesses. However, they can also pose unique hazards on the roadways. According to Schecter (2018), the risk factors particular to oil tankers include the following:

**Explosions**: Tanker trucks barrel down the road hitched to tanks containing up to 11,000 gallons of oil or gasoline. The sheer quantity of flammable liquid creates a significant risk of a deadly oil tanker explosion in the event of an impact. This type of fuel tanker explosion can cause death or serious injury not only to those directly involved in the accident but to others in the surrounding area.

**Fire**: Even in the absence of an explosion, an oil tanker's flammable cargo always presents a risk of fire in the aftermath of a collision or due to mechanical failure or a defective part. Whatever the cause, a gasoline fire can do serious harm to anyone in the vicinity, as well as causing significant property and environmental damage.

**Rollovers**: The rollover threshold of oil tankers is significantly lower than other trucks, making them more prone to this type of accident. It should go without saying that a rollover accident involving a fuel tanker truck can lead to devastating damage and injury.

**Loss of control**: Oil tanker trucks present a unique handling challenge to their drivers, particularly when the tank is not completely full, sloshing of the liquid cargo can cause the driver to lose control and crash into other vehicles on the road.

**Spills or leaks**: Improper loading or maintenance of the tank can lead to spills or leaks of an oil tanker's cargo, which can, in turn, cause a collision. Oil or gas that spills from a tanker truck can also create a hazard for other vehicles on the road, even after the tanker has left the scene.

**Improper loading or maintenance**: The fuel tanker apparatus is equipped with plenty of safety features, but it must be handled properly by professionals and never overloaded. If the driver or other employees of the trucking company failed to do so, it may lead to a spill or an accident.

**Negligence and tanker truck accidents**: Due to their excessive size and weight, fuel tanker trucks have much longer stopping-times, and they lack the manoeuvrability of smaller vehicles. Thus, driving one of these tankers requires extra care and ability. Nonetheless, tanker accidents often result from the truck operator's negligent or reckless driving, which may include any of the following:

- Distracted driving, including texting while driving
- Driving under the influence of alcohol or drugs
- Drowsy driving
- Failure to maintain the vehicle or secure cargo properly
- Failure to obey traffic laws and signs
- Speeding
- Tailgating or brake checking
- Reckless or aggressive driving
- Failure to take precautions in inclement weather.

## 2.19 Preventive Measures for Road Tanker Accidents

In today's age, there are many more safety and security features that can help trucking companies and their respective drivers to prevent accidents on the road. Truck companies are required to enforce safe vehicle operation by their employees to avoid potential risks. Most trucks are now equipped with electronic data recorders, similar to that of an airplane black box, that track how many hours a truck has been driven as well as the vehicle operations.

Tanker drivers must be aware of how long they have been driving and the driving conditions. Failure to do so can cause fatigue and affect the overall safety. Commercial truck drivers are trained on how to prevent conditions that lead to significant or fatal road accidents. They must follow the regulations enforced by the Federal Motor Carrier and pay attention to factors and conditions that may affect their ability to safely manoeuvre such as massive road entity. Through abiding by established rules and regulations in the trucking industry as well as formalized traffic laws, accidents can be significantly reduced. A study by Gangadhari *et al*. (2020) to analyse accidents involving petroleum tankers and their consequences in India recommends the following prevention measures to prevent future accidents:

- Care must be taken in the design, licensing and maintenance phases of the tankers. Vehicle monitoring system (currently existing) shall be placed in all vehicles, periodically inspecting vehicles for any abnormalities.
- Drivers should be selected based on qualification, knowledge, and they should be trained according to the requirement. Driver duty should be scheduled in such a way that he is not fatigued. Families of drivers should be included in training programs; drivers should be given incentives based on their performance in safety.
- The company should provide weather conditions, road conditions, traffic density, parking locations information to drivers for safe driving practices.
- The driver should be aware of the materials they are transporting and use of fire extinguishing methods, emergency procedures in case of an accident.

## 2.20 International Standards for the Transportation of Dangerous Goods

According to Ambisisi, et al. (2015) the aim of the international standard for the transportation of dangerous goods is to maintain a global regulatory system for dangerous goods transportation that will enhance their safe, secure and efficient movement. They also maintained that harmonization of international and domestic standards enhance compliance and improve the efficiency of the transportation system by minimising the regulatory burden on the public. There are regulations to deal with the carriage of dangerous goods and the purpose of these regulations is to protect everyone either directly involved (such as consignors or carriers), or who might become involved (such as members of the emergency service and public) (UNECE, 2015). Also, Regulations place duties upon everyone involved in the carriage of dangerous goods to ensure that they know what to do to minimise the risk of incidents and guarantee an effective response. The transport of such goods is governed by a complex network of national and international regulations along with programs that have extremely broad applicability across many industries. As such, any company involved in transporting dangerous or hazardous materials, even at very small quantities, is required to comply with the regulations or seek a waiver.

### 2.20.1 U.S standards for transporting hazardous materials (HAZMAT)

The U.S. Department of Transportation (DOT) has the primary responsibility for overseeing the transportation in commerce of hazardous materials, commonly called "Hazmat." DOT is comprised of a number of administrating agencies, such as the Federal Aviation Administration (FAA) and Federal Motor Carrier Safety Administration (FMCSA). The administration responsible for the transport of Hazmat is the Office of Hazardous Materials Safety (OHMS), which is housed under the Pipeline and Hazardous Materials Safety Administration (PHMSA). DOT's regulations govern the transport of Hazmat by ground, air, rail, inland water, and sea. The scope of DOT's regulatory reach is broad: thousands of products and tens of thousands of businesses are regulated under the DOT HazMat program.

In the US, different businesses transport over one million Hazmat shipments, and every one of them is subject to the DOT standards. The regulations establish standards for Hazmat identification, training, labelling, use of proper containers, recordkeeping, reporting, placarding, and vehicle safety. Any business that offers Hazmat for shipment must train its HazMat employees and adhere to the stringent standards DOT has established. The regulations are complex and businesses often require the assistance of seasoned and experienced professionals to navigate the regulatory framework to ensure compliance.

### 2.20.2 EU standards for transporting hazardous materials (HAZMAT)

The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) was done at Geneva on 30 September 1957 under the auspices of the United Nations Economic Commission for Europe, and it entered into force on 29 January 1968. The Agreement was itself amended by the protocol amending article 14 (3) done at New York on 21 August 1975, which entered force on 19 April 1985 (United Nations, ADR 2015). This authoritative Agreement is intended to increase the safety of international transport of dangerous goods by road. Its Annexes **A** and **B** contain the technical requirements for road transport and the conditions under which dangerous goods, when authorized for transport, maybe carried internationally, as well as uniform provisions concerning the construction and operations of vehicle carrying dangerous goods. They also establish international requirements and procedures for training and safety obligations of participants.

Carriage of Dangerous Goods and use of Transportable Pressure Equipment regulations (CDG) and the European Agreement concerning the International Carriage of Dangerous Goods by Road ECE/TRANS/225 (Vol. I & II) (ADR) together regulate the carriage of goods by road within the EU, whereas the International Air Transport Association Dangerous Goods

Regulations (IATA DGR) set forth the international standard for shipping dangerous goods by air. (International Civil Aviation Organization (ICAO) is the regulation; IATA is the ICAO interpretations with individual contributions from airlines).

Council Directive EC Directive 96/35/EC of June 3, 1996, on the appointment and vocational qualification of safety advisors for the transport of dangerous goods by road, rail, and inland waterway requires from January 1, 2000, that all companies involved in the consigning and carriage of dangerous goods appoint a qualified Dangerous Goods Safety Advisor (DGSA).

Employers (including the self-employed) who load or transport dangerous goods beyond the thresholds set forth in the regulations must appoint a safety advisor to guide them on the legal, safety, and environmental aspects of the transport of dangerous goods. Companies have the option to appoint a person within their employment or to use the services of a DGSA consultant; whichever is chosen, the DGSA must be certified by the Scottish Qualifications Authority (SQA). The ADR specifies that persons other than the driver involved in the carriage of dangerous goods, shall receive training in the requirements governing the carriage of dangerous goods. This training takes the form of general awareness training, function-specific training, and safety training.

Also, there is a Globalised Harmonised System of Classification and Labelling of Chemicals (GHS, Rev.7) which addresses the classification of chemicals by types of hazards and proposes harmonized hazard communication elements, including labels and safety data sheets. It aims at ensuring that information on physical hazards and toxicity from chemicals be available in order to enhance the protection of human health and the environment during the handling, transport and use of these chemicals. The GHS also provides a basis for harmonization of rules and regulations on chemicals at national, regional and worldwide level.

### 2.20.3 Laws Governing the Transportation of Petroleum Products in Nigeria

According to Ambituuni *et al*. (2015) there is an apparent framework for regulating safety and environmental issues within the downstream sector of petroleum activities, including product distribution operations in Nigeria. They include: Petroleum Act (2004), Harmful Waste Act (2004), Petroleum Product Distribution Act (2004), Oil Pipelines Act (1990); and the NESREA Act (2007). These Acts can be considered to have cover key regulations relating to “good oil practices” in refining, transporting/distributing and marketing of products, and also ensure safe and environmentally friendly synergy within downstream facilities (Ambituuni et al. 2015).

In Nigeria, the Federal road safety commission (FRSC) and the Vehicle Inspection Officers (VIO) are two outstanding organizations established by government to oversee road safety matters. However, the activities and achievements of these two organizations reveals that they are still far from attaining the international standards set by the US and the EU (see section 2.6.1 & 2.6.2) for the transportation of dangerous goods aimed at safety. Therefore, a continuous dependence on the FRSC and the VIO to carry out such daunting tasks as Road safety policy research and development, contemporary quantitative risk and hazard analysis coupled with overall transportation risk management would yield little or no results. It is therefore imperative that the role of the FRSC and VIO be reviewed and defined.

## 2.21 Risk Management Frameworks for HAZMAT Transportation

### 2.21.1 The Philosophy of Risk Research

Most philosophical studies of risk are closely related to problems in the philosophy of science or in ethics. This corresponds to two major problem areas in more general discussions on risk, namely, how we should assess risks and what risks we should accept. However, the philosophy of risk also has strong connections with several other areas in philosophy, including epistemology, decision theory, political philosophy, and the philosophy of technology (Hansson, 2017).

Various philosophical orientations guide the diverse definitions of risk. For instance, risk has been defined as an objective state of the world (expressed in ontological realism). Research methodology designed with this philosophical view, therefore, believes that risk has to exist independent of perception and knowledge, and devoid of subjective judgement about what is at risk and how likely a risk will manifest (Eugene and Rosa, 2003). Additionally, also, by granting risk an ontological status, risk paradigms debate is placed into an arena of disagreement over questions of knowledge, perceptions and understandings of risk, versus the understanding of how groups and societies choose to be concerned with some risks while ignoring others (Aven and Renn, 2010).

Underlying the definition of risk is the concept of hazard; defined as a characteristic or group of characteristics that provides the potential for a loss (Muhlbauer, 2004) or put simple, hazard is anything that can cause harm (Marris, 2007). Risk on the other hand is an exposure to uncertain event with well-known probability (Aven, 2009). Following these definitions, it becomes clear that risk typically includes a consideration for probability or chance and the potential magnitude of loss. This also suggests that risk can somewhat be foreseen and the corresponding probability of occurrence of the risk event can thus be estimated.

In summary, the identification methods of risk cause research are mainly based on a statistical analysis of accident history data or the application of data mining algorithms to dig out hidden cause factors. Cause research mostly focuses on specific types of accidents and identifies risk sources from the perspective of transportation system components while the causes of dangerous goods transportation accidents are mostly concentrated on the state of cargo, means of transportation, transportation facilities, and human factors (Huang et al. 2021).

### 2.21.2 Risk Management, Assessment and Identification

The International Organization for Standardization (ISO) defines risk management as the ‘coordinated activities to direct and control an organization with regard to risk’ (ISO/IEC Guide 73:2009 73:2009 2009). In other words, as explained by the European Network and Information Security Agency (ENISA), risk management is the ‘process of identifying, quantifying and managing the risks that an organization faces. In the field of hazardous materials transportation, a risk-based approach is favoured by all stakeholders and has therefore become unavoidable. Risk management involves a multitude of actors and stakeholders, including at least the operator of a high-risk installation or process, the regulatory or competent authority, a number of government bodies and agencies, various interest groups and the general public involved in risk management. For all of them, easy access to risk-related information is essential. Also, there are five basic steps to be followed to ensure as illustrated in Figure 11 to ensure exposure to risk is managed.

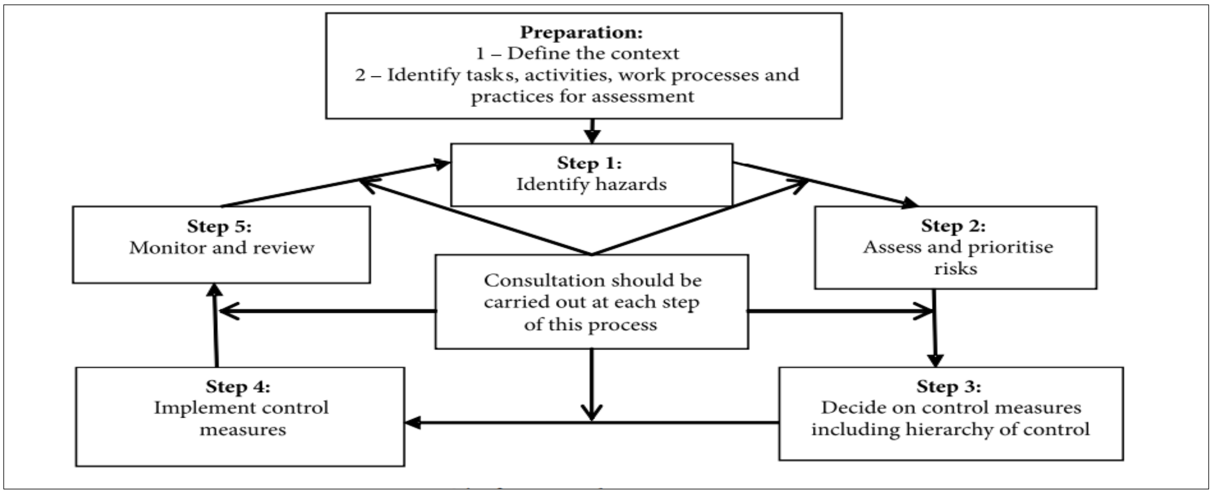



*Figure 11 The five-step risk management process. Adapted from Batarlienė, (2008)*

Therefore, the concept of risk management can be explained as a systematic process of risk assessment together with judgment made during risk characterisation from the input material upon which risk management options are evaluated, assessed and selected. It is these outcomes that drive decision making processes in risk management. Thus, risk management is described as a decision-making process (Fernandes et al., 2010). Such decision making requires assessment and prioritisation based on a methodological approach that integrates a risk philosophy. (Aven & Renn, 2010).

Risk assessment is a science that has been developed in the past 40 years to help understanding and controlling the risk of accident events. This allows the rational management of hazardous industrial activities, through their systemic understanding (Shankar et al. 2018). Covello & Merkhoher (2013) in Ghaleh *et al*. (2019) defined risk assessment as a systematic process used to measure both the quantitative and qualitative risks associated with hazardous materials, processes, actions and accidents on people, equipment, and the environment. Performing a risk assessment involves processes and technologies that help identify, evaluate and report on any risk related concerns. Thus, risk assessment is a key component of the risk management process and is primarily focused on the identification and analysis of risk management. Therefore, assessment implies evaluation, and any valuation requires a value system and a metric for measurement.

From a hazardous material transportation viewpoint, risk management forms the basis of safe dispatching of fleet. The aim is to conduct qualitative or quantitative analysis of the risk of accidents in the process of transportation, and evaluate the possibility of accidents and the severity of accident consequences, so as to seek for the lowest accident rate and the least loss (Ma *et al*. 2020). The consequences of an accident involving a truck or a train are often substantial, but the stakes increase considerably if the vehicle carries dangerous goods that can harm people, other living organisms, the environment, property and cause disturbances in the transport system (Floden & Woxenius, 2021). This represents a major concern both to the government and the different stakeholders in the oil and gas industry (NNPC, 2008).

According to the US Department of Transport (DOT), a key goal of the risk management framework is to serve as a unifying structure and self-evaluation resource that will encourage and guide the voluntary use of risk assessment and risk management concepts and tools by the many disparate parties involved in transportation of hazardous materials. In this context, a "framework" is meant to describe an overall organizing structure that identifies the main elements of a process and explains how they fit together. In terms of risk management frameworks, Figure 12 describes a risk management framework for managing sustainability risks in sustainable freight transport systems (SFTSs). Sustainability risks are defined as the potential disruptions that can cause a loss for a system in terms of its target values of sustainability performance and effectiveness evoked by uncertain developments in its environmental, economic and social behaviour originated by the occurrence of triggering events (Shanker *et al*. (2018).

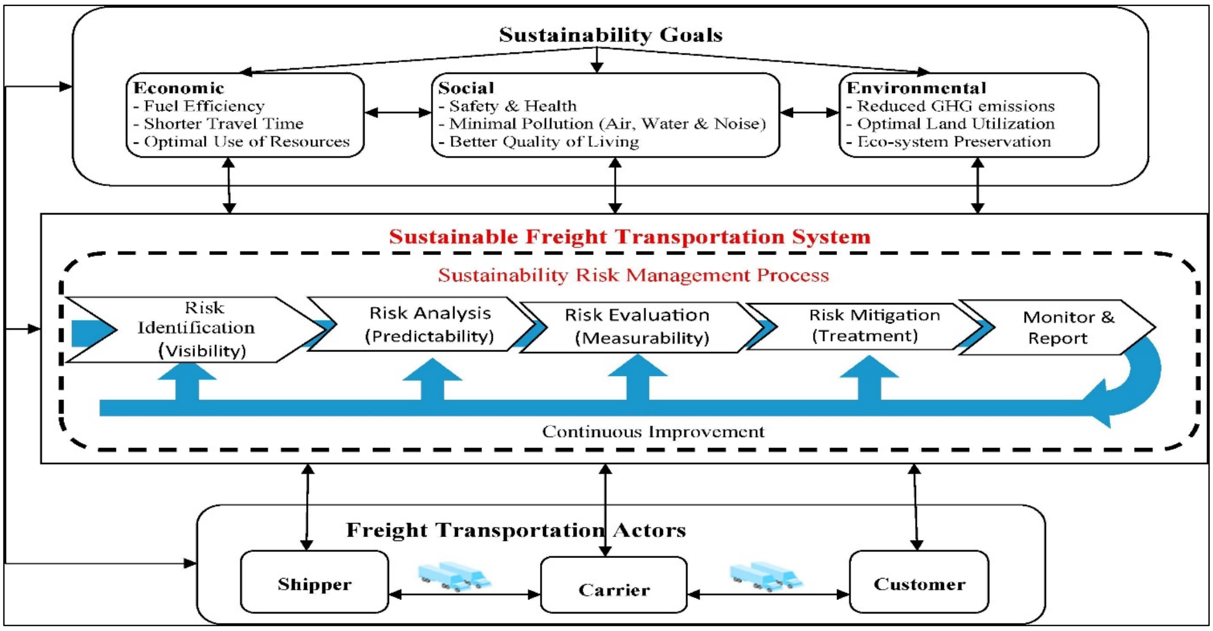



*Figure 12 Framework for managing sustainability risks in (SFTSs). Adapted from Shanker et al. (2018).*

Various research on transport accidents and transport risks of hazardous materials has been conducted since the 1970s and has taken the research results through four stages: the first stage (before 1985), was mainly focused on the accident analysis of nuclear fuel and its waste; the second stage (1985−1989) was mainly concentrated on the probability of transportation accidents and casualties of hazardous materials; the third stage (1990−1999) mainly used traditional methods to study the risk measurement model of hazardous materials transportation, while the fourth stage (from 2000 to now) employed modern information technology to analyze the transport risk of hazardous materials (Ma *et al.* 2020). Figure 13  presents the keywords co-occurrence network of hazardous materials studies showing how previous studies focus mainly on variables such as road network, risk analysis, optimization, dangerous goods, methodology, and so on.

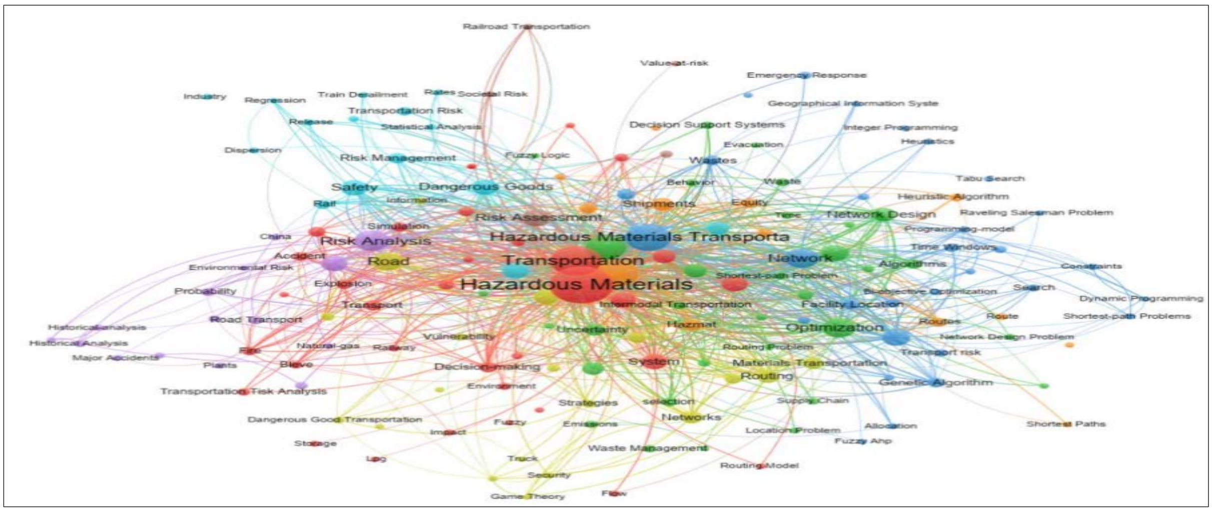



*Figure 13 Keyword co-occurrence network of hazardous materials studies. Source: Adopted from Ma et al. (2020).*

Many accidents involving trucking petroleum products by road in Nigeria have been associated with consequential effects on human safety and the environment. According to Ambituuni *et al*., (2015) such accidents have exposed the lack of accident risk management structure in Nigeria. Therefore, there is a need to have a risk assessment framework that exposes the financial implications of accidents involving petroleum tankers in order to bridge the gaps in regulatory enforcement due to fragmented characters of petroleum product transport operators in Nigeria. In the view of Ambituuni *et al*, most transport companies involved in the transportation of hazardous materials cling to the perception that adhering to good safety and environmental standards are expensive. Therefore, there is need to uncover the real, and often high, but hidden costs of poor safety standards to operations through risk assessments (Ambituuni *et al.*, 2015).

A number of hazmat accidents have resulted from the transportation of flammables, such as explosives and gasoline (Sen and Downs, 2008). Also, the problem of hazmat transportation risk analysis has become very popular and has received a lot of attention over the past two decades, however, most of the work focused on risk assessment and route selection (Erkut, Tjandra and Verter, 2007). For instance, Fan *et al*. (2015) states that to perform an accurate transport risk analysis (TRA), the knowledge of territorial information of comparable accuracy is of paramount importance and data are needed about local distribution of population, accident rates, and weather conditions.

A report by PHMSA, (2013) agrees to the fact that hazardous materials transportation risk assessment is often designed for different purposes and used in different ways by government agencies and by the private sector. To this end, freight transportation and chemical industries, government regulatory and enforcement agencies at the federal and state levels, and local emergency planners and responders must routinely share information, resources and expertise to ensure that risk is well assessed and managed.

## 2.22 Risk Assessment Models Applicable to Transporting Hazardous Materials

Bronfman *et al*., (2015) maintained that the routes prescribed by authorities for the transport of hazmat and the defined rules that vehicle carrying hazmat must obey are two approaches to risk mitigation in the transport of hazardous materials. This can lead to the determination of alternative routes with respect to that usually chosen by truck drivers. This is because HAZMAT routing differs from conventional vehicle routing due to additional consequences that can result when hazmat transport vehicles are involved in accidents (Rahman and Lownes, 2013). Qin *et al*. (2009) took risk minimization as the goal and considered the weather change to construct a robust optimization model for the selection of hazardous materials transportation route.

Zhao and Cheng (2011) analysed the transport risk of hazardous chemicals from the perspective of accident rate estimation, and adopted Poisson regression model to fit the transport accident data of hazardous chemicals in Shanghai from 2000 to 2006, and they proposed a probability estimation method for the transport risk of hazardous chemicals by comparing the solution results of the normal distribution. Also, Vasiliki *et al*. (2011) established an optimization model for the transportation route of hazardous materials that takes into account both transportation risks and transportation costs, and conducted simulation analysis with Monte Carlo method. The research results show certain reference value for the optimization design of transportation network between single start and end points.

Mohammadfam *et al*. (2020) conducted a study aimed at assessing the quantitative risk in the road transport of hazardous materials using a Bayesian network and the fuzzy inference system. The study conducted a cause–consequence analysis of material leakage from trucks using a bowtie analysis in a Bayesian network, and adopted the hybrid equations and a fuzzy inference system to evaluate the severity of health and safety consequences and determine the severity correction factor of the studied nodes as shown in Figure 14. The results from the study shows that the combination of the Bayesian network (BN) and the fuzzy inference system (FIS) could be used as a precise tool for assessing the quantitative risk of hazardous chemicals' transport.

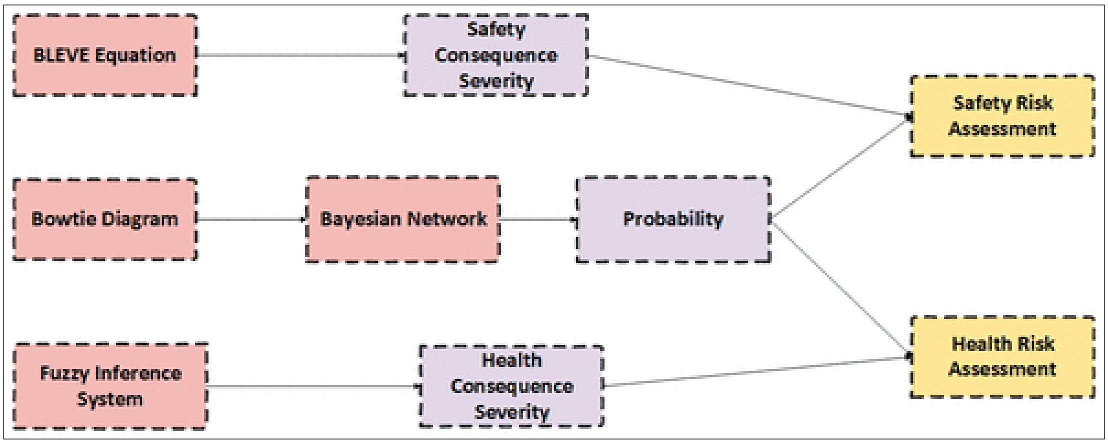



*Figure 14 Quantitative risk assessment using a bowtie analysis. Adopted from Mohammadfam et al. (2020).*

Guo and Verma (2010) investigated the impact of different truck capacities on transport risk from moving flammables, such as gasoline or explosives, on a given route using three scenarios, under risk-neutral and risk-averse assumptions, to develop conditions for preferring a specific vehicle size. Landucci *et al.*, (2017) analysed the Viareggio accident in Italy as a paradigmatic event in Hazmat transportation in Europe by analysing reference approaches for risk assessment in Hazmat transportation by comparing impact distances with those considered in Hazmat transportation assessment.

Ghaleh *et al*. (2019) conducted a study with the aim of proposing the safety risk assessment pattern of road fleet for transportation of hazardous materials and classifying trucks with a safety approach by combining fuzzy analytical hierarchy process (AHP) method and failure mode and effects analysis (FMEA) approach. The study analysed the technical and structural characteristics of trucks and investigated their role in road accidents of oil materials transportation. The results from the study showed that the most important safety risk contributing factors (SRCFS) in the road fleet of hazardous materials transportation in the carrier and tank groups were “technical characteristics of the carrier” and “technical characteristics of the tank”. In addition, the most important Sub-SRCFS included unsuitable inspection of the truck (tank and carrier), poor brake system, and lack of the strength of front and rear shields of the carrier (Ghaleh *et al.* 2019).

Torreta *et al.* (2020) in a study proposed a modified algorithm for risk evaluation and a decision support system called TrHaM (Transport of Hazardous Materials) in order to both quantify the overall risk due to the transport of hazardous materials via road, railroad, waterway and pipeline and help in planning transport activities. The algorithm evaluates and shows the risk distribution using a stand-alone global information system (GIS) software, which also considers sensitive targets with high crowding (such as schools, hospitals, shopping malls, stadiums and camping areas). Also, TrHaM has proven to be very reliable in the circulation of hazardous materials in the Varese district (Northern Italy), an area characterized by a high level of both population and industrial density combined with heavy road traffic.

Fazal *et al*. (2019) conducted an assessment to determine the awareness of the petrol tanker driver on the chemical exposure during the transportation of petroleum products. The assessment on hazardous awareness of the petrol tanker driver was conducted through questionnaire survey. The questionnaire was designed by considering the variables such as the age of the driver, working experience, working hours in a day and knowledge on chemical hazard presence in the petroleum oil. A reliability test of Cronbach's Alpha was performed to validate the questionnaire and the Chi-Square test was conducted to determine the correlation among the studied variables. The findings from the study revealed that the drivers who frequently come into direct contact with petrol cannot identify that spillage had occurred during working. The study concluded by recommending the conduct of training on safe handling of petroleum oil in order to eliminate the risk of chemical hazards exposure to the tanker driver.

In Nigeria, many tanker drivers are not equipped with adequate information about the risk of the cargo they are transporting.  A lot of the drivers are not aware of the risk such a job could pose to themselves and to the community if anything goes wrong during the transportation of such cargo. They do not have adequate knowledge of the concepts of risk assessment and management of hazardous materials. In most advanced nations, risk assessment and management of hazardous materials transportation has been a major concern to all stakeholders involved in the transportation and distribution of hazmat because of the risk it poses (Li *et al*. 2019). Even though this could be true for other countries including Nigeria, however, not much has been done in terms of risk management in the field of hazmat transportation in Nigerian.

Also, tanker driving is seen in Nigeria as a job for people who are not educated. As such, majority of tankers fleet are driven by either illiterates or semi-illiterates' drivers. However, some major oil companies have a good recruitment process that requires from drivers' certain qualifications before they are employed to drive tankers. They do this as part of a risk management process.

## 2.23 Environmental Impact of Road Tanker Transportation

Oil pollution is one of the main problems that affect the natural conditions of petroleum products in Nigeria. The Niger Delta area of Nigeria has been subject to special attention due to periodic oil spills from wells. In addition to the above, local authorities suspect the existence of leaks from hydrocarbon pipelines that cross the arears and seas, as well as the possible release and runoff of various substances chemicals for industrial or agricultural use (Anyadiegwu, 2015). Pollution issue has aroused the interest of researchers and scientists to study and analysed the deterioration that the environment is suffering from as a result of pollution from petroleum products. The pollution produced by the different activities of the industry petrochemicals is transferred to the land areas through infiltration and hauling hydrocarbons in the various rivers or streams that flow into it (Ehinomen and Adeleke, 2012).

Road transport is the most common type of transportation in various countries of the world and hazardous materials (HAZMAT) truck accidents are among the most important problems in the road transportation (Ghaleh *et al*. 2019). Due to their pressurized storage in tanks, hazardous gases and chemicals can be considered as the greatest risk to individuals and property along the road as they can induce severe consequences such as fatality, injuries, evacuation, financial loss and environmental damage (Chakrabarti & Parikh, 2013). The environmental consequences of HAZMAT accidents include air pollution, followed by water, soil and biological degradation. In proposed HAZMAT models, population exposure to HAZMAT accidents is considered to be less significant compared to environmental pollution. However, there have been disasters involving HAZMAT accidents which have resulted in the deaths of hundreds of people.

According to the U.S Department of Transportation (DOT), it has been predicted that freight railroad demand will rise to 88% by 2035. For instance, there was a total of 15,919 incidents resulting in 12 fatalities and 81,365,866 damages in the USA (DOT). In the U.S, the approximate 1.7 million carloads of hazmat transported by rail each year present a “Toxic Inhalation Hazard” (TIH).

A study was conducted by Jabbari *et al*. (2020) to determine the suitable margin of safety/survival of individuals in HAZMAT road transportation accidents for use in Emergency Response Planning (ERP). The chemical tanker trucks in Iran's road transport fleet were investigated and the full-bore rupture of the tanker trucks was used as a case study while the safety margin and survival margin were determined using the ALOHA and PHAST software and the Chemical Exposure Index (CEI). The results show that using the CEI, among the selected chemicals, ammonia, chlorine and 1,3-butadiene had the highest chemical release potential with the exposure indices of 597, 548 and 284, respectively. The study concluded by recommending codification of standards based on safety and survival margins for chemicals.

Bondzic *et al*. (2021) conducted a study whose aim was to assess the exposure of people with disabilities to the impact of hazmat road accidents, in order to provide evidence-based knowledge necessary for the establishment of competent disaster preparedness procedures. A case study was developed for ammonia release from a tanker truck in the vicinity of the Institution for Children and Youth with Disabilities in Veternik, a suburban settlement of Novi

Sad, Serbia. An integrated methodology for the risk assessment of the identified problem was proposed focusing on environmental and human-induced variables with a significant impact on the hazard magnitude. The simulation conducted with ALOHA (Areal Locations of Hazardous Atmospheres) confirmed assumption that the combination of high temperature and low wind speed can cause the worst-case scenario i.e., to expose a larger surface area to the influence of released ammonia.

## 2.24 Safety Requirements for Articulated Lorries (Tankers/Trailers) Operations in Nigeria.

In most developed countries like the United Kingdom, USA and Germany, the driving of articulated Lorries (Tankers and Trailers) requires special skills and knowledge of traffic laws and regulations. It is mandatory to get the appropriate training, knowledge, experience and certification before anyone can drive a tanker or lorry. Even much knowledge, training and experience is needed when it concerns the transportation of hazardous materials. This is because of the high risk involved in the transportation of hazmat owing to the nature of the goods being transported. This initiative has increased the safety of drivers on the road by reducing accidents. In the UK, it is a criminal offence to drive a truck or heavy goods vehicle HGV without going through the necessary training. Nigeria has many drivers of articulated Lorries (Tankers/Trailers) who are not qualified to operate such vehicles as they are not properly licenced and lack the basic requirements to operate such vehicles, hence the high incidences of Road Traffic Crashes (RTC) on the highways. In view of this high rate of road crashes resulting from unprofessional conduct and carelessness by some tanker/ trailer drivers on the highways, the Federal Government mandated the Federal Road Safety Commission (FRSC) to establish Minimum Safety Requirements for heavy good vehicles. The responsibilities of the FRSC relating to tankers/trucks operations include monitoring, certifying, registering and enforcing compliance with regulations governing safety operations of articulated vehicles in Nigeria. It has been reported over the years that even with these guidelines and regulations, accidents involving tankers transporting petroleum products like the petrol, diesel and kerosene has been on the increase.

## 2.25 Wholesale, Distribution and Marketing of Petroleum Products

Wholesale distributors are generally synonymous with oil marketing companies. In Nigeria, the African Petroleum (AP), Total Plc and Oando Nig plc are some of the major wholesale distributors of petroleum products across the country. Other major wholesale distributors of petroleum products in the country include Agip, Conoil and Texaco. Wholesale marketing involves the acquisition from the bulk supply link of petroleum products of the quality and in the volume appropriate to the market (PPMC, 2006). Products are delivered by road tanker to the oil marketing companies affiliated (branded) retail service stations, as well as to bulk consumers such as power generation plants, industry, large commercial customers, government agencies, and transport fleet operators such as trucking companies and bus operators. In other countries, oil marketing companies may also deliver petroleum products to independent retailers under supply contract sales arrangements. For instance, in Gambia, oil marketing companies (OMCs) procure and sell refined imported petroleum products to bulk consumers and the general public through retail outlets like fuel stations and other reselling outlets. The key OMCs or petrol station company players in the Gambia’s downstream energy sector are Petrol Gas Ltd (formerly Galp Energia Gambia Ltd and Shell Marketing), Total Ltd, Atlas (formerly Elton Oil) Ltd, Castle Oil Ltd, Gambia National Petroleum Company (GNPC), Jah Oil Company, Sandalee Oil & Trading and Speed Limited (Manneh, 2020). In Ghana, the distribution of petroleum products is similar to how it is done in the Gambia. The major actors obtain licence to procure petroleum products from Tema oil refinery (TOR) for sale to bulk consumers and the general public through petroleum retail stations and outlets.

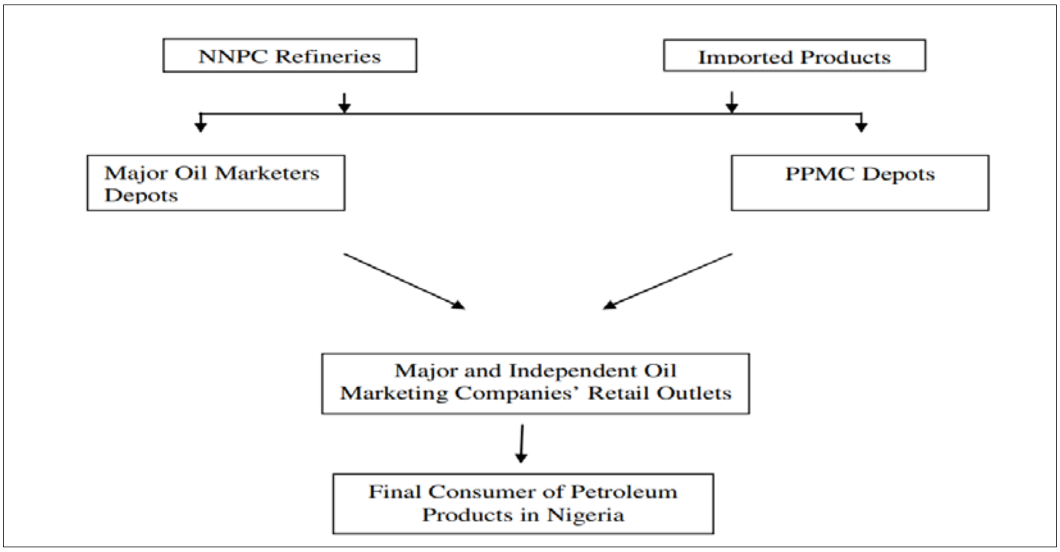



*Figure 15 The physical flow of products: the retail route used by major and independent companies in Nigeria. Source: NNPC/PPMC Bulletin, 2010*

## 2.26 Research Gaps in Hazardous Materials Transportation and Risk Management

The research gaps from the reviewed literature can be summarised as follows:

1. The main research gap to be addressed in this research relates to safety and accident mitigation during the transportation of petroleum products through the use of road tankers. This is because little has been done so far on developing a system that can be used for the safety assessment in order to manage the risk involved in transporting petroleum products from a storage depot to a retail station. As stated in section 2.7, Ma *et al*. (2020) concluded that "risk management of hazardous materials transportation is

the basis of safe dispatching of fleet, whose goal is to conduct qualitative or quantitative analysis of the risk of accidents in the process of transportation, and evaluate the possibility of accidents and the severity of accident consequences, so as to seek for the lowest accident rate and the least loss. Therefore, this research seeks to develop a safety assessment framework for the transportation of petroleum products in order to mitigate road accidents and promote road safety.

2. Most work reviewed on petroleum products transportation using road tankers did not consider performing a comprehensive risk assessment in the supply chain network to ensure safe distribution of petroleum products. For instance, a lack of safety checks on a tanker vehicle at the point of loading could result in an accident and this could result products not getting to their destinations. The need to develop a safety assessment framework that would ensure risk assessment starts from the loading depot until products gets to the retail outlet becomes important.

3. There are few studies on risk management frameworks from a Nigerian petroleum industry context to guide against the risks posed by the transportation of hazardous materials in Nigeria. Also, there is no adequate information and knowledge regarding transport safety most especially HAZMAT transportation.

4. Also identified are gaps between the frameworks underpinning the petroleum industry in Nigeria and the pace at which it catches up with international best practices and knowledge in the field of petroleum product transportation and distribution.

## 2.27 Summary of Chapter Two

This Chapter sets the stage for the work carried out in this thesis by discussing major theoretical concepts behind the transportation of hazardous materials using road tankers. In the downstream oil and gas transportation and distribution of refined petroleum products to end users, road tankers play a crucial role in the supply chain system. As such, adequate regulations in terms of safety and risk management, environment, technology, training for tanker drivers and a proper investigation into the causes of tanker accidents become very necessary to ensure safety in the transportation and distribution of petroleum products. In this chapter, the theoretical framework for this research was also presented and various accident causation model were discussed. This chapter identifies some risk factors such as fire, rollover, explosions, spills or leaks, loss of control etc that are associated with the transportation of hazmat using tankers. Also in this chapter, some standards and practices for the transportation of dangerous goods from a global perspective were identified and discussed. For instance, the U.S. Department of Transportation (DOT) has the primary responsibility for overseeing the transportation in commerce of hazardous materials known as HAZMAT while the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) is intended to increase the safety of international transport of dangerous goods by road. In Nigeria, the NNPC, PPMC and its various subsidiaries are the key players in terms of the regulations guiding the activities of the supply chain network while the FRSC was set up by the government to ensure vehicle safety on the road. The chapter discussed the environmental impact of the transportation of hazardous materials using road tankers. Furthermore, the safety requirements for articulated lorries (Tankers/Trailers) Operations in Nigeria were discussed. Wholesale distributors of petroleum products in Nigeria and some other like Ghana and the Gambia were reviewed in this chapter. The chapter was concluded with a summary of the research gaps from the review of literature.

# 3 CONCEPTUAL FRAMEWORK

## 3.1 Introduction

This chapter presents the conceptual framework for this research based on the literature review discussed in chapter two. The findings from the literature conducted in chapter two suggest that human factors, mechanical factors and environmental factors are responsible for hazardous materials transportation accidents involving road tankers. A review of the risk management frameworks for the transportation of hazardous materials was also performed in order to identify the various risks and hazards associated with the transportation of hazmat using road tankers. The findings from the literature review chapter two revealed that most developed nations like the US and the European Union (EU) adheres to safety standards and regulations to ensure that the transportation of hazardous materials is performed in a safe way. These regulations have no doubt contributed to the safety of hazmat transportation in those regions of the world. Finding from the literature shows that technology such as the Global Positioning Systems (GPS) have also contributed to the safety of hazardous materials transportation. Based on the analysis and key findings from the literature review, a conceptual framework for this research would be developed by identifying the relationship between the key independent variables (IV) and the dependent variables (DV) identified in the literature review of this study. The conceptual framework for this research would adopt the Bow-tie accident causation model. The bow-tie model combines the analysis of accident causation and risk assessment scenarios, thus the reason for adopting the method in the development of the conceptual framework (see chapter 2).

## 3.2 Definition of a Conceptual Framework

A conceptual framework is a foundation structure for research that is not focused on one theory or concept (Agyem, 2018). A conceptual framework aids in summarising the findings from the literature and the data collection. This summary can be a model or conceptual framework which represents an integrated way of presenting a problem or situation. According to Regoniel, (2015) a conceptual framework represents the researcher's synthesis of literature on how to explain a phenomenon and it maps out the actions required in the course of the study given his previous knowledge of other researchers' point of view and his observations on the subject of research. It sets the stage for the presentation of the particular research question that drives the investigation being reported based on the problem statement which presents the context and the issues that caused the researcher to conduct the study. Also, Miles and Huberman, (1994) and Robson, (2011) described conceptual framework as a system of concepts, assumptions, expectations, beliefs, and theories that supports and informs research and is a key part of research design that can be represented as a visual or written product, that explains, either graphically or in narrative form, the main items to be studied, the key factors, concepts, or variables and the presumed relationships among them. This agrees with the view of Nicholas, (2013) and Magher, (2017) that the conceptual framework provides an outline of how to plan and conduct the research for a thesis, however, it goes further by also positioning the study within the larger field of research. According to McGaghie *et al*. (2001) the conceptual framework lies within a much broader framework called the theoretical framework. The latter draws support from time-tested theories that embody the findings of many researchers on why and how a particular phenomenon occurs.

## 3.3 Related Existing Conceptual Framework for the Transportation of Petroleum Products

Coelho (2016) conducted a study to access the transportation of liquid fuels in South Africa using Multi-Criteria Decision Analysis (MCDA). The study proposes a model which integrates the MCDA and stochastic analysis in the hope that it would provide a faster and more cost-effective alternative for assessing liquid fuel transportation problems. Also, Ambituuni (2016) in a study proposes a risk management framework for pipelines and road truck transport systems by carrying out a preliminary review of the entire downstream petroleum industry regulations which identified key legislations and stakeholder interests within the context of accident prevention and response. The study revealed that 79% of accidents are due to human factors while control points for the prevention of accidents were identified for the truck risk management framework.

The above frameworks did not address the problems faced by tanker drivers during the transportation of petroleum products between a loading depot and a retail station. These gaps would be addressed in this research work by developing a framework that would be used to mitigate accidents between a loading depot and a retail outlet during the transportation and distribution of petroleum products and also putting the concerns of tanker drivers into consideration.

## 3.4 Development of the Conceptual Framework

Some identified key variables from the literature review that has an impact in the overall accident mitigation plan for the safe transportation of petroleum products between a storage depot and the retail station as shown in Figure 16 are:

- Drivers' challenges/factors causing accidents
- Technology
- Risk and safety management
- Environmental factors
- Regulations and standards
- Training for tanker drivers.

Therefore, the following hypothesis are developed based on the relationship between independent variables and the accident mitigation plan.

**Hypothesis 1**: identification of factors causing accident / drivers challenges has a significant positive influence in accident mitigation when transporting petroleum products.

**Hypothesis 2:** the use of technology in tankers have a significant positive influence in accident mitigation when transporting petroleum products.

**Hypothesis 3**: Effective risk management and safety procedures have a significant positive influence in accident mitigation when transporting petroleum products.

**Hypothesis 4**: Environmental factors have a significant positive influence in accident mitigation when transporting petroleum products.

**Hypothesis 5**: Regulations and standards have a significant positive influence in accident mitigation when transporting petroleum products.

**Hypothesis 6**: Training and supervision for tanker drivers have a significant positive influence in accident mitigation when transporting petroleum products.

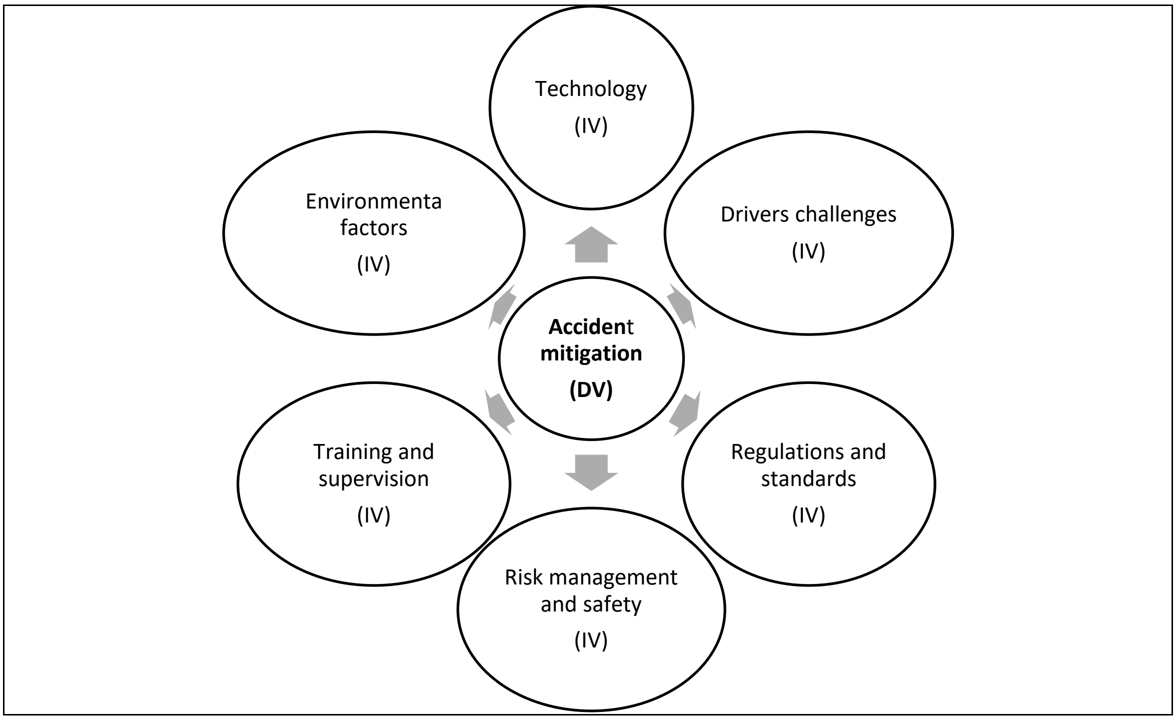



*Figure 16 Relationship between independent variables and the dependent variable.*

The proposed framework that would emerge from this research would be used to mitigate accidents and improve safety on the road during the transportation of petroleum products using tankers in the following areas as shown in Figure 17: Depot loading operations, On-the-road operations and Un-loading operations

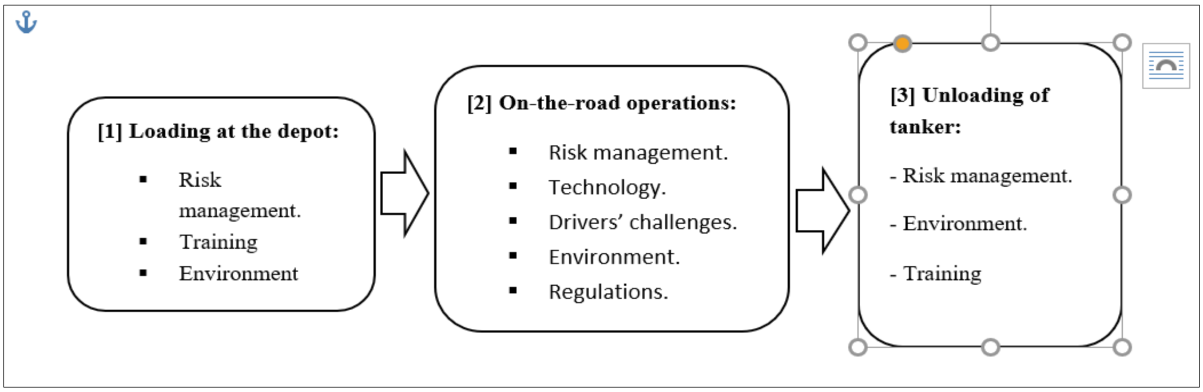



*Figure 17 The stages of road tanker transportation*

In every oil depot where petroleum products are stored, there are many possibilities of hazards such as explosion, fire, BLEVE (Boiling Liquid Expanding Vapour Explosion), confined and unconfined vapour cloud explosions and hazards during transportation (Kumar, 2016). These may result in incidents either at the loading depot, during transportation or at the point of unloading. It is therefore important to ensure that measures are put in place to minimize the occurrence of these hazards as well as mitigate the risk. Hazard identification and risk assessment is therefore a method by which the main hazardous substance can be identified, and as such, their effects can be reduced (Kumar, 2016).

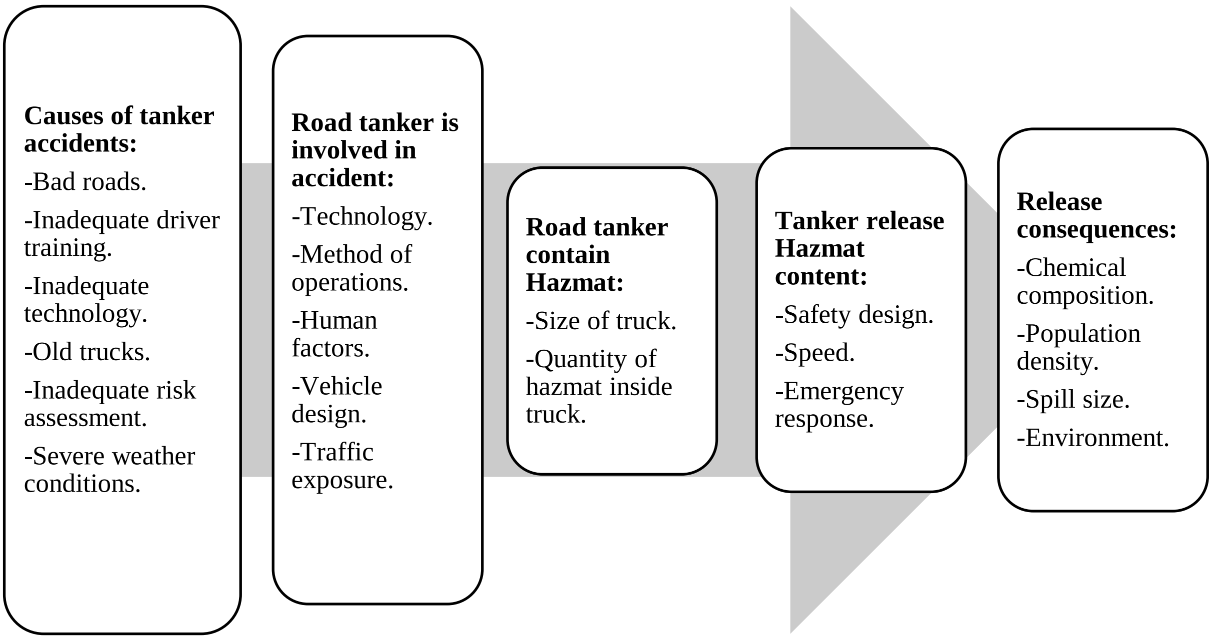



*Figure 18 Chain of events leading to a tanker accident*

## 3.5 Findings from Literature Review on the Transportation of Hazardous Materials

The first objective of the research is to perform a literature review on the Nigerian downstream petroleum industry while the second objective is to investigate the causes of road accidents involving tankers transporting petroleum products in Nigeria. The details of the first and second objectives have been discussed in chapters one and two. The key findings however are summarised below:

- Due to the bad state of Nigeria roads, an appreciable number of tankers transporting volatile petroleum products have been involved in accidents during their journey from the depot or the refineries to the retail outlets which is the final destination from where the products are being sold to the consumers.
- In addition to personal injuries and fatalities, tanker accidents can result in environmental hazards like spill of cargo. These accidents can result in severe financial consequences. There is therefore a strong motivation, from both vehicle safety and financial aspects, to study how these accidents can be prevented or minimised.
- There is a strong relationship between technology and accident mitigation to promote road safety during petroleum products transportation.
- Safety-related ITS applications are intended to provide information to vehicles to avoid potentially dangerous traffic situations or to reduce the seriousness of an accident.
- The NNPC owns and operates an extensive network of refining and distribution facilities nationwide and is responsible for petroleum products distribution through its subsidiary, the Pipelines and Products Marketing Company of Nigeria (PPMC).
- The transportation and distribution of dangerous goods like petrol is a high-risk activity involving heavy vehicles on the public road and the rail network.
- The route planning for hazmat transportation is an important aspect of risk management in the transportation of hazardous materials. Problems relating to risk management become even more complex when the problem of route planning is not adequately addressed.

- In Nigeria, the authorities involved in the transportation of hazardous materials are still laid back in enforcing policies and regulations that would help to minimise the risks involved in the transportation of hazmat.
- There are standards and regulations for the transportation of hazardous materials because of the risks it transportation and movement poses.
- In Nigeria, the authorities involved in the transportation of hazardous materials are still laid back in enforcing policies and regulations that would help to minimise the risks involved in the transportation of hazmat.
- In most developed countries like the United Kingdom, USA and Germany, the driving of articulated Lorries (Tankers and Trailers) requires special skills and knowledge of traffic laws and regulations. It is mandatory to get the appropriate training, knowledge, experience and certification before anyone can drive a tanker or lorry.

## 3.6 Identified Problems in the Transportation of Petroleum Products in Nigeria

- Operational diversity: There is fragmentation in operations between the major oil marketing companies and the independent oil marketing companies as it relates to the transportation of petroleum products in Nigeria.
- Technological barriers: The lack of modern technologies in tankers transporting petroleum products has posed a challenge to the downstream petroleum industry in Nigeria.
- Lack of standards: Compare to the developed countries, the standard and regulations for transporting petroleum products in Nigeria are very weak and also not effective.
- Lack of regulatory enforcement: The lack of regulatory enforcement has been a major challenge in the downstream petroleum industry in Nigeria.

## 3.7 How the Framework was Developed

The framework (Figure 19) consists of 6 components which are labelled from [A] to [F] that relates to the transportation and distribution of petroleum products using road tankers. These components were areas identified from the review of literature that have a relationship with tanker accidents as it relates to the transportation of petroleum products. They include: drivers challenge and factors causing accidents, technology, risk management and safety, environment, regulations and training.

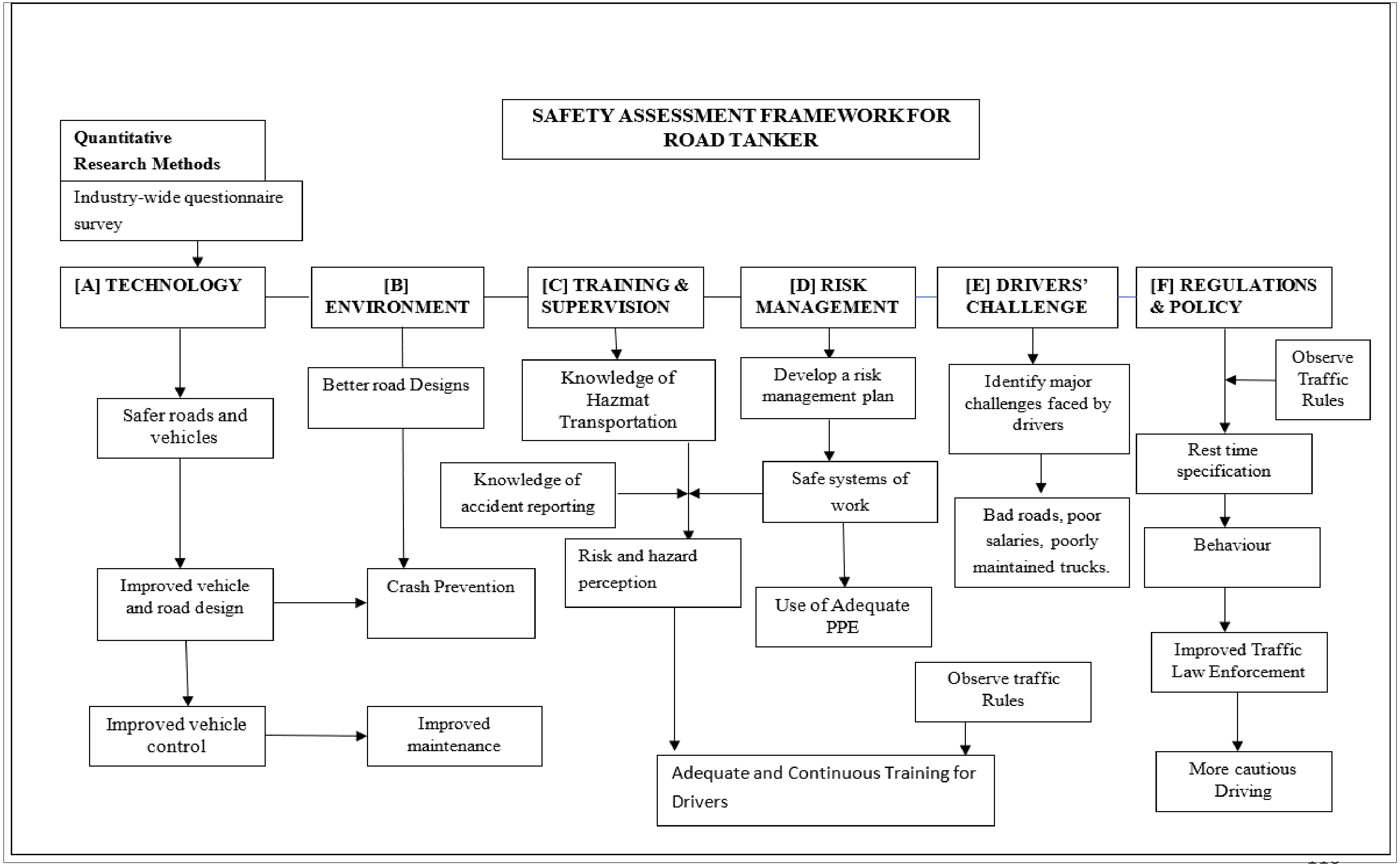



*Figure 19 Conceptual Framework*

Component [**A]** shows how technology can be used to improve road safety in order to mitigate accident during road transportation of petroleum products using tankers. Various studies have shown that technology have an impact in safety of hazardous material transportation. For instance, Advanced vehicle technologies (AVTs) such as forward collision warning (FCW) systems (e.g., Eichelberger and McCartt, 2014; Kusano and Gabler, 2012), lane departure warning system (LDW) (e.g., Navarro et al., 2012) and blind spot detection systems (e.g., Chun et al., 2010) have been framed as a potential strategy to improve road safety (Furlan et al., 2010). AVTs are electronic, in-vehicle systems that can perform or assist drivers in performing various behind-the-wheel tasks for which humans may be prone to error and/or complacency (Furlan et al., 2010).

Component [**B**] of the framework presents how environmental factors can impact road accidents. The impact of severe weather conditions Malin et. al., (2019) and other environmental factors that can impact road accidents can be found in chapter two of this research. Studies on freight-related crashes reveal the impacts of some specific roadway characteristics on freight-related crashes. For instance, Dong et al., (2015) find that freight-related crashes are associated with the horizontal curvature, vertical grade and shoulder of the road design.

Component [**C**] of the framework presents the training and supervision factors. Studies have shown that training could have an impact in accident mitigation (see chapter two). Assailly (2017) described road safety education (RSE) as one of the main strategies of traffic safety, one of the “four E’s”: education, enforcement, engineering, emergency systems. According to the study, teaching road safety is good but the implementation of strategies to improve road safety gives immediate result to mitigate accident. For example, converting a “X” road to a roundabout would increase traffic flow and reduce road congestion, thereby reducing road crashes (Assailly, 2017). Also, education includes both the pre- and post-license training of drivers, as well as the education of the wider public (Mcllroy, 2019). Other factors hinged to training and supervision that would form part of the framework are: knowledge of accident prevention strategies, knowledge of how to respond to emergencies, knowledge of hazards perception, knowledge of safe systems of working, knowledge of accident reporting procedures and the impact of continuous training for tanker drivers.

Component [**D**] presents the risk management and safety aspect of the framework. Various studies have been performed to show the relationship between risk management and road safety. For instance, Zhao et al., (2014) in Li et al., (2019) proposed a systematic framework for risk management of hazmat road transportation, which is consistent with the process of general risk management composed of three steps: risk identification, risk assessment, and risk control.

Component [**E**] of the framework presents the challenges that drivers faced while performing their jobs to ensure petroleum products are distributed across the country. This is part of the investigation of the causes of tanker accidents on the road which stems from findings from literature. The impact of driver's challenges (see chapter 2) such as bad roads, poorly maintained vehicles, drivers' remunerations, lack of adequate technologies, insufficient rest time during travel and outdated trucks have been discussed in chapter 2.

Finally, component [**F**] of the framework presents the regulatory aspect of the framework. This is where the various regulatory policies that promote road safety to reduce the impact of accidents would be integrated into the framework. They include the definition of standards, policies, regulations and incentives. According to Zhigerbayeva and Yang (2021) there is need to develop a systematic approach that can translate the regulatory requirements of HazMat transportation into specified safety measures (both technical and administrative) to support the risk management.

## 3.8 Summary of Chapter Three

In this chapter, the conceptual framework for this study was presented. The aim of this research is to develop a safety assessment framework for the transportation of petroleum product. The framework comprises of six elements related to the transportation of petroleum products. The framework was developed based on the findings from the literature review of this research. The Bow-tie accident causation theory was adopted in the development of the framework because it can combine different risk assessment scenarios and also suggest control measures which makes it a good fit for this research framework. Finally, this chapter concludes with a diagrammatic representation of how the various components of the framework were linked up. In the next chapter, the methodology for this research would be presented.

# 4 RESEARCH METHODOLOGY

## 4.1 Introduction

This chapter outlines the research design and methodology adopted for achieving the aim and objectives of this study. A mixed research method was adopted whereby the qualitative strand consolidates the quantitative one (Creswell, 2009). It first presents the justification for adoption of quantitative and qualitative research approaches, and the reasons behind merging them. The chapter is organised in sections covering the research approach; literature review; types of research approach; questionnaire design; interviews (focus group discussion); data analysis and validation of the research findings. An overview of the research design is shown in *Figure 20* below.

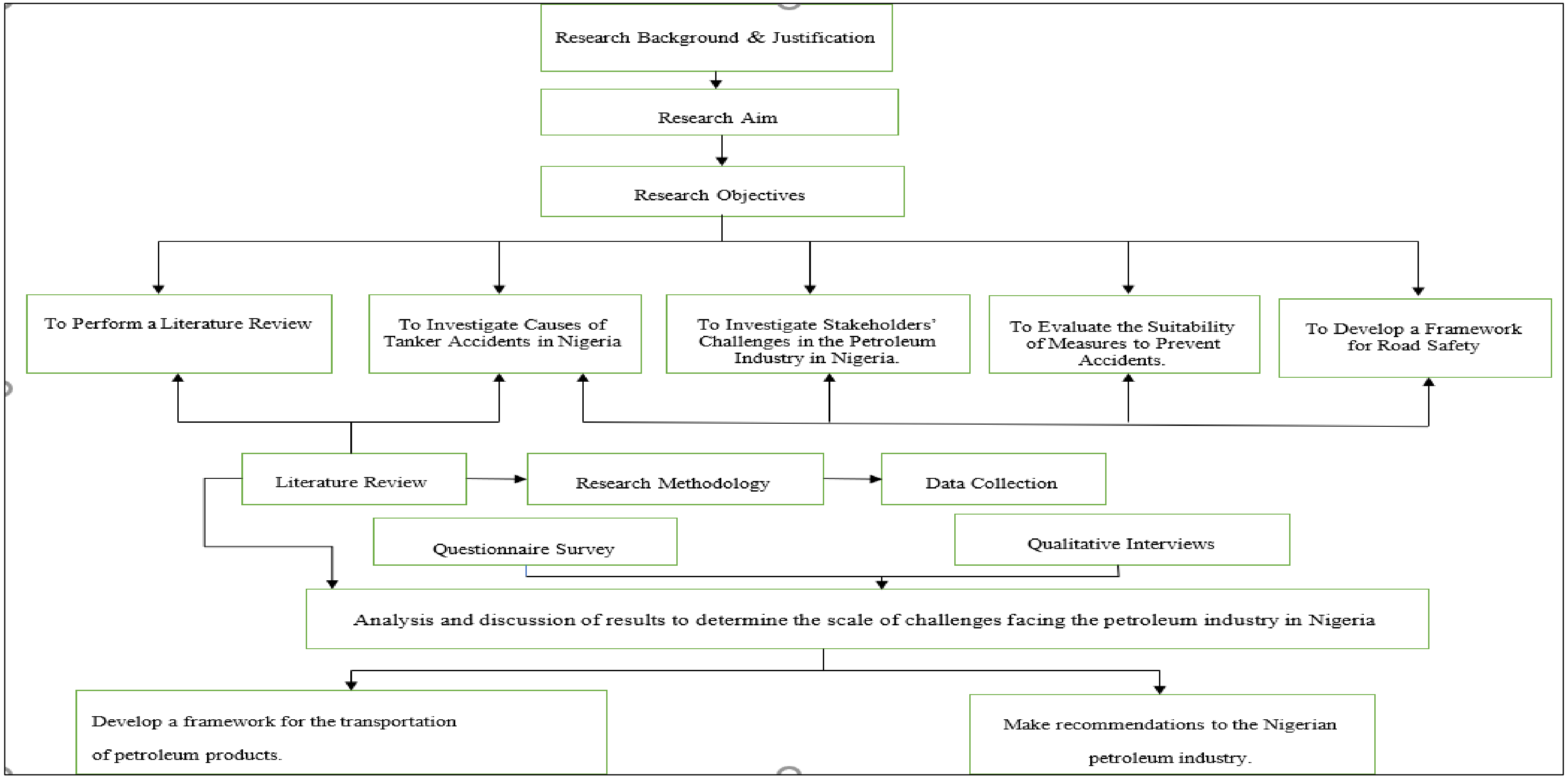



*Figure 20 Overview of the research design*

## 4.2 Research Methodology

This section presents the proposed methodological framework for the research, and explains which research methods were utilized to achieve each of the objectives of the study. According to Fellows (2015), the practical method used for the procedures and the principles for the operation of the scientific research are generally referred to as the research methodology. There is also a substantial body of knowledge concerning research principles, which describes the philosophical prospects, methods, designs and strategies. Bryman and Bell (2015), Creswell (2012), Saunders *et al*., (2012) and Kagioglou et al., (2000) exemplify different kinds of model for conducting social research, and writings by these authors were used to develop the research methodology. Saunders *et al*., (2012) have categorized research into six phases and have presented the model as a research onion as shown in Figure 21. They separated the research into categories incorporating approaches, strategies, philosophies, time horizons, choices, techniques and procedures, and each layer of the onion explains a more comprehensive phase of the research (Saunders *et al*., 2012). This method offers an efficient progression from which the methodology of the research can be designed. Besides this, it provides a logical description of the organization of the research as the strategy of the research and also gives an explanation in a theoretical way about the assumed issues used in the research design. Based on the work of authors, the philosophy phase was started by the researcher, who passed through each of the layers and continued till the layer in which final data collection methods are identified (Saunders *et al*., 2012). It follows that selecting a method for collecting data for any piece of research should be based on research philosophy, approach and strategy.

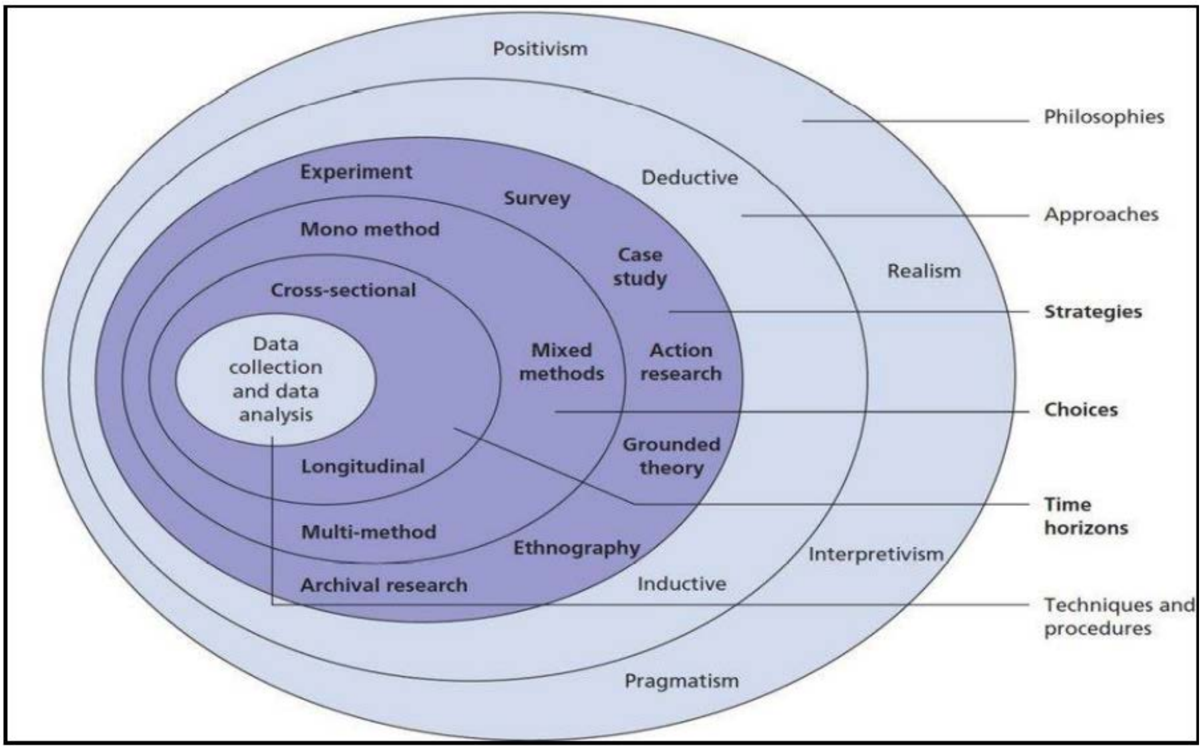



*Figure 21 The research Onion. (Source: Saunders et al., 2012).*

The research onion was found useful for this research due to its adaptability for almost any type of research methodology (Saunders *et al*., 2012; Bryman and Bell, 2015). The remainder of this section discusses the different areas of the research onion, based on the goal of the current research, and showing how these influenced the methodology adopted for this research.

## 4.3 Research Philosophy

A research philosophy refers to the set of beliefs concerning the nature of the reality being investigated (Bryman, 2012). It is the underlying definition of the nature of knowledge. (Bryman and Bell, 2015). It is through the use of assumed issues in a research philosophy that the commencement of the justification and validation of the research is conducted (Flick, 2011). According to Creswell (2012), 'Research Philosophy' refers to the nature and progress of knowledge. For the purposes of this research, it is imperative to understand the nature of knowledge based on the subject being investigated. This helps in ensuring the best approach to achieve the aim of the research being pursued. The choice of research philosophy is defined by the type of knowledge being investigated in the research project (May, 2011). As a result, understanding the researcher's philosophy could be beneficial in the explanation of the matters assumed in the research procedures and the way in which they fit into the methodologies used in the research. There are three popular philosophies of research. These are ontology, epistemology and axiology (Flowers 2009).

### 4.3.1 Ontology

According to Blaikie (2007), ontology is the branch of philosophical science of the study of being. Ontology describes the nature of reality, more especially, an objective reality that really exists, or a subjective reality created in peoples' minds. According to Flowers (2009), there are some deeply embedded ontological assumptions that affect every one's view about reality and whether existence is attributable to one set of things over others. These underlying assumptions would need to be identified and considered in order to protect the study from being blinded to certain aspects of the inquiry or certain phenomena. Thus, ontology is about the reality and how its perception will influence the behaviour of people.

### 4.3.2 Epistemology

Epistemology refers to what constitutes acceptable knowledge in a field of research. It brings out what is acceptable knowledge in the field of research and what information is considered the truth and is regarded as facts after rigorous testing. According to Easterby-Smith, Thorpe and Jackson (2008), epistemology talks about the ways that are most appropriate for enquiring into the nature of the world and what knowledge is, and what are the sources and limits of knowledge. Flowers (2009), opined that epistemology is a philosophy that is most commonly used in scientific research as outcomes, information and facts require to be proved without doubt rather than changeable situations and opinions. Hatch and Cunliffe (2012) summarise epistemology as knowing how you can know, and how is the knowledge generated, what criteria discriminate good knowledge from bad knowledge, and should reality be represented and described.

### 4.3.3 Axiology

Axiology gives the researcher the understanding and recognition of the role their opinion and values can play in the conduct of the research as opposed to eliminating or trying to balance the influence in it. Referring to the research onion model based on Saunders et al (2009) as shown in Figure 21, these three philosophies of ontology, epistemology and axiology have been included in this particular diagram as three additional elements.

## 4.4 Research Paradigms

Denzin and Lincoln (2009) described a research paradigm as an interpretive framework. According to Saunders (2009), a paradigm is a way of examining a social phenomenon from which particular understandings of these phenomena can be gained and explanations attempted. Key research paradigms are contained in layer one of the research onions in Figure 21 and are discussed in the subsequent subsections.

### 4.4.1 Positivism

Positivism regards science as constituting a collection of facts, with the role of theory restricted to the organization of these facts into a logically coherent system from which new facts can be deduced or predicted (Heather, 1996). Furthermore, positivism builds on advocating natural science methods as the only way to study the world (Arbnor and Bjerke, 2009), including the study of social science (Bryman and Bell, 2015). Bryman and Bell summarize the positivism principles as the principle of phenomenalism, the principle of deductivism, the principle of inductivism, and objective research procedures (Bryman and Bell, 2015). Saunders *et al*., (2012) support these principles and explain that the positivist researcher would most likely deal with a social reality confirmed by senses, create hypotheses based on existing theory, and then test those hypotheses using statistical analysis that leads to "law-like generalizations". Saunders *et al*., (2012), also mention that positivism advocates objective research processes. This objectivity can be regarded as an advantage of positivism. Besides, positivism usually leads to a highly structured methodology and standardized observations to facilitate replication (Gill and Johansson, 2010). As some scholars (e.g., Hogan and Sinclair, 1996) argue, the replication possibility is an advantage of positivism that allows the validity of the research findings to be checked (Gill and Johansson, 2010). According to Brand (2009), the system of belief which arises from the practices in the natural sciences assumes that issues which are the subject of research are likely to be studied objectively and so their reliability can be recognized with a practical degree of certainty. This way of thinking is referred to as positivism and is consistent with the thoughts from Saunders *et al*, (2012), where it is plausible to investigate the social sciences in a corresponding way to that of natural science: in other words, the views and opinions of the researcher are eliminated in the research, so it is also referred to as a value-free way.

### 4.4.2 Interpretivism

According to Bryman and Bell (2015), interpretivism is an alternative to positivism. They explain that the study of people and their institutions is different from natural science and demands a kind of logic to explain the distinctiveness of human beings. Interpretivism argues that the social worlds of business and management are more complex to put them in generalized principles like physical science. Interpretation is shaped according to the researcher's set of meanings that he or she gives to the world. Furthermore, some authors claim that the interpretivism perspective is most appropriate in social science research (Saunders et al., 2012), and it is often related to qualitative research (Bryman and Bell 2015). However, in comparison to positivism, interpretivism considers idealism and relativist positions in relation to ontological and epistemological conventions. Reality is viewed by interpretivism as socially built (Saunders *et al*., 2012) and hence is also referred to as social constructivism. The interpretivist view is that people determine reality and it is not generally obtained from external or objective factors (Easterby-Smith *et al*., 2002). The interpretations of people will affect their actions when they put themselves in distressed situations. According to social constructivism, people use disparate constructions and interpretations, based on their experience, due to their interaction with the environment through which situations are analysed and interpreted (Saunders *et al*., 2012; Easterby-Smith *et al*., 2002). In this research, it was necessary to determine which perspective, interpretivism or positivism, would help to investigate the development of the safety assessment framework (SAF) to aid road safety in the downstream petroleum industry in Nigeria. The nature of the subject, however, presents both objective and subjective approaches. Also, the idea of SAF as a game changer can be objectively deduced based on its impact, there is subjectivity regarding the advantages of SAF and the likelihood of it being implemented in the Nigerian downstream petroleum industry.

### 4.4.3 Constructivism

Constructivism means the construction of social phenomena by actors in the social arena. This philosophy believes that reality is not objective and exterior, but socially constructed by people.

It is founded on what people belief and therefore develops around the experience of people. Constructivism also relies on fundamental laws to explain social phenomena.

### 4.4.4 Objectivism

Objectivism is the opposite of constructivism and its arguments are that social phenomena and their existence is separate from the influence of social actors. This is one of the aspects of 102 ontology that supports the position that, social entities exist in reality, external to social actors concerned with their existence.

### 4.4.5 Realism

Realism has similarities with positivism in its process and in its belief, that social reality and the researcher are independent of each other and so will not create biased results. Their difference is that realism believes that scientific methods are not perfect. It is also the belief in realism that theory can be revisited and revised and that our ability to know reality is possible with new research approached from new research methods.

### 4.4.6 Pragmatism

Pragmatists are of the opinion that both constructivist and objectivists are valid approaches to research. Pragmatism enables the researcher to approach research from the two viewpoints either on the influence or on actions of the social actors and utilise these to develop an approach, which is practical to research. According to Saunders *et al* (2009), the pragmatism argument is that the most important determinant of the research philosophy adopted is the research question, as one research may be more suitable than the other in answering the research questions. Where the research question is not specific on either to use positivist or interpretivist, then the pragmatist view that it is perfectly possible to use both philosophies is acceptable.

Tashakori and Teddlie (2010) are of the opinion that it is more appropriate to think of the philosophy adopted as a continuum rather than opposite positions. They further explained that it is better for the researcher to study what interests him and is of value to him, and to study the subject matter in the different ways he considers appropriate, and also to use the results in the best ways he considers would bring about positive results to the value system (Tshakkori and Teddlie, 2010). Having reviewed the philosophies of research, positivism has been identified as the appropriate research philosophy for this study which is to develop a safety framework for the transportation of petroleum products for the downstream petroleum industry in Nigeria. A mixed design approach may also be used in research (Robson, 2002), as it makes use of two or more methods, and could yield both quantitative and qualitative data. The quantitative research method gathers information for comparison with one another. The use of such methods is reasonable for developing quantifiable and comprehensible outcomes (Bell, 2009). Thus, one of the techniques of data collection that is regarded as significant is the quantitative method. Further, the collection and analysis of quantitative data are done through other common methods which involve statistics and survey techniques.

## 4.5 Research Approach

The deductive approach and inductive approach are both used in research work. Easterby-Smith *et al.*, (2002) elucidate that positivist research is more inclined towards a deductive approach, whereas interpretivist research favours the inductive one. As mentioned, these approaches have also led to the two traditional methodologies: quantitative methodology, which is aligned more with positivism, and qualitative methodology, which is more associated with interpretivism. The research adopted a mixed method approach and an exploratory sequential research design. This means that the main aspect of the research is quantitative with a supporting qualitative aspect.

### 4.5.1 Deductive Approach

Deductive means the researcher will start with a statement or question and the research will set out to provide answers to the question or statement. 104 According to Saunders *et al*. (2009,) deduction is largely suited to scientific research. It involves the development of a theory that is subjected to rigorous scientific test. The thought process of deduction runs from theory to the research question, to data collection, to findings that will lead to rejection or confirmation of the research question or statement. The deductive research method is the approach, which seeks to develop a theory and hypothesis with a research design to test the hypothesis (Saunders *et al*, 2009).

### 4.5.2 Inductive Approach

Induction means finding over knowledge that can be used to create a theory. The process moves in the opposite direction to the deductive approach taking its focus from the research title and not from existing theory. This means the research move from research question, to observation and description to analysis and final theory. Saunders et al (2008) have however, suggested that it is advantageous to combine deduction and induction approaches in the same piece of research. The qualitative research approach entails inductive orientation as well as an exploration of comprehensive social and human challenges where information is collected from the participants in their natural environment by the use of evolving flexible queries and the process involved (Creswell, 2012). However, there are many designs, such as ethnography, phenomenology, grounded theory, narrative and case study (Creswell, 2012).

## 4.6 Research Strategies

Layer 3 of the research onion presents the various research strategies in use. These are choices, which need to be made to collect and analyse the data. Different strategies may be associated with different philosophies. The researcher may choose more than one strategy to design and collect data so long as this is needed and is justifiable.

### 4.6.1 Experiment

Experimental research design emanated from natural sciences but is now used in social and management science. Experimental design is very rigid and scientific in its structure and largely used to test cause and effect relationships. Experimental strategies generate data suitable for statistical analysis and they have been used in exploratory and explanatory types of research to explain how and why questions (Saunders *et al*., 2009).

### 4.6.2 Survey

The goal of survey research is to acquire information about the characteristics, behaviour and attitudes of a population by administering a standardized questionnaire or survey to a sample of individual (Babbie, 1990). Also, Babbie (1990) explained that, the survey research has the ability to provide the researcher with a quantitative explanation of events, trends, attitudes, behaviours or opinions of a certain population by investigating a sample of that population. A survey strategy also makes it easy for the researcher to collect data that are both qualitative and quantitative in nature and which can be analysed using statistical tools like descriptive statistics and inferential techniques. In addition, data collected using a survey strategy can be used to establish and explain relationships between variables and to develop models of these relationships. A survey strategy makes it possible to collect data using sampling and make findings that are representative, which can be used to make generalisation. Surveys strategies are a good way of collecting a large amount of data, providing a broad perspective. Surveys may be electronically administered or by telephone or through an e-mail or by face to face. In developing countries like Nigeria where government data sources are often out of date and of poor quality, questionnaire surveys are a primary means of collecting data on people and their characteristics. In this study, a survey strategy is used to collect data from respondents using questionnaires and interview methods.

### 4.6.3 Case Study

The case study design is an extensive study of one or more individuals, groups or cases in a real-life scenario. Stake (1995), explained that case studies' strategy of research is where the researcher explores a programme, event, activity, process or one or more individuals in depth. He explained further that the cases being studied are bounded by time and activity, and the researchers collect over a period of time detailed information using a variety of data collection techniques. However, Saunders *et al*. (2009) are of the view that a case study strategy has an unscientific feel, though the strategy can be useful when exploring existing theory. In addition, a well-planned case study strategy gives the researcher the room to explore an existing theory and also provide him with options to develop new research question.

### 4.6.4 Action Research

Action research is about addressing issues to find solutions. To research a solution to a problem, action research is a strategy that allows the researcher to be part of the organisation, system or case study that requires that particular solution. Specific data to be collected may include watching aspects of the participants' behaviour or their setting, interviews with participants and record searching.

### 4.6.5 Grounded Theory

Grounded theory is a strategy of research that enables the researcher to derive a general, abstract theory of a process, action, or interaction grounded in the views of the participants. It uses inductive methods to make prediction and explanation of behaviour to develop theory. The process begins with data collection by means of observation methods, making theory and prediction from that data and then testing the predictions made. Though grounded theory is a strategy that generates new theory, it is still however grounded by existing theory and literature on the topic.

### 4.6.6 Ethnography

Ethnography has its roots in anthropology. According to Cresswell (2007), ethnography is a research strategy where the researcher observed a cultural group that is intact in a natural setting over a long period of time by basically collecting data through observation and interview. The researcher using this strategy will be required to be part of the community or situation he is studying. Saunders *et al*. (2009) explained that this strategy has disadvantage of time consumption and may take place over an extended time period as the researcher needs to immerse himself in a social world being researched as completely as possible.

### 4.6.7 Archival Research

This strategy is about making use of administrative records and documents as sources of data. According to Saunders *et al*. (2009), the archival research strategy address research questions focusing upon the past and the changes that happen over time to be, be they descriptive, explanatory or exploratory. However, the accuracy and breadth of the data available may be an issue for research relying on archival strategy. The nature of the administrative records will however determine whether the use of the strategy will be able to answer the research questions. This research on the cost of heavy goods vehicles accidents and its impact on the Nigerian economy is designed to make use of survey as its research strategy in view of the fact that it needs to collect data from the field and would have to sample the population to obtain a representative result.

### 4.6.8 Time Horizons

This is represented in layer five of our research onion. There are only two-time horizon choices, cross-sectional and longitudinal. Cross-sectional is research done within a short time while longitudinal is research carried out over a longer period.

Longitudinal study Longitudinal study is an event over a long period, associated with constructionist research (Easterby-Smith *et al*., 2012). Longitudinal designs can also use qualitative and quantitative research but they study events and behaviours using concentrated samples over a longer period.

### 4.6.9 Cross-sectional Study

According to Saunders et al. (2009), cross-sectional study is an event at a particular period of time. Cross-sectional study can use qualitative and quantitative research choices and is a study that measures an aspect of behaviour of many groups or individuals and at a single point in time. Cross-sectional studies often employ the survey strategy Easterby-Smith *et al*. (2012).

## 4.7 Research Design Selected to Develop SAF for the Transportation of Petroleum Products in Nigeria.

From the discussions carried out in Sections 4.3 and 4.4, an appropriate design has been adopted for this research. Denzin and Lincoln (2011) suggest that design in research provides the directions for linking the elements of the methodology adopted for an investigation in association with the model to the strategy of the research, and then linking the strategy to the approaches for the collection of pragmatic data. Based on this, Creswell (2012) advises that the research design should link the research questions, the data collected and the results. After the review of research philosophies and approaches, this section presents the design adopted for this research and provides a justification for how it can help to ensure this research leads to reliable results.

### 4.7.1 Philosophical Stance

According to Creswell (2012), for any investigative research whose main objective is to find the factors or variables which impacts the result of determining the causes, the positivist approach is adequate. There is an extensive body of knowledge in the transportation of hazardous materials from a global context, however, there is little or no empirical evidences of safety assessment frameworks that would aid the transportation of hazmat in Nigeria especially in the petroleum industry transport sector. This suggests that the identified relationships may not be exhaustive enough or some do not actually exist, as such, there is need for exploration to fully ascertain the relationships. This has led to the need for an interpretivist look at the development of a safety framework for the Nigerian petroleum industry. The goal of this research is to develop a safety assessment framework for the transportation of petroleum products in the Nigeria petroleum industry, which has an impact on accident mitigations and improvement of road safety, as such, this study has adopted a positivist paradigm to underpin the research. In this research, there was a need, therefore, to test for the knowledge and benefits of the safety framework in Nigeria based on what has been studied elsewhere, and this can be done through a mixed research method to gather views on the factors and contexts specific to Nigeria that may impact the petroleum industry. There are instances where a researcher may combine different perspectives or rational opinions based on the nature of the problem to be studied (Creswell, 2012; Felizer, 2010). For this reason, this research has adopted a pragmatic approach (Creswell, 2020).

One of the major goals of adopting a pragmatic approach in the present research is to obtain valid and reliable knowledge as a set of universal principles that can explain, predict and control human behaviour across the target sample. Thus, the pragmatic approach enables the researcher to take a controlled and structural approach to conduct the research by initially identifying a research topic, constructing appropriate research questions, adopting a suitable research approach, collecting data, and analysing and interpreting the relationships between the variables (Denzin and Lincoln, 2011).

## 4.8 Research Approaches

In order to find the appropriate study approach, different approaches are used, such as deductive and inductive research, which are developed from epistemological or theory applications, as well as the type of questions asked by the researchers. Considering the epistemological positions discussed in Section 4.3.2 as well as the research questions presented in Chapter 1, this research has taken a mixed approach to the study, which aligns with the deductive approach that was taken to investigate the challenges faced by the downstream petroleum supply chain network in Nigeria. As the research study investigates the causes of tanker accidents in Nigeria as well as the identification of problems faced by the downstream petroleum sector, the quantitative approach has been used in order to provide a clear insight into the study. As presented in Saunders *et al*., (2012), the deductive method can be used to answer queries relating to who, what, when, where, how, how much, and how many. For instance, it helped it answering the research question “What are the causes of tanker accidents in Nigeria during the transportation of petroleum products?” On the other hand, some aspects of the research demanded an inductive approach, so as to be able to understand the reason for the current state of the Nigeria petroleum supply chain using road tankers. This required the use of qualitative approaches which were aligned with the interpretivist perspective. As Yin (2013) suggests, the qualitative approach helps to answer questions about ‘how’ and ‘why’ by delving deeper into the issues being investigated. This helps to bring different views (multiple realities) of the problem, thus enabling a better comprehension of the issues. For instance, it helped in finding the strategies to adopt in answering to the research question “How could the petroleum industry benefit from the implementation of a safety assessment framework?”. This research, therefore, took a varied methodological approach uniting aspects of both qualitative and quantitative research.

## 4.9 Research Methods

After deciding the approach to be adopted, the researcher was faced with different options of methods based on the approach adopted. Research methods were selected to provide the types of collection of information, analysis and interpretation for developing the results of the research. Saunders *et al*., (2012) suggest that research methods are ‘research strategies or the tools employed to conduct the research. These include experiments, surveys, case studies, and interviews (Saunders *et al*., 2012). According to Moody (2007), the success of any study depends on the methods selected to gather data. Each method presents a set of pros and cons which are related to the research approach adopted. The survey research method is known to be especially applicable where opinions relating to facts are sought (Descombe, 2007). Interviews, on the other hand, are used to gather in-depth information on a phenomenon, while case studies are adopted when a phenomenon is to be studied in its real-life context (Cohen et al., 2000; Yin, 2013). As this research took a pragmatic approach by making use of both quantitative and qualitative methods, different methods were adopted, with the main two being a survey by means of questionnaires, and interviews, as discussed below.

### 4.9.1 Questionnaire Survey

A questionnaire survey was undertaken as according to Denscombe, (2007), this allows to determine information such as opinions and perspectives from the participants in addition, to answering “Who”, “What”, “Where”, “How many”, and “How much” types of questions. One of the effective ways of gathering a large amount of quantitative information is through a questionnaire. This can be given to any individual at any time, and one does not need to investigate when the participants answer the questions. Questionnaires may be utilized in various ways such as by telephone, e-mail, internet, or face-to-face interview (De Vaus, 2002; Naoum, 2008). Cautiously structured questions, which are selected after careful consideration, can only be compiled after the literature review as the questions should be linked and correlate with the findings of the literature. The major objective of the questionnaire is to obtain reliable responses from a chosen sample, with the aim of finding out what a selected group of participants do, think or feel (Collis and Hussey, 2009). Considering the strengths of this method, the questionnaire was used to gather facts on the major contributory factors to tanker accidents in Nigeria and the challenges faced by tanker drivers during the transportation of petroleum products using road tankers. Gaining this information required the views of a good number of professionals in the industry to ensure a representative answer was gained. Certain precautionary measures were taken when designing the questionnaires. The questions were designed in a way that would be comprehensible to the respondents. As McQueen and Knussen, (2012), emphasizes the questions must be clear and easily understood by the respondents. It should be easy to administer so that the recorded answers can be easily edited, coded and transferred onto a computer file for statistical analysis. Also, its flow, length and structure must motivate respondents to complete the questionnaire.

#### 4.9.1.1 Design of the Questionnaire

A questionnaire may incorporate open-ended questions along with close-ended questions with a scheduled group of answers for the participants to select from (Fellows and Liu, 2009). Numerical responses can be obtained from the use of closed questions, thereby providing an opportunity to use descriptive or inferential statistical analysis, while the open-ended questions allow the researcher to review further and discover a richer meaning to the responses of the closed questions. The use of a questionnaire enabled primary data to be collected from petroleum tanker drivers in Nigeria with a view of investigating the challenges faced by tanker transportation of petroleum products. Utmost care was taken to ensure that the questions were organized in a similar manner. The design of a good questionnaire is vital in achieving a successful response rate. In order to achieve this, a piloting process was first undertaken. The questionnaire was designed based on the research aim and objectives. The issues were also obtained from the literature review. The questionnaire consists of 6 parts. The first part consists of three questions which requested information about drivers' perception of technology, the second part focuses on drivers challenges during the transportation of petroleum products in Nigeria and it consist of three questions, the third part consist of three questions on risk management and safety, the fourth part consist of three questions on environmental factors, the fifth part consist of three questions that focuses on regulations and policies while the sixth part consist of 4 questions that focusses on training. In the design of the questions, some of the questions adopted the Likert scale to ensure that the answer options provided variations for the respondents. For example, questions on the level of agreement and concerns were designed to not just provide a yes or no answer, as according to Johns (2010) this greater flexibility provides the advantage of capturing different levels and views on the Likert scale. The answer options ranged between two extremes, from 'completely disagree/not at all concerned' to 'completely agree/extremely concerned'. Between these extremes, respondents were able to select their level from minimal agreement to a high level of agreement. The answer options were carefully chosen so as to be simple for respondents to understand and relate to. The questionnaire was designed and written in English. However, most of the participants cannot read and therefore, the questionnaire was read to them and explained clearly to ensure they fully understood the questions. A draft of the questionnaire for this research is attached to this thesis as appendix 1.

### 4.9.2 Interviews

An interview is an appropriate way of collecting weighty and in-depth information and views relevant to the issue being investigated (Denscombe, 2010). Participants were asked a range of designed questions by the interviewer in relation to the research in order to collect answers that would be relevant to the goal of the research (Bailey, 2007). A face-to-face interview is necessary where interpersonal contact is important for describing the situation, and so the information of the respondent is acknowledged (De Vaus, 2002). Adopting interviews as a method of data collection has several benefits. It provides an opportunity for better communication between the participant and the interviewer, providing better control of the process of the interview (Naoum 2008). Furthermore, there is also a higher chance of obtaining detailed and in-depth information that is of high quality. Other advantages are in the accuracy of the answers, speed, and high response rate, flexibility to reframe the questions and give the researcher chance to seek further clarification of the issues and obtain more details (Naoum 2013). There are three forms of interviews: unstructured, structured and semi-structured (Bailey, 2007). The unstructured interview corresponds to a conversation directly related to the research where the interviewee is allowed to develop ideas and follow their sequence of thought, whereas in a structured interview, questions are provided to different interviewees in a similar order and in similar wording in a strictly controlled format of questions and answers (Silverman, 2003). In fact, it is like a questionnaire being used in a face-to-face interview (Denscombe, 2007). However, in a semi-structured interview, there is more flexibility with respect to the order in which questions are responded to. It also provides the respondents with the opportunity to form ideas and speak clearly about them. Therefore, semi-structured interviews were adopted in conducting the present research. The adoption of interviews as a data collection method helped to gain further insight into the challenges of petroleum product transportation in Nigeria. Some investigation in the study required in-depth knowledge and analysis of the questions, and the semi-structured interview provided the best means to gather this information. A draft of the semi-structured interview questions is attached to this thesis as appendix 2. The next section discusses how data was collected for this research, based on the chosen methods.

## 4.10 Data Collection

Saunders *et al*., (2012) regard the data collection and analysis as the most important aspect of the research undertaking. This is illustrated and explained in this section of the research.

### 4.10.1 Ethical Considerations

It can be said that this is the most important aspect of field research (Bailey, 2007). Ethical considerations are crucial for protecting the participants as well as their organizations. They also improve the quality of research and can defend it from any improperness (Creswell, 2012; Farell, 2011). Ethical issues were given great importance in conducting this research, in terms of the selected topic, data collection process and analysis. The research was carried out in such a manner that the confidentiality and integrity of participants were respected and valued. The objectives of the research were openly stated to the participants, and it was ensured that they were doing it on a voluntary basis. The participants were also assured that the data provided by them would remain secured all through the process of data analysis and would be destroyed at the end of the research. The participants were also informed that they have the right to withdraw from the research at any time without explanation. The participants were also told that their withdrawal from the study does not attract any penalty. Participants did not receive any payment for participating in the study. The questions were designed in such a manner that they were free from any threat or any kind of misguidance or deception. Prior to contacting any of the participants, ethical approval was obtained from Wolverhampton University's School of Architecture and Built Environment Ethics Committee.

### 4.10.2 Sampling Types

The method by which individuals from a group of people are selected to take part in the collection of data during the research is known as sampling (Saunders *et al*., 2012). There are two methods of sampling for the purposes of research:

- Probability or representative sampling – whereby each sample has the chance of being selected randomly.

- Non-probability or judgmental sampling – whereby generalization is not significant, and each sample does not have the chance of being selected randomly.

#### 4.10.2.1 Probability Sampling Methods

In probability sampling methods, every item of the population has an equal chance of inclusion in the sample, thus each population element has a known (non-zero) chance of being chosen (Henry, 1990). This equal chance helps to eliminate the danger of researchers being biased in the selection process because of their own desires or opinions. Bias must be eliminated before the results of the research can be generalised from the sample to the whole of the population since the sample represents the population (Frey *et al.,* 2000). There are four common types of probability sampling techniques (Latham 2007). These are simple random sampling, systematic random sampling, stratified random sampling and cluster random sampling.

#### 4.10.2.2 Non- Probability Sampling

If the goal of the research requires an alternative way of choosing the sample, then non probability sampling techniques are utilized (Saunders *et al*., 2012). Saunders *et al*. (2012) explain that non-probability sampling consists of purpose sampling as one of the strategies. Such sampling is conducted when generalization is not significant, and it is not plausible to select a sample randomly. Bryman and Bell (2015) divide non-probability sampling into four different types:

1. Quota Sampling - Whereby the aim to represent the major characteristics of the population by sampling a proportional amount of each respondent. It is easier to organize and more reliable as compare to random sampling.

2. Convenience Sampling - Whereby any subjects are selected because of their convenient accessibility and proximity to the researcher. They are not representative of the entire population.

3. Snowball Sampling - This is usually carried out when there is a very small population size. Whereby research participants recruit other participants for who also meets the criteria of the research. It is used where potential participants are hard to find for the study and allows for studies to take place where otherwise it might be impossible to conduct because of a lack of participants.

4. Purposive Sampling - The main objective of a purposive sample is to produce a sample that can be logically assumed to be representative of the population. This is often accomplished by applying expert knowledge of the population to select in a non-random manner a sample of elements that represents a cross-section of the population (Bryman and Bell 2015).

The procedure and design of sampling are very significant for the design of the research. As a result, in the context of this research ‘Probability Sampling’ using Simple Random Sampling is proposed to be used to select participants for the research. The reasoning for this is to target a large number of participants with the required skill set, so as to acquire a significant response that will enable swift and focal data collection. For this research, a convenience non-probabilistic sampling approach was adopted to choose the depots where the questionnaires were distributed and then a probabilistic approach to choose the drivers in in the depot. For the purposes of the interview, however, a non-probabilistic sampling method was used where different professionals were purposely selected for the interview using purposive sampling approach.

### 4.10.3 Quantitative Data Collection Through Questionnaires

The quantitative data was collected using questionnaires. This section discusses the sampling technique found to be suitable in collecting the quantitative data; how the questionnaire was piloted and improved; the channels used in distributing the questionnaires; and the sampling size used in conducting the research.

#### 4.10.3.1 Sampling Technique Adopted

Sampling is the technique by which units from a population are chosen to participate in the data collection phase of a research (Saunders *et al*., 2009). Hence, for the context of this research, the simple random sampling technique using a probabilistic sampling method was used to select the research participants (tanker drivers). Considering the goals of this research, the sample population used for the quantitative survey were petroleum tanker drivers. The aim was to have an even distribution that would be representative of the population. The depot is a very good channel of reaching out to the population. Tanker drivers were chosen because they are the drivers of the vehicles used in transporting petroleum products and as such, they are the first point of contact with regards to accidents involving petroleum products transportation.

## 4.11 Tankers Drivers

Tanker drivers are a group of people who are responsible for piloting trucks loaded with petroleum products in Nigeria. This group of workers are identified and targeted for sampling bearing in mind the fact that they are the potential victims of any accident case involving their vehicles. They are therefore in the best position to provide first hand and reliable information about the accidents they get involved in and also provide reliable information about their occupation. This group of workers always gather at the depot waiting for their trucks to be loaded with products for onward delivering to retail station across the country. For this reason, the researcher decided to meet with them in the early hours of the morning after seeking consent from the depot managers. The researcher employed two research assistants to help with the distribution of the questionnaires as the depots were in different locations. The research assistants were introduced to the depot managers to enable them carryout their task smoothly. The research assistants understood the importance of the survey as they were university students on holiday who took the opportunity to earn some extra income.

## 4.12 Sampling Tanker Drivers

Using the correct sample size is very crucial for the success of this study. A sample that is too big will cause the waste of resources like time and money. A sample that is too small is also likely to prevent the researcher from gaining reliable insights. The size of a sample therefore depends on how accurate the researcher wants the survey data to be, or how closely the research results are required to match those of the entire population. According to Saunders et al (2009), the choice of a sample size is governed by the confidence level, the margin of error that can be tolerated, and the types of analysis techniques and the size of the total population from which sample is drawn. The population of truck drivers on Nigerian roads is estimated to be about 70,000 (FRSC, 2011). There is an estimate of 5,000 tankers involved in wet cargo haulage, to move about 150 million litres of fuel on Nigeria roads daily (Obasanjo et., al 2014). Technically, an estimated 5000 tanker drivers transport hazardous petroleum products daily along Nigeria roads. In determining a representative sample from the estimated total population of tanker drivers in 2017, the adoption of a formula for determining sample size from Yomens (2000) was used. The formula is given as follows.

$$SS = \frac{N}{1+N(e)2} \qquad \textit{Equation 1}$$

Where SS is the sample size, $N$ is the population size and $e$ is the tolerable error in investigating the population. This is based on the summation by Saunders et al. (2009), which puts the 95% best margin of error under such circumstance.

Therefore,

$$SS = \frac{5000}{1+5000(0.05)2} = 370.4 \qquad \textit{Equation 2}$$

Hence, 370 questionnaires were to be administered in the survey based on the sample size as shown in Equation 2, but to take care of unreturned, no response and achieve good response rate, 400 questionnaires were distributed. See (Appendix 1) for the detailed drivers' questionnaire. At the end of the survey, all the questionnaires from the 3 depots were collated and 268 questionnaires were returned representing 67% of the total questionnaires distributed. The researcher then took time to check the returned questionnaires one after the other and found that out of the 268 returned, only 170 questionnaires representing 42.5% are the ones that qualified for the analysis, hence 170 questionnaires were used for this research analysis. The remaining 230 representing 57.5% were discarded because some of them were not completed at all while some were half completed and cannot be used for analysis. In a similar study, Fizal et al., (2019) administered 70 questionnaires to tanker drivers for an assessment of chemical hazard awareness. The questionnaires covered several sections to gather data on the duration of exposure to chemicals, the driver’s lifestyle or health awareness and knowledge level regarding chemical hazard. The measurement of the questionnaire was based on Linkert scale, where the scale was based on a rating score of 1-5.

*Table 7 Distribution of Questionnaires at oil depots in Nigeria.*

| Depot | Number of questionnaires distributed | Number of questionnaires completed | Percentage of questionnaires completed (%) |
|---|---|---|---|
| **Mosimi** | 150 | 70 | 41.17 % |
| **Kaduna** | 150 | 56 | 32.94 % |
| **Benin** | 100 | 44 | 25.88 % |
| **Total** | 400 | 170 | 100% |

## 4.13 Qualitative Data Collection Through Interviews

According to Merriam (2009), qualitative research methods are the ideal methods to extract information based on knowledge and experience. Qualitative research derives meaning expressed through words, collected non-standardized data requiring classification and conducts analysis through conceptualization (Saunders *et al*., 2012). Hence to achieve the research objective, interviews were conducted to investigate the problems facing the transportation of petroleum products in Nigeria in order to develop a safety framework to mitigate accident and promote safety during products transportation using tankers. The participants used for this research are different from the tanker drivers with different subjective views. One advantage of the qualitative data collection through the use of interviews was that it allowed the participants to express their opinions in their own way and explain their own experience in relation to the problems facing the downstream transportation of petroleum products in Nigeria.

In turn, this allowed for the construction of valid explanations and conceptualizations from the details provided.

### 4.13.1 The Interview Design

By referring to the standard best practice guidelines as recommended by Bryman (2012), the starting point for the design of the interview questions was based on findings from the critical review of the literature with respect to the research aim and objectives. Thus, the semi structured interview questions were carefully designed to elicit the interviewees' ideas and opinions on the topic of interest. In the first instance, interviewees were asked the nature of their job, their experience on the job and the position they hold in their organisations. The questions are grouped into the following categories:

- Drivers Challenges- 2 questions
- Technology – 3 questions
- Risk Management and Safety – 3 questions
- Environment – 1 question
- Regulations – 3 questions
- Training and supervision – 3 questions
- Safety assessment framework - 1

In all, 23 participants answered the 15 questions asked during the interview in order to investigate the problems facing the transport sector of the oil and gas industry in Nigeria. In the questionnaire survey, the questions were asked under the same theme as the qualitative. The reason for the qualitative is to get the opinion of non-drivers to complement the result of the quantitative survey to enhance the reliability and credibility of this research.

### 4.13.2 The Sampling Process

23 participants were selected for the semi-structured interview. They all have experience and knowledge in the downstream sector of the oil and gas industry in areas such as depot management, health and safety and petrol station management. Also, participants were drawn from the FRSC, DPR, NNPC/PPMC, IPMAN, MOMAN, NOSDRA and NEMA. According to Sbaraini et al. (2011) purposive sampling (a non-probability sampling technique, also known as initial sampling) is one of the vital characteristics of a qualitative study. In addition to this they also mention that the purposive sampling should be adopted in selecting those particular samples who are the best few persons to explain the basic concerns of the study. Accordingly, the sampling of the interview participants for this research has taken this into consideration. Moreover, the interview participants were selected from a group of professionals who understand what research of this nature is about. All the participants were anonymised in this research due to ethical considerations. As suggested by Groenewald (2004), participants were selected who have knowledge of the research topic.

## 4.14 Data Analysis

The categorization, examination, tabulation, testing or combination of both quantitative and qualitative results for addressing the original proposals of the investigation are referred as the procedure of data analysis (Yin, 2013). The analysis of the collected data was carried out in a reliable manner which was coherent with the collection procedures and kind of data collected. This section offers a brief description of procedures used in the analysis of the data collected for the research.

### 4.14.1 Quantitative Data Analysis

Saunders et al., (2012), indicate that the main purpose of quantitative data is to derive meanings from numbers, resulting from numerical and standardized data and that the data must be analysed through diagrams and statistics. Saunders et al., (2012), also suggest that numerical data from surveys can be analysed using ‘Descriptive’ or ‘Inferential’ statistics. The descriptive statistics produces an expressive analysis of the questionnaire survey data collected; this could be conducted by different approaches such as mean, average and mode. Descriptive statistics are used to describe the central tendency of the data as well as describe the dispersion of the data from the central tendency (Denscombe, 2007). While the inferential statistics are conducted through probability and correlational statistics. Inferential statistics allow the data to be tested for strength and significance of relationships between variables (Saunders et al., 2012). The hard copies of the questionnaires were coded so they can be accepted by the SPSS software for data analysis. For this research, the methods used in the analysis of data included descriptive statistics, inferential statistics, Kruskal Wallis H test, Kendall’s W test and the Spearman’s Ranked Order Correlation in SPSS.

The Spearman ranked order correlation is a statistical measure of the direction and strength of the monotonic between two continuous variables. It is the non- parametric alternative of Pearson correlation and it is used when your data have violated the assumption of Pearson.

### 4.14.2 Kruskal Wallis H Test

The Kruskal-Wallis’s test is a version of the independent measures (one-way) ANOVA that can be performed on ordinal (ranked) data. It is a non-parametric method used for testing whether samples originate from the same distribution. Kruskal-Wallis is used for comparing two or more samples that are independent and that may also have different sample sizes.

The researcher has chosen the Kruskal-Wallis's non-parametric test due to the following reasons:

- Samples were collected from three different oil depots.
- The groups are independent of one another.
- The independent group have different sample sizes.

As shown in Table 8 below, the Kruskal-Walli's test significant level is set at **.050**. The null hypothesis is retained if the p-value is greater than 0.05, otherwise, we reject the null hypothesis. P-value > 0.05 indicates there is no statistically significant differences in the responses of the tanker drivers across the three oil depots (Kaduna, Mosimi and Benin).

*Table 8 Drivers opinions on the use of technologies across the oil depots*

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 1 | The distribution of the use of vehicle location monitoring systems is the same across categories of Oil loading depots. | Independent-Samples Kruskal-Wallis Test | .493 | Retain the null hypothesis. |
| 2 | The distribution of Vehicle condition monitoring systems is the same across categories of Oil loading depots. | Independent-Samples Kruskal-Wallis Test | .000 | Reject the null hypothesis. |
| 3 | The distribution of Route planning systems is the same across categories of Oil loading depots. | Independent-Samples Kruskal-Wallis Test | .076 | Retain the null hypothesis. |

| | | | | |
|---|---|---|---|---|
| 4 | The distribution of Driving behaviour monitoring systems is the same across categories of Oil loading depots. | Independent-Samples Kruskal-Wallis Test | .200 | Retain the null hypothesis. |
| 5 | The distribution of Crash preventing monitoring systems is the same across categories of Oil loading depots. | Independent-Samples Kruskal-Wallis Test | .266 | Retain the null hypothesis. |
| 6 | The distribution of Freight status monitoring systems is the same across categories of Oil loading depots. | Independent-Samples Kruskal-Wallis Test | .012 | Reject the null hypothesis. |
| 7 | The distribution of Weight-in-Motion systems is the same across categories of Oil loading depots. | Independent-Samples Kruskal-Wallis Test | .807 | Retain the null hypothesis. |
| 8 | The distribution of Cargo tampering prevention systems is the same across categories of Oil loading depots. | Independent-Samples Kruskal-Wallis Test | .236 | Retain the null hypothesis. |
| Asymptotic significances are displayed. The significance level is .050. | | | | |

*Table 9 Kruskal Wallis H Test for Variables in the Questionnaire Survey*

| Ranks | | |
|---|---|---|

| Variables | Mosimi, Kaduna and Benin depots | N | Mean Rank | Kruskal Wallis H | P-value |
|---|---|---|---|---|---|
| Age of drivers | Mosimi | 70 | 89.10 | 1.934 | .380 |
| | Kaduna | 56 | 87.54 | | |
| | Benin | 44 | 77.17 | | |
| | Total | 170 | | | |
| Drivers' years of experience | Mosimi | 70 | 83.21 | .737 | .692 |
| | Kaduna | 56 | 90.00 | | |
| | Benin | 44 | 83.42 | | |
| | Total | 170 | | | |
| The use of vehicle location monitoring systems | Mosimi | 70 | 90.22 | 1.784 | .410 |
| | Kaduna | 56 | 80.08 | | |
| | Benin | 44 | 84.89 | | |
| | Total | 170 | | | |
| The use of vehicle condition monitoring systems | Mosimi | 70 | 86.75 | 33.337 | <.001 |
| | Kaduna | 56 | 108.13 | | |
| | Benin | 44 | 54.70 | | |
| | Total | 170 | | | |
| The use of route planning systems | Mosimi | 70 | 94.19 | 6.449 | .040 |
| | Kaduna | 56 | 84.80 | | |
| | Benin | 44 | 72.57 | | |
| | Total | 170 | | | |
| | Mosimi | 70 | 96.39 | 13.373 | .001 |
| | Kaduna | 56 | 87.61 | | |

| | | | | | |
|---|---|---|---|---|---|
| The use of driving behaviour monitoring systems | Benin | 44 | 65.49 | | |
| | Total | 170 | | | |
| The use of crash preventing systems | Mosimi | 70 | 91.86 | 4.536 | .104 |
| | Kaduna | 56 | 85.59 | | |
| | Benin | 44 | 75.26 | | |
| | Total | 170 | | | |
| The use of freight status monitoring systems | Mosimi | 70 | 88.85 | 10.696 | .003 |
| | Kaduna | 56 | 95.95 | | |
| | Benin | 44 | 66.88 | | |
| | Total | 170 | | | |
| The use of Weight-in-Motion systems | Mosimi | 70 | 84.23 | 3.078 | .215 |
| | Kaduna | 56 | 93.23 | | |
| | Benin | 44 | 77.68 | | |
| | Total | 170 | | | |
| The use of cargo tampering prevention systems | Mosimi | 70 | 92.24 | 7.271 | .026 |
| | Kaduna | 56 | 89.37 | | |
| | Benin | 44 | 69.85 | | |
| | Total | 170 | | | |
| Speed cameras to reduce accidents | Mosimi | 70 | 88.12 | 1.052 | .591 |
| | Kaduna | 56 | 87.10 | | |
| | Benin | 44 | 79.30 | | |
| | Total | 170 | | | |
| | Mosimi | 70 | 94.66 | 9.467 | .009 |
| | Kaduna | 56 | 70.41 | | |

| | | | | | |
|---|---|---|---|---|---|
| Average age of trucks for transporting products | Benin | 44 | 90.13 | | |
| | Total | 170 | | | |
| Poor road conditions | Mosimi | 70 | 79.00 | 12.166 | .002 |
| | Kaduna | 56 | 96.00 | | |
| | Benin | 44 | 82.48 | | |
| | Total | 170 | | | |
| Extreme weather conditions | Mosimi | 70 | 89.14 | .906 | .636 |
| | Kaduna | 56 | 83.07 | | |
| | Benin | 44 | 82.80 | | |
| | Total | 170 | | | |
| Overloading of trucks | Mosimi | 70 | 66.86 | 29.788 | <.001 |
| | Kaduna | 56 | 89.93 | | |
| | Benin | 44 | 109.52 | | |
| | Total | 170 | | | |
| Poorly maintained trucks | Mosimi | 70 | 63.21 | 33.650 | <.001 |
| | Kaduna | 56 | 103.29 | | |
| | Benin | 44 | 98.32 | | |
| | Total | 170 | | | |
| Insufficient rest time during travel for drivers | Mosimi | 70 | 65.36 | 27.987 | <.001 |
| | Kaduna | 56 | 97.23 | | |
| | Benin | 44 | 102.61 | | |
| | Total | 170 | | | |
| | Kaduna | 56 | 92.49 | | |
| | Benin | 44 | 78.16 | | |

| | | | | | |
|---|---|---|---|---|---|
| | Total | 170 | | | |
| | Kaduna | 56 | 81.90 | | |

### 4.14.3 Kendall's W Test

The Kendall's coefficient of concordance W is a non-parametric test used to find out if there is an agreement or concordance among judges of N objects or individuals. The interpretation of the value of W is high agreement when W is equal to one (W = 1) or no agreement when W is equal to zero (W = 0). In this study, the Kendall's W test was performed using the SPSS software to measure the level of agreement of the tanker drivers who completed the questionnaires at the three oil depots where the questionnaires were distributed as shown in Table 10 below.

*Table 10 Mean Rank for Variables*

| **Ranks** | |
|---|---|
| | |
| Variables | Mean Rank |
| Age of drivers | 14.21 |
| Educational Qualification | 8.08 |
| The use of vehicle location monitoring systems | 16.97 |
| The use of vehicle condition monitoring systems | 13.18 |
| The use of route planning systems | 12.19 |
| The use of driving behaviour monitoring systems | 12.34 |
| The use of crash preventing systems | 11.25 |
| The use of freight status monitoring systems | 11.86 |

| | |
|---|---|
| The use of Weight-in-Motion systems | 12.31 |
| The use of cargo tampering prevention systems | 11.80 |
| Poor road conditions | 4.77 |
| Extreme weather conditions | 3.70 |
| Overloading of trucks | 2.95 |
| Poorly maintained trucks | 3.75 |
| Insufficient rest time during travel for drivers | 3.83 |
| Average age of trucks for transporting products | 15.57 |
| Average salary of a tanker driver | 14.66 |
| Operations of Major and Independent oil marketers | 7.99 |
| Drivers' knowledge of Hazardous Materials | 17.36 |
| Drivers' knowledge of safety procedures | 17.75 |
| Importance of training for tanker drivers | 18.29 |
| Importance of continuous training for tanker drivers | 18.19 |

*Table 11 Kendall's W test*

| Test Statistics | |
|---|---|
| N | 170 |
| Kendall's W[a] | .678 |
| Chi-Square | 2419.393 |
| df | 21 |
| Asymp. Sig. | .000 |
| a. Kendall's Coefficient of Concordance | |

From the table above, the Kendall's W is .678 with a p- value of .000. Since the p-value is less than 5%, we can reject the null hypothesis and conclude there is an agreement among the different participants who completed the questionnaires at the three oil depots where the survey was performed.

### 4.14.4 Test for Normality

According to Elliot and Woodward (2007), normality tests are supplementary to the graphical assessment of normality. Some of the main tests for the assessment of normality are the Kolmogorov-Smirnov, Lilliefors corrected K-S test, Shapiro-Wilk test and the Anderson–Darling normality test (Elliot and Woodward, 2007; Peat and Barton, 2005; Steinskog, 2007). The main reason for carrying out normality test in research is to deduce whether a data has been sampled from a normal distribution. For instance, the Kolmogorov-Smirnov (K-S), Shapiro-Wilk and the Anderson-Darling normality test rejects the hypothesis of normality when the p-value is less than or equal to 0.05 ($p < 0.05$) which means the distribution is not normal. On the other hand, if $p > 0.05$ then we accept the null hypothesis ($H_0$) and this concludes that the distribution is normal. In this research, Kolmogorov-Smirnov (K-S) and Shapiro-Wilk test for normality in the distribution of the age of the tanker drivers, years of experience and their educational qualification was performed using the SPSS software as shown in the table below.

*Table 12 Test of Normality for Drivers Years of Experience*

| Tests of Normality (Years of Experience) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Tanker drivers' years of experience | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
| N = 170 | | Statistic | df | Sig. | Statistic | df | Sig. |
| Mosimi, Kaduna and Benin depots | 1-5 years | .280 | 32 | <.001 | .764 | 32 | <.001 |
| | 6 -10 years | .333 | 29 | <.001 | .715 | 29 | <.001 |
| | 11 -15 years | .260 | 52 | <.001 | .782 | 52 | <.001 |
| | 16 -20 years | .355 | 39 | <.001 | .699 | 39 | <.001 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 21- 25 years | .385 | 11 | <.001 | .724 | 11 | <.001 |
| | 26 years & above | .435 | 7 | <.001 | .600 | 7 | <.001 |
| a. Lilliefors Significance Correction | | | | | | | |

*Table 13 Test of Normality for the Educational Qualifications of Tanker Drivers*

| | **Educational Qualifications** | **Kolmogorov-Smirnov[a]** | | | **Shapiro-Wilk** | | |
|---|---|---|---|---|---|---|---|
| **N = 170** | | **Statistic** | **df** | **Sig.** | **Statistic** | **df** | **Sig.** |
| Mosimi, Kaduna and Benin depots | Primary school | .268 | 94 | <.001 | .801 | 94 | <.001 |
| | Secondary school | .417 | 53 | <.001 | .629 | 53 | <.001 |
| | OND/NCE | .437 | 23 | <.001 | .582 | 23 | <.001 |
| a. Lilliefors Significance Correction | | | | | | | |

*Table 14 Test of Normality for the Age of Tanker Drivers*

| **Tests of Normality (Age of tanker drivers)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Age of tanker drivers** | **Kolmogorov-Smirnov[a]** | | | **Shapiro-Wilk** | | |
| **N = 170** | | **Statistic** | **df** | **Sig.** | **Statistic** | **df** | **Sig.** |
| Mosimi, Kaduna and Benin depots | 20 - 30 years | .288 | 22 | <.001 | .768 | 22 | <.001 |
| | 31 - 40 years | .347 | 27 | <.001 | .714 | 27 | <.001 |
| | 41 -50 years | .332 | 43 | <.001 | .740 | 43 | <.001 |
| | 51 -60 years | .229 | 74 | <.001 | .802 | 74 | <.001 |
| | 61 -70 years | .212 | 4 | <.001 | <.719 | 4 | <.001 |
| a. Lilliefors Significance Correction | | | | | | | |

The Shapiro-Wilk test is based on the correlation between the data and the corresponding normal scores and provides better power compared to the K-S test even after the Lilliefors correction.

## 4.15 Cronbach's Alpha Reliability Test

A reliability test of Cronbach's Alpha using SPSS (SPSS software version 28.0) was performed to validate the questionnaire prior to the distribution to the respondents (Tavakol and Dennick, 2011). As shown in Table 15, it can be observed that the Cronbach 's Alpha for the tanker drivers' questionnaires is close to one. Cronbach's Alpha test was conducted with the reliability of the sum or average of q measurements that satisfy the parallel assumption with equal variance and covariance (Bonett and Wright, 2014). This is also referred to as internal consistency reliability of the test item (Cho and Kim, 2015).

*Table 15 Cronbach's Alpha measurement for internal consistency*

| Constructs | No of measurement items | Cronbach's Alpha |
|---|---|---|
| **Technology** | 3 | 0.703 |
| **Drivers' challenges** | 3 | 0.814 |
| **Risk Management/Safety** | 4 | 0.709 |
| **Environmental** | 3 | 0.752 |
| **Regulations** | 3 | 0.824 |

| | | |
|---|---|---|
| **Training/supervision** | 4 | 0.784 |

## 4.16 Qualitative Data Analysis

The researcher used explanation building (Yin, 2013) as a method of qualitative data analysis. It enabled the qualitative raw data to be thoroughly scrutinised and several explanations were used to discover the associations between the objects of research. This resulted in analytical conclusions that answered the original "how" and "why" research questions. The qualitative data gathered through the interviews were analysed with the help of the thematic content analysis method which helped establish the meaning of the data through encoding and decoding of the data, searching and retrieving of the data and the formation of themes which indicated the intercalations within the data gathered (Boyatzis, 1998). This method is considered to be a suitable and malleable way of collecting and communicating ideas and themes that arise during an interview (Aronson, 1994). Braun and Clarke (2006) further argue that this approach provides the researcher with rich and detailed meaning out of the responses of the interview.

### 4.16.1 Content Analysis

Content analysis is a way of interpreting textual data by the systematic classification procedure of coding and identifying themes, which emerge from the analysis of narrative responses, for example those from open-ended survey questions, interviews, focus groups and observations (Kondracki and Wellman, 2002).

## 4.17 Research Findings and Framework Evaluation

In mixed methods research validation, the researcher starts validating the findings from the quantitative measures and compares the validity of the qualitative results. In mixed research approach, further validity attention emerges. The precision of the overall results might be affected because the investigator does not take into account using various samples for each stage of the research. This reduces the significance of one stage structure on the other. Also, an insufficient sample size can be challenged on whichever quantitative aspect of the research or the qualitative aspect. Planning a worthy mixed methods study is influenced by diverse internal or external factors (Seliger and Shohamy, 1989; Creswell, 2014). However, this research utilised the interviews conducted as a mechanism to evaluate the framework.

## 4.18 Summary of Chapter Four

In this chapter, the relevant literature in relation to the research methodology have been discussed. Furthermore, the philosophies of research, as well as the strategies and methods of data collection were deliberated in detail with the intention of comprehending the applicable strategies and philosophies for undertaking the study on the problems facing the transportation of petroleum products in Nigeria. From the discussion, the researcher has accepted that this specific study on developing SAF takes the philosophical stance of pragmatism and as such, adopted the mixed method approach to address the research problem. This has led to the selection of a questionnaire and interview (mixed methods) as being the particularly appropriate research strategies. The Kruskal Wallis and the Kendall's W test were performed in the chapter along with the normality test for the different variables used in the research. The next two chapters would present the discussion of the analysis and findings from the mixed method research.

# 5 QUANTITATIVE DATA ANALYSIS

## 5.1 Introduction

This research first collected quantitative data followed by the collection of the qualitative data with the aim of capturing and understanding the current state of the Nigerian downstream oil and gas sector as it relates to the transportation of petroleum products using road tankers. This chapter presents the analysis and discussion of results from the quantitative data captured. The essence of this chapter is to use the results and findings from the quantitative survey to develop a safety framework for the transportation of petroleum products in Nigeria. The chapter is divided into three main sections. The first part presents information on the demographic profile of the respondents to the research. Part two presents the descriptive statistics on the data collected in relation to the problems facing road transportation of petroleum products using tankers. The final part analyses and discusses the relationships between the variables of this research through correlational analysis. The quantitative data gathered from this research was analysed using descriptive and inferential analytical tools.

## 5.2 Demographic Information on Participants

This section provides demographic information on the participants for this research such as the background of participants, their age group and their job descriptions. The results help to paint a good picture of the participants and provides a basis for analysing their views on the research topic. It must be reiterated at this stage, that all research participants were petroleum tanker drivers.

### 5.2.1 Response Rate

*Table 16 Response rate of participants*

| Depot | Number of questionnaires distributed | Number of questionnaires completed | % of completed questionnaire |
|---|---|---|---|
| **Mosimi** | 150 | 70 | 41.17% |
| **Kaduna** | 150 | 56 | 32.94% |
| **Benin** | 100 | 44 | 25.88% |
| **Total** | 400 | 170 | 100% |

As shown in Table 16, a total of 400 questionnaires were sent out to tanker drivers at three oil loading depots in Nigeria to capture data on their views on the challenges of tanker transportation of petroleum products. Out of the 400, 268 were returned back representing 67% of the total questionnaires sent out. This response rate suggests a good representative of the population of tanker drivers (see section 4.11) especially as the respondents were randomly selected. After checking carefully, only 170 questionnaires representing 42.5% were correctly completed and can be used for the data analysis.

*Table 17 Distribution of age of research participants*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | 20 - 30 years | 22 | 12.9 | 12.9 | 12.9 |
| | 31 - 40 years | 27 | 15.9 | 15.9 | 28.8 |

| | | | | | |
|---|---|---|---|---|---|
| | 41 -50 years | 43 | 25.3 | 25.3 | 54.1 |
| | 51 -60 years | 74 | 43.5 | 43.5 | 97.6 |
| | 61 -70 years | 4 | 2.4 | 2.4 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

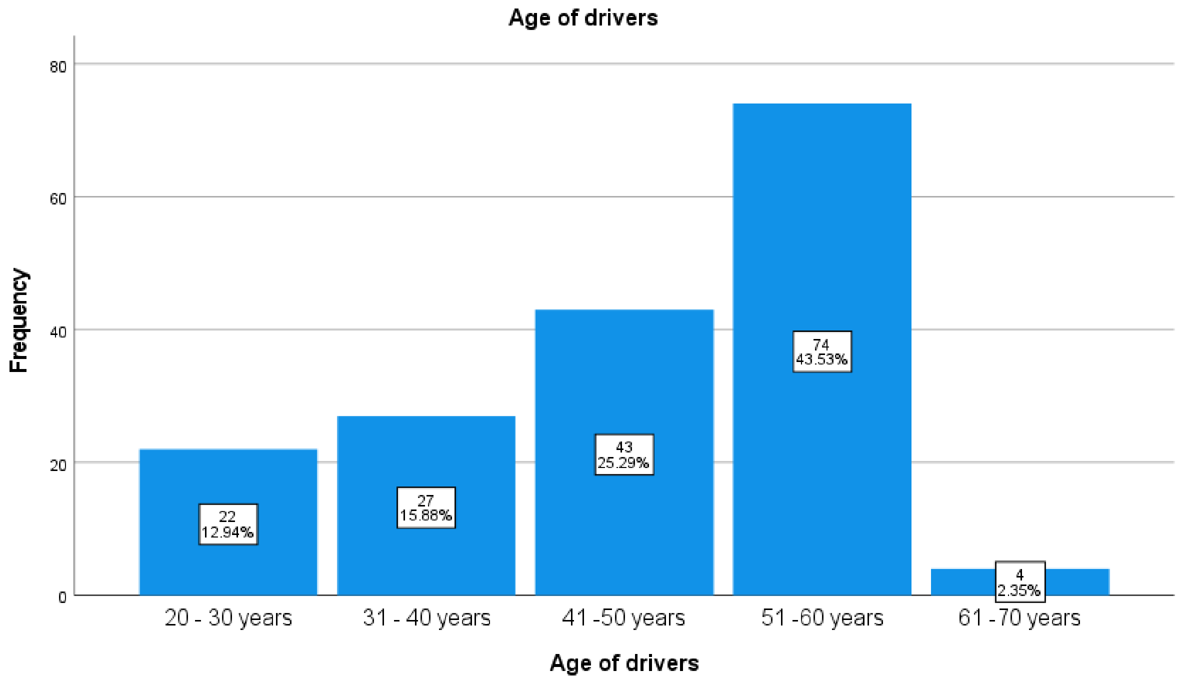



*Figure 22 Age of drivers*

As shown in Table 17, majority of the drivers in the study area are between the age group of 51 - 60 years and 41-50 years representing 74(43.5%) and 43(25.3%) respectively. 22 drivers representing 12.9% are between the age group of 20-30 years while 27 drivers representing 15.9% are between the age group of 31-40 years of age. None of the drivers are 70 years and above. This shows that tanker drivers in Nigeria are in their prime years and would be able to withstand the rigours of truck driving, which requires energy, skills and perseverance. This result is expected because tanker drivers are normally expected to have garnered previous years driving experience from driving other vehicles and gradually moving to bigger vehicles. Drivers' licences are legally issued to people who are 18 years of age in Nigeria (FRSC, 2011). For Heavy Goods Vehicles including road tankers the National Road Traffic ACT (2012) requires drivers to be 26 years of age before they are licenced to drive that category of vehicles. However, many freight companies do not really comply with this requirement since the result of this survey is showing that some of the drivers are below 26 years. In the United Kingdom, tankers, drivers are required to hold an ADR licence before they can be qualified to drive a tanker. ADR stands *European Agreement on the International Carriage of Dangerous Goods by Road* (see section 2.19.2). The holder of ADR licence is qualified to drive tankers of all sizes, which often contain liquids like milk, petrol or other volatile or toxic materials.

### 5.2.2 Geographical Location

Three petroleum loading depots were selected at random for the distribution of the questionnaires. The selected depots are: NNPC Kaduna depot, NNPC Mosimi depot and NNPC Benin depot as shown in Figure 23.

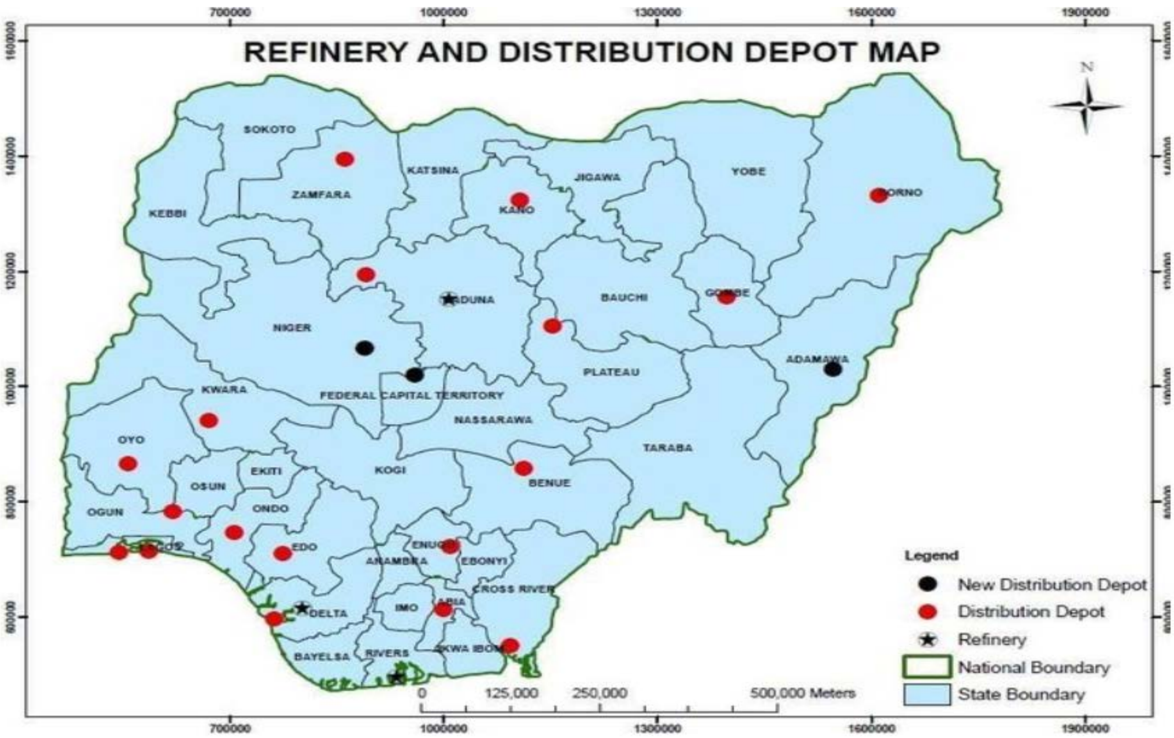



*Figure 23 Geographical location of Depots, Source: (Tata et al., 2016).*

### 5.2.3 Justification for Choice of Depot

The selection of the oil depots by the researcher was mainly due to geographical locations of the depots. The three oil depots where the questionnaires were administered to the tanker drivers are in the north, south and western part of the country. The three depots chosen by the researcher are very relevant to the distribution of petroleum products to the big cities around the depots. For instance, the NNPC Kaduna depot supplies petroleum products to most of the northern states in Nigeria including Kano state which is the biggest economic state in the northern part of Nigeria. Also, the NNPC Mosimi depot supplies petroleum products to most cities in the western part of Nigeria including Lagos which is the economic nerve of the country. The number of accidents affiliated to these depots during products transportation was another reason they were chosen by the researcher for the survey (see Table 18).

*Table 18 Selection of oil depots in Nigeria*

| **Kaduna depot** | **Mosimi Depot** | **Benin Depot** |
|---|---|---|
| ▪ Kaduna is the second largest city in Northern Nigeria and the second most industrialised state. It is also home to the only petroleum refinery in the region. | ▪ The Mosimi NNPC depot supplies petroleum products to the western part of Nigeria including Lagos. Lagos is the commercial nerve centre of Nigeria and home to its biggest port establishment. Many tanker/truck companies in Lagos service these economic interests. | The Benin NNPC deport distribute petroleum products within the southern part of the country. Benin is located in Edo state which connects some other states and as such the depot serves a hub supplying petroleum products in Benin and environs. |
| ▪ There are high concentrations of tankers/truck owners in the city who are responsible for the distribution of petroleum and other industrial products to other states in the country. | ▪ Some severe tanker accidents occur along the Lagos-Ibadan expressway and the tankers get their petroleum products from the Mosimi oil depot. | ▪ Some tanker accidents have occurred in the Benin axis after loading products from the Benin depot. |

### 5.2.4 Gender

The tanker drivers who completed the questionnaires at Kaduna, Mosimi and Benin oil depots were all males. Road tankers and trucks and other heavy goods vehicle (HGV) are usually not driven by women in Nigeria. As expected, only male drivers completed the questionnaires.

### 5.2.5 Educational Qualification of Tanker Drivers

As shown in Table 19, majority of the tanker drivers in Nigeria either has a primary or secondary education.

*Table 19 Educational qualification of tanker drivers*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Primary school | 94 | 55.3 | 55.3 | 55.3 |
| | Secondary school | 53 | 31.2 | 31.2 | 86.5 |
| | OND/NCE | 23 | 13.5 | 13.5 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

The result from Table 19 reveals that majority 90 (52.9%) of tanker driver in the country have primary school education, 94 (55.3%) followed by secondary education 53 (31.2%). Only 23 (13.5%) have a diploma/NCE certificate. This means that none of the drivers have a university degree or higher degree. It is therefore right to conclude that all tanker drivers in Nigeria have a certain level of literacy.

*Table 20 Drivers' years of experience*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | 1-5 years | 32 | 18.8 | 18.8 | 18.8 |
| | 6 -10 years | 29 | 17.1 | 17.1 | 35.9 |
| | 11 -15 years | 52 | 30.6 | 30.6 | 66.5 |
| | 16 -20 years | 39 | 22.9 | 22.9 | 89.4 |
| | 21- 25 years | 11 | 6.5 | 6.5 | 95.9 |
| | 26 years & above | 7 | 4.1 | 4.1 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

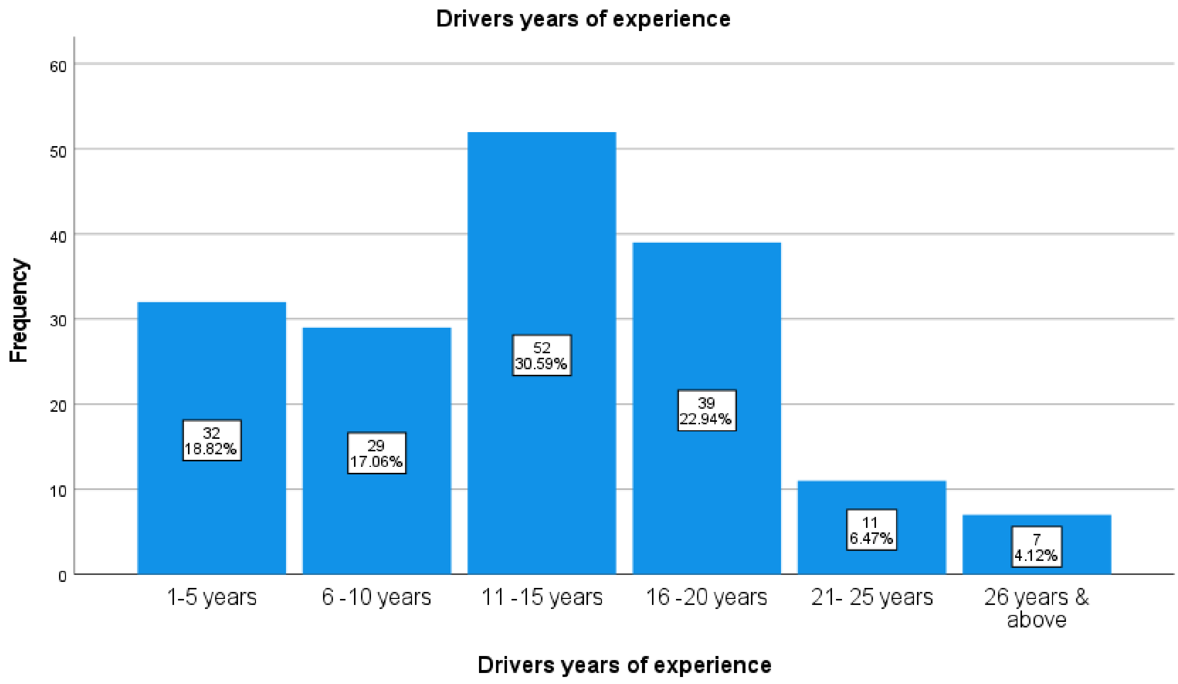



*Figure 24 Drivers' years of experience*

Table 20 above displays the years of experience of the tanker drivers who took part in the survey. From the table, it can be seen that all the drivers have driving experience. Majority of the drivers have between 11-15 years representing 30.6% of the total population. 32 (18.8%) of the drivers have between 1- 5 years of experience. Also, 29 (17.1%) have between 6 -10 years of driving experience while 39 (22.9%) and 11(6.5%) drivers have 16-20 years and 21 - 25 years of driving experience respectively. Only 7 (4.1%) drivers have 26 years and above driving experience. The results show that all the tanker drivers who completed the questionnaire have driving experience.

## 5.3 Data Analysis and Discussion

In analysing the responses from the respondents (tanker drivers) in the questionnaires, the following statistical methods have been used (see 4.13.1). Frequency distribution of responses using Bar charts representation. The statistical software used for the analysis was SPSS (statistical package for social sciences).

## 5.4 Perceptions of drivers on the use of technologies in tankers to mitigate accidents.

In question one of the questionnaire, tanker drivers were asked to state their level of agreement to the use of technology in the tanker-truck they drive to transport petroleum products. The reason for this question is for the researcher to know if the road tankers used to transport petroleum products and other hazardous materials in Nigeria are equipped with modern vehicle safety technologies. The technologies taken into consideration for this question are: vehicle location monitoring systems (VLMS); vehicle condition monitoring systems (VCMS); route planning systems (RPS); driving behaviour monitoring systems (DBMS); crash preventing systems (CPS); freight status monitoring systems (FSMS); Weight-in-Motion systems (WMS) and cargo tampering prevention systems (CTPS). The variables were grouped on a 5-point Likert-scale (completely disagree, disagree, neither agree nor disagree, agree and completely agree).

### 5.4.1 Respondents rating of the Vehicle Location Monitoring Systems (VLMS)

*Table 21 The Use of Vehicle Location Monitoring System*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | completely disagree | 2 | 1.2 | 1.2 | 1.2 |
| | disagree | 20 | 11.8 | 11.8 | 12.9 |
| | neither agree nor disagree | 19 | 11.2 | 11.2 | 24.1 |
| | agree | 107 | 62.9 | 62.9 | 87.1 |
| | completely agree | 22 | 12.9 | 12.9 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

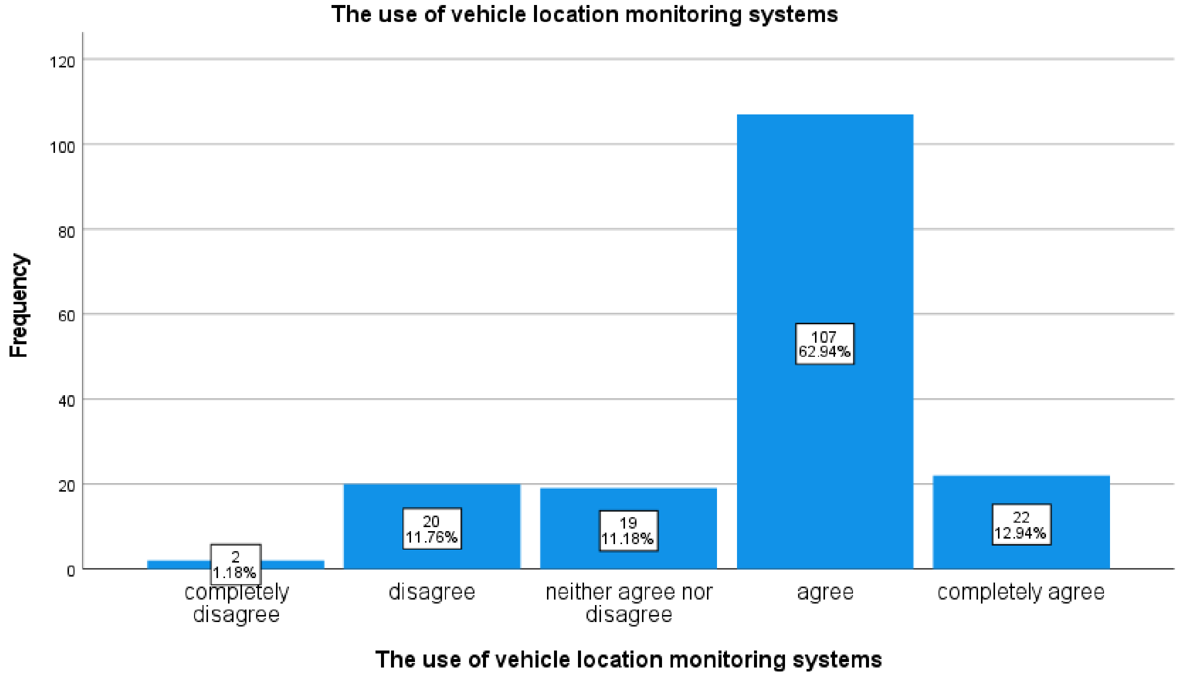



*Figure 25 The Use of Vehicle Location Monitoring Systems*

As shown in Table 21 and Figure 25 above, 129 respondents representing 76% of the total respondents in the three oil depots either completely agreed or agreed that VLMS are used by tankers on the road during the transportation of petroleum products in Nigeria. 22 respondents representing 13% of the total respondents either disagreed or completely disagreed to the use of VLMS by tankers while 19 respondents representing 11% of the total respondents neither agreed nor disagreed to the use of VLMS. From the above analysis, there is a strong indication that VLMS are used by road tankers during the transportation and distribution of petroleum products in Nigeria. The VLMS technology can be used to monitor the location of a tanker during the transportation of petroleum products between loading depot and the retail station such that the actual location of the vehicle can be monitored at intervals during its journey. According to Vineth *et al* (2019) "the Vehicle tracking system combines the use of automatic vehicle location in individual vehicles with software that collects the fuel level of the vehicle and the location of the vehicle".

### 5.4.2 Respondents Rating of Use of Vehicle Condition Monitoring Systems (VCMS) Technology

*Table 22 The Use of Vehicle Condition Monitoring Systems*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | completely disagree | 17 | 10.0 | 10.0 | 10.0 |
| | disagree | 77 | 45.3 | 45.3 | 55.3 |
| | neither agree nor disagree | 15 | 8.8 | 8.8 | 64.1 |
| | agree | 54 | 31.8 | 31.8 | 95.9 |

| | | | | | |
|---|---|---|---|---|---|
| | completely agree | 7 | 4.1 | 4.1 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

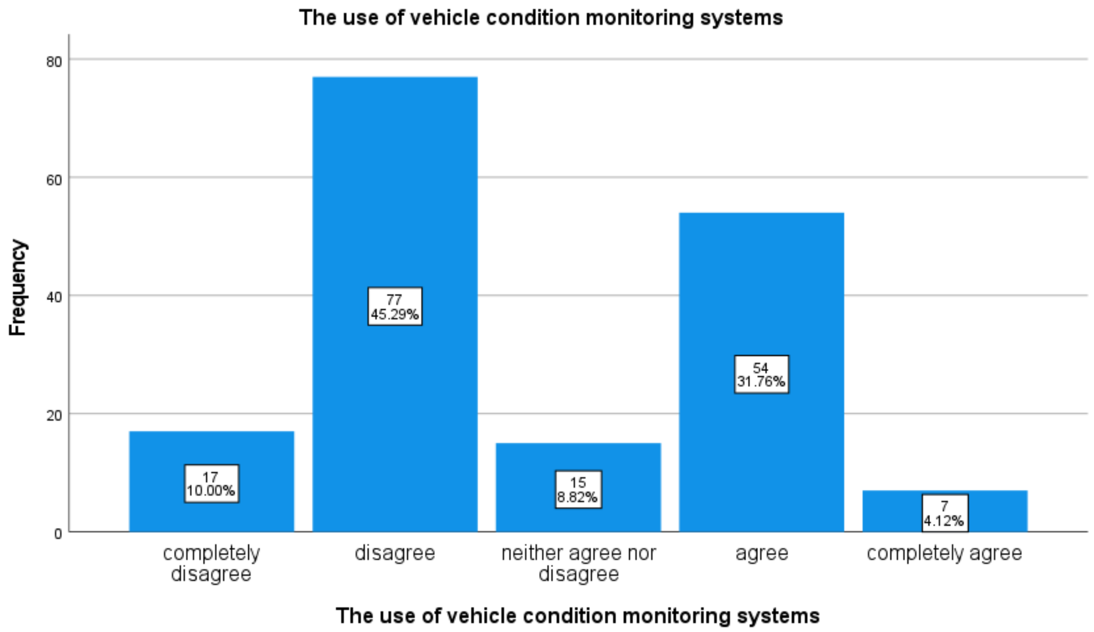



*Figure 26 The Use of Vehicle Condition Monitoring Systems*

As shown in Table 22 and Figure 26 above, 61 respondents representing 35.88% of the total 170 respondents either completely agree or agree that the VCMS are used by tankers. However, 94 respondents representing 55.29% of the total respondents either disagreed or completely disagreed to the use of VCMS by tankers while 15 respondents representing 8.82% of the total respondents neither agreed nor disagreed that VCMS are used by tankers. From the above analysis, there is an indication that VCMS technology are mostly not used by road tankers during the transportation and distribution of petroleum products in Nigeria. The system communicates with the Electronic Control Unit (ECU) in Controller Area Network (CAN) through the On-Board Diagnostics (OBD) interface to obtain the real-time condition data of the vehicle and improve the active safety of the vehicle (Xuan Shao *et al* 2020).

### 5.4.3 Respondents Rating of Use of Route Planning Systems (RPS) Technology

*Table 23 The Use of Route Planning System*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | completely disagree | 22 | 12.9 | 12.9 | 12.9 |
| | disagree | 96 | 56.5 | 56.5 | 69.4 |
| | neither agree nor disagree | 10 | 5.9 | 5.9 | 75.3 |
| | agree | 32 | 18.8 | 18.8 | 94.1 |
| | completely agree | 10 | 5.9 | 5.9 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

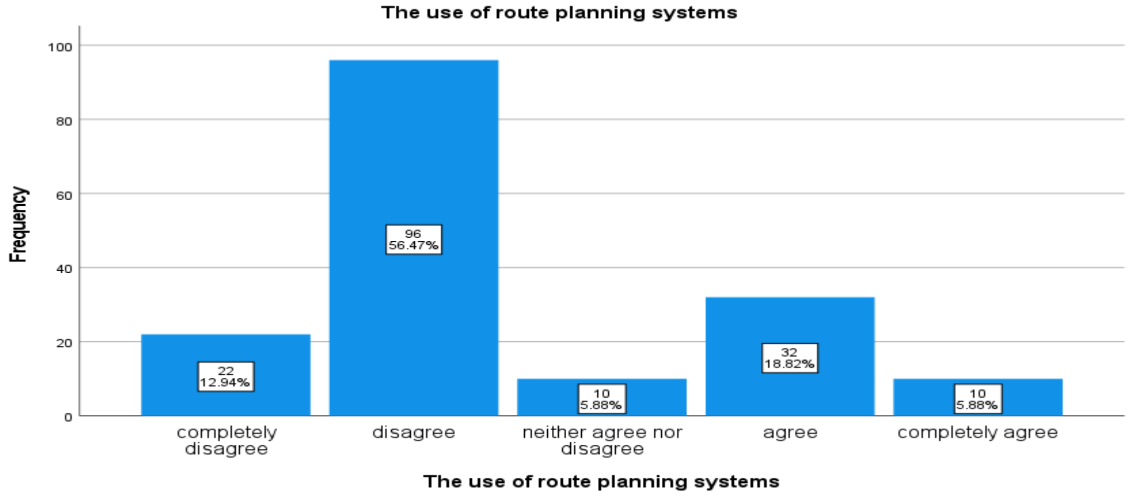



*Figure 27 The Use of Route Planning System*

As shown in Table 23 and Figure 27 above, 42 respondents out of a total of 170 representing 24.7%% either agree or completely agree to the use RPS by tankers. 96 respondents representing 56.5% disagreed to the use of RPS by tankers while 10 respondents representing 5.9% neither agreed nor disagreed to the use of RPS. From the above analysis, there is a strong indication that the drivers do not agree that RPS technologies are used in their trucks. In the transportation of hazmat, route planning is very important due to the nature of the substance. For instance, Huang et al., (2004) suggested in their study an urgent to improve the way trucks carrying hazardous materials (HAZMATs) are being routed on urban and suburban road networks. According to the study, routing of such vehicles should not only ensure the safety of travellers in the network but also consider the risk of the HAZMAT being used as weapon of mass destruction.

### 5.4.4 Respondents Rating of Use of Driving Behaviour Monitoring Systems (DBMS) Technology

*Table 24 The Use of DBMS*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | completely disagree | 15 | 8.8 | 8.8 | 8.8 |
| | disagree | 96 | 56.5 | 56.5 | 65.3 |
| | neither agree nor disagree | 17 | 10.0 | 10.0 | 75.3 |
| | agree | 37 | 21.8 | 21.8 | 97.1 |
| | completely agree | 5 | 2.9 | 2.9 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

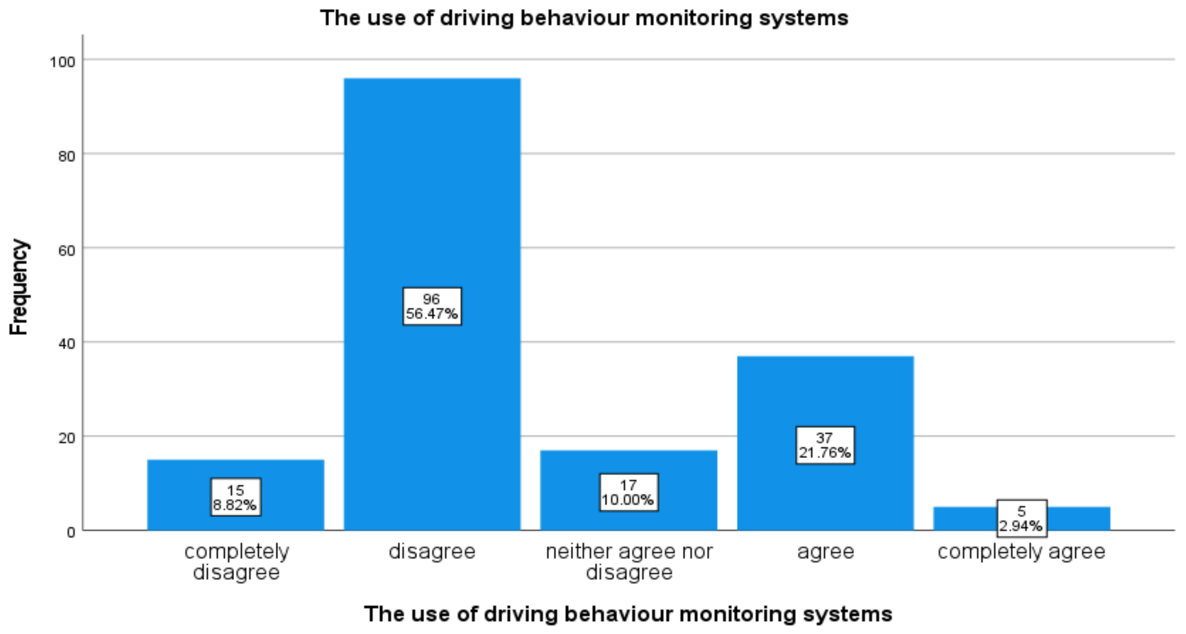



*Figure 28 The Use of Driving Behaviour Monitoring Systems*

As shown in Table 24 and Figure 28 above, 42 respondents representing 24.7% out of a total of 170 respondents either agree or completely agree to the use of DBMS by tankers. 111 respondents representing 65.3% either disagreed or completely disagreed to the use of DBMS by tankers while 17 respondents representing 10% neither agreed nor disagreed to the use of DBMS by tankers. From the above analysis, there is a strong indication that drivers perceive that DBMS are not mostly used by road tankers during the transportation and distribution of petroleum products in Nigeria. A study performed by Kumar and Patra (2018) developed a low-cost, real-time driver's drowsiness detection system with acceptable accuracy. The system contains a webcam that records the video and driver's face is detected in each frame employing image processing techniques. As such, facial landmarks on the detected face are pointed and subsequently the eye aspect ratio, mouth opening ratio and nose length ratio are computed and depending on their values, drowsiness is detected based on developed adaptive thresholding. Most tanker drivers in Nigeria drive through long distances and become fatigued so this type of technology would help to monitor their behaviour on the road to promote safety.

5.4.5 Respondents Rating of Use of Crash Preventing Systems (CPS) Technology

*Table 25 Use of CPS*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | completely disagree | 18 | 10.6 | 10.6 | 10.6 |
| | disagree | 116 | 68.2 | 68.2 | 78.8 |
| | neither agree nor disagree | 9 | 5.3 | 5.3 | 84.1 |
| | agree | 25 | 14.7 | 14.7 | 98.8 |
| | completely agree | 2 | 1.2 | 1.2 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

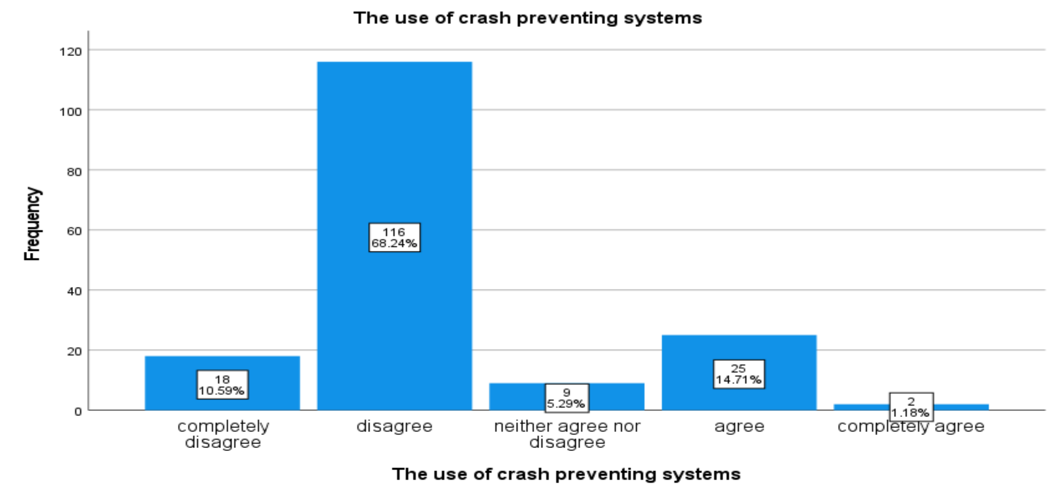



*Figure 29 Use of CPS*

As shown in Table 25, and Figure 29 above, 27 respondents representing 15.8% of the total 170 respondents either agree or completely agree to the use of CPS by tankers. 134 respondents representing 78.8% of respondents either disagreed or completely disagreed to the use of CPS while 9 respondents representing 5.3% neither agreed nor disagreed to the use of CPS by tankers. From the above analysis, there is a strong indication that the tanker drivers are of the opinion that CPS are not used by road tankers during the transportation and distribution of petroleum products in Nigeria.

### 5.4.6 Respondents Rating of Use of Freight Status Monitoring Systems (FSMS) Technology

The bar chart and the table below present the respondents rating to the use of freight status monitoring systems.

*Table 26 Use of FSMS*

| | | **Frequency** | **Percent** | **Valid Percent** | **Cumulative Percent** |
|---|---|---|---|---|---|
| **Valid** | completely disagree | 22 | 12.9 | 12.9 | 12.9 |
| | disagree | 87 | 51.2 | 51.2 | 64.1 |
| | neither agree nor disagree | 26 | 15.3 | 15.3 | 79.4 |
| | agree | 29 | 17.1 | 17.1 | 96.5 |
| | completely agree | 6 | 3.5 | 3.5 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

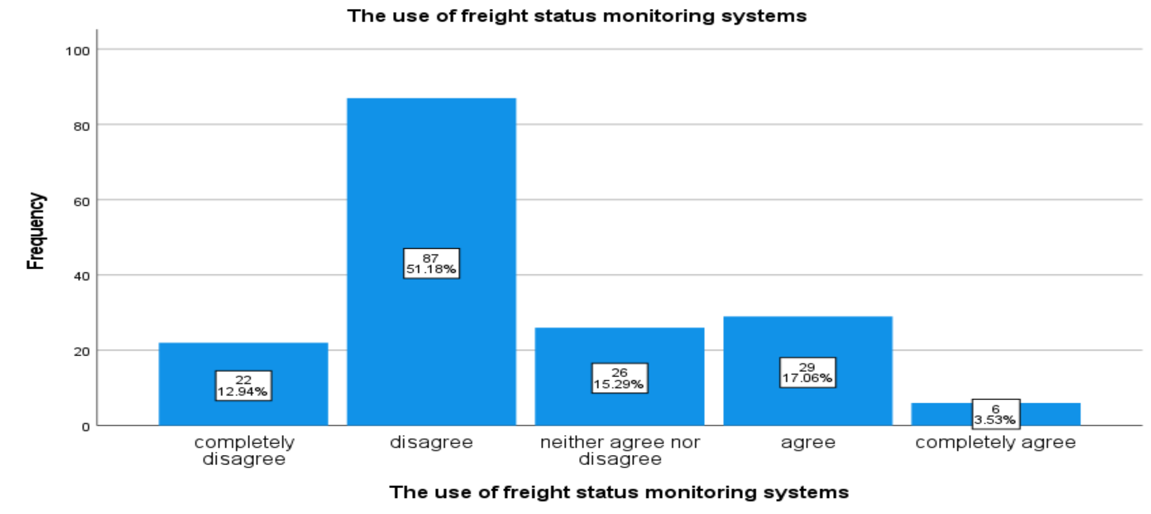



*Figure 30 Use of FSMS*

As shown in Table 26, and Figure 30 above, 35 respondents representing 20.6% of the total 170 respondents either agreed or completely agreed to the use of FSMS technology by tankers. 109 respondents representing 64.1% either disagreed or completely disagreed to the use of FSMS while 26 respondents representing 15.3% neither agreed or nor disagreed to the use of FSMS by tankers. From the above analysis, there is a strong indication that drivers are of the opinion that FSMS are not used by road tankers during the transportation and distribution of petroleum products in Nigeria.

5.4.7 Respondents Rating of Use of Weight-in-Motion Systems (WMS) Technology

*Table 27 Use of WMS*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | completely disagree | 21 | 12.4 | 12.4 | 12.4 |
| | disagree | 91 | 53.5 | 53.5 | 65.9 |

| | | | | | |
|---|---|---|---|---|---|
| | neither agree nor disagree | 8 | 4.7 | 4.7 | 70.6 |
| | agree | 46 | 27.1 | 27.1 | 97.6 |
| | completely agree | 4 | 2.4 | 2.4 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

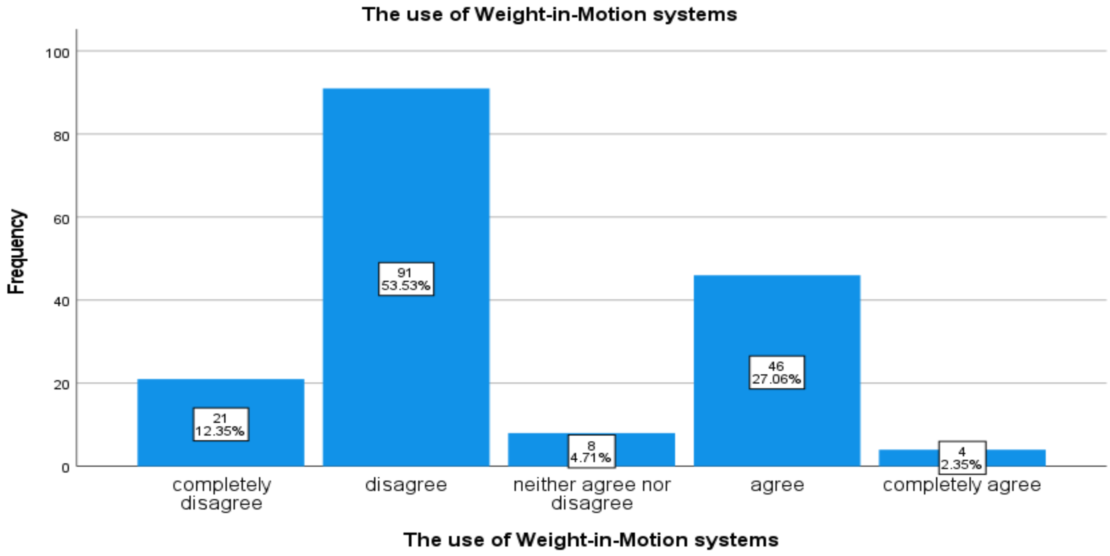



*Figure 31 Use of WMS*

As shown in Table 27 and Figure 31 above, 50 respondents representing 29.4% of the total 170 respondents either agree or completely agree to the use of WMS by tankers. 112 respondents representing 65.9% either disagreed or completely disagreed to the use of WMS by tankers. Only 8 respondents representing 4.71% neither agreed nor disagreed to the use of this technology. From the above analysis, there is a strong indication that tanker drivers are of the opinion that WMS technologies are mostly not used by road tankers during the transportation and distribution of petroleum products in Nigeria. The results from the analysis confirmed the fact that many tanker accidents in Nigeria have been attributed to overloading of the truck.

Faruk et al., (2016) conducted a study to evaluate the potential application of portable WIM systems as a means for bringing the WIM technology to some high-volume rural highways in America. The study findings indicated that the portable WIM unit can be used as a convenient and cost-effective means for collecting reliable traffic information for design, analysis, and monitoring purposes.

5.4.8 Respondents Rating of Use Cargo Tampering Prevention Systems (CTPS) Technology

*Table 28 Use of CTPS*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | completely disagree | 29 | 17.1 | 17.1 | 17.1 |
| | disagree | 87 | 51.2 | 51.2 | 68.2 |
| | neither agree nor disagree | 6 | 3.5 | 3.5 | 71.8 |
| | agree | 47 | 27.6 | 27.6 | 99.4 |
| | completely agree | 1 | .6 | .6 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

*Figure 32 Use of CTPS*

As shown in Table 28 above and Figure 32 below, 48 respondents representing 28.2% of the 170 total respondents either agree or completely agree to the use of CTPS by tankers. 116 respondents representing 68.2% either disagreed or completely disagreed to the use of CTPS by tankers. Only 6 respondents representing 3.5% neither agreed nor disagreed to the use of this technology. From the above analysis, there is a strong indication that CTPS are mostly not used by road tankers during the transportation and distribution of petroleum products in Nigeria. According to Miler and Bujak (2014) securing the supply chain through the securing of containers during transit could help to lower costs for consumers through the potential reduction of billions of dollars that are lost to theft and other spoilages. Also, an effective container transport security system and supply chain security solution must include end-to-end container tracking and full container intrusion monitoring in real time (Miler and Bujak, 2014).

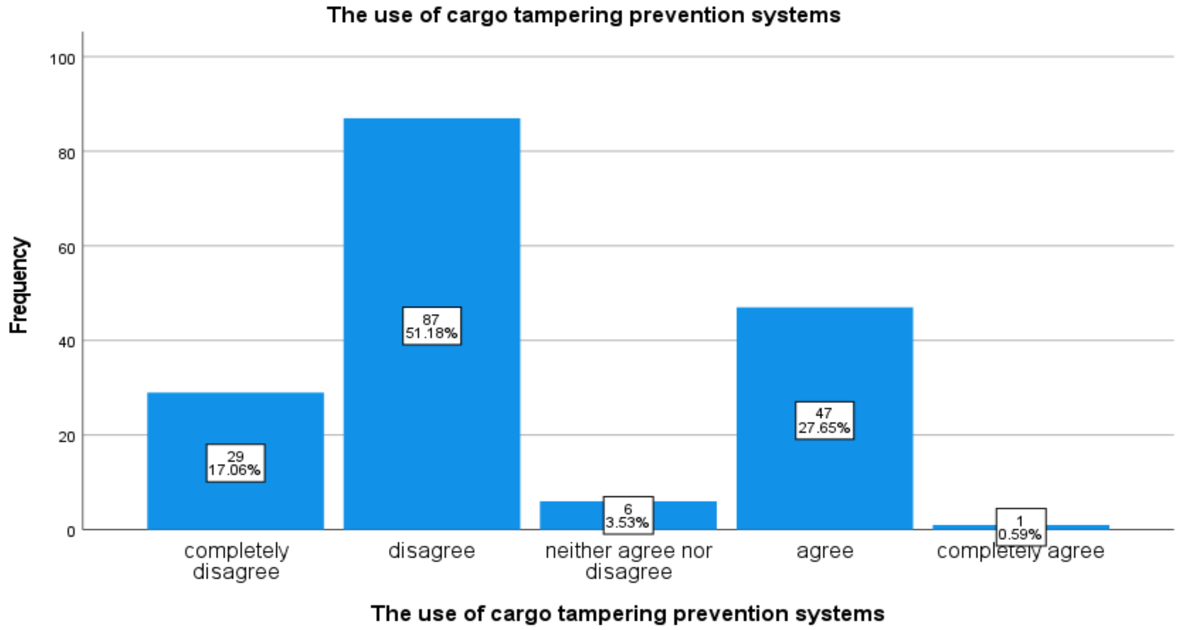



*Figure 32 Use of CTPS*

5.4.9 Respondents rating of speed cameras to reduce accidents

*Table 29 Speed cameras to reduce accidents*

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| **Valid** | Do not know | 9 | 5.3 | 5.3 | 5.3 |
| | less than or equal to 20% | 6 | 3.5 | 3.5 | 8.8 |
| | 20-40% | 38 | 22.4 | 22.4 | 31.2 |
| | 60-80% | 59 | 34.7 | 34.7 | 65.9 |
| | More than 80% | 57 | 33.5 | 33.5 | 99.4 |
| | 5 | 1 | .6 | .6 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

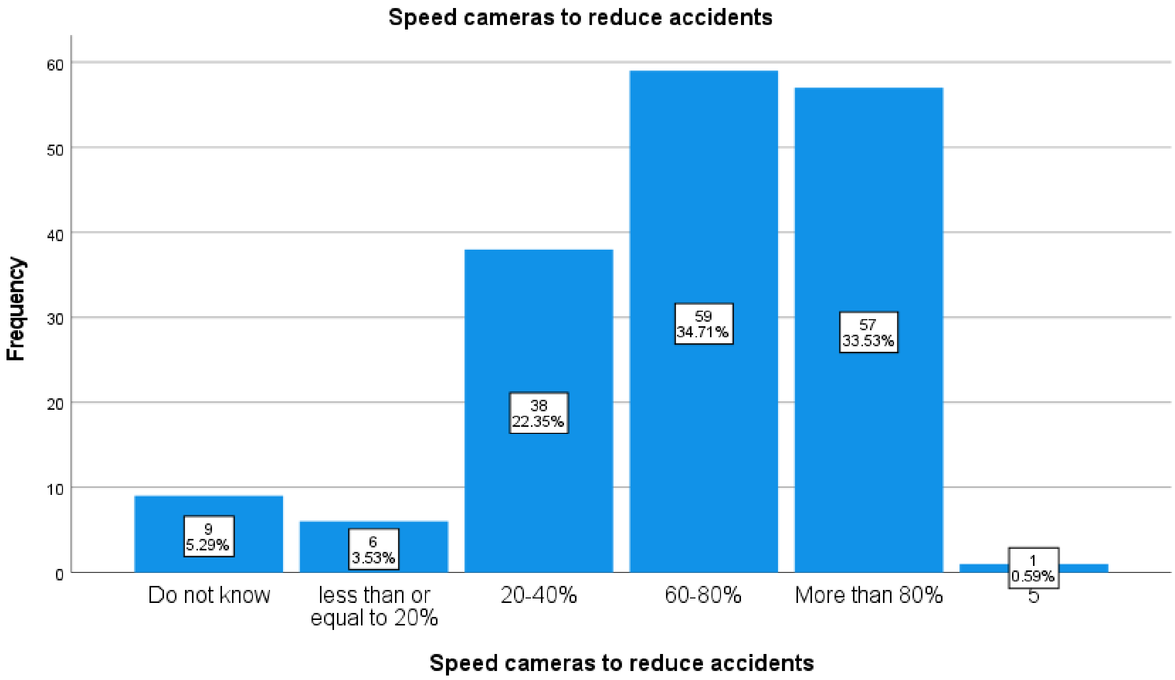



*Figure 33 Speed cameras to reduce accidents*

As shown in Table 29 and Figure 33, 57 tanker drivers representing 33.5% of the total 170 drivers who participated in the survey were of the opinion that speed cameras on Nigerian roads have the potential to reduce accidents by more than 80% while 59 tanker drivers representing 35% believed that speed cameras can reduce accident by 60 -80%. 38 tanker drivers representing 22.4% were of the opinion that speed cameras have the potential to reduce accidents by 20 – 40%. Only 6 (3.4%) drivers were of the opinion that speed cameras have the potential to reduce accidents by less than or equal to 20% while 9 (5.3%) drivers stated that they do not know if speed cameras have the potential to reduce accidents. From the analysis, there is a strong indication that speed cameras have the potential to reduce accidents on Nigerian roads. It means that if there are speed cameras on the road to monitor the speed of tanker drivers, they would drive within safe speed limits thereby increasing safety on the road and mitigate accidents.

5.4.10 Respondents rating of average age of trucks for transporting petroleum products

*Table 30 Average age of trucks for transporting products*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Do not know | 14 | 8.2 | 8.2 | 8.2 |
| | Less than 5 years | 5 | 2.9 | 2.9 | 11.2 |
| | Between 5 and 10 years | 11 | 6.5 | 6.5 | 17.6 |
| | Between 10 and 15 years | 26 | 15.3 | 15.3 | 32.9 |
| | Between 15 and 20 years | 88 | 51.8 | 51.8 | 84.7 |
| | More than 20 years | 26 | 15.3 | 15.3 | 100.0 |

| | | | | | |
|---|---|---|---|---|---|
| | Total | 170 | 100.0 | 100.0 | |

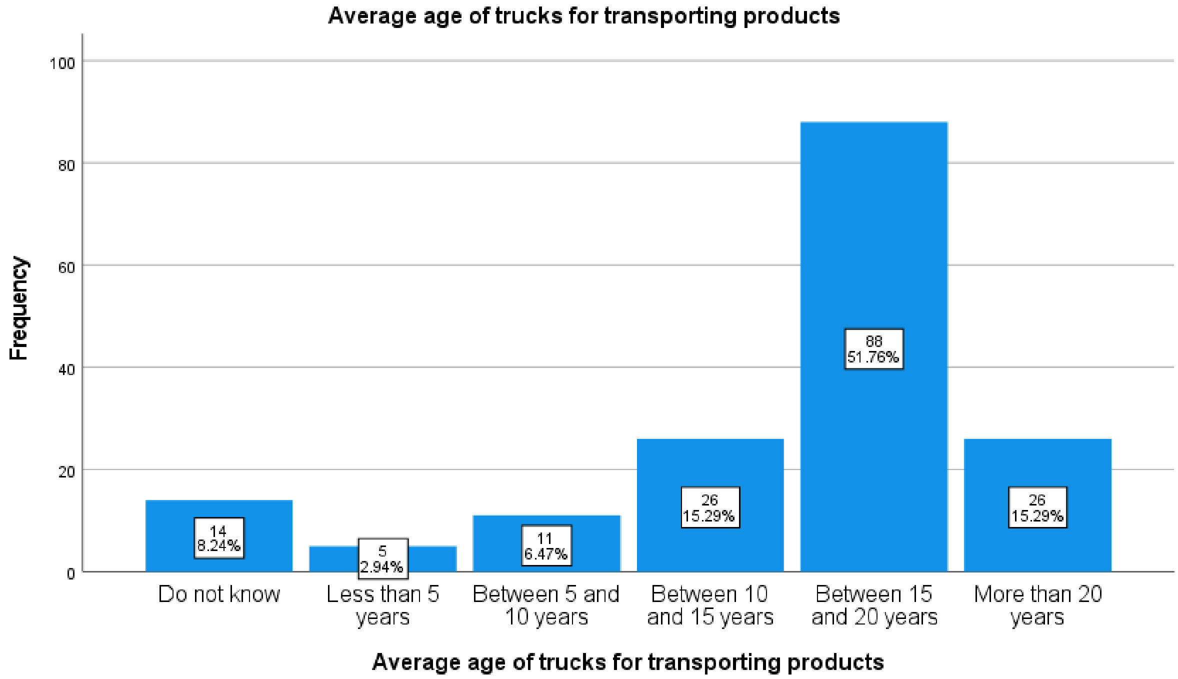



*Figure 34 Average age of trucks for transporting products*

As shown in Table 30 and Figure 34 above, 26 (15.3%) tanker drivers out of the 170 that participated in the survey believed that the average age of trucks used for transporting petroleum products in Nigeria is more than 20 years. 88 (51.8%) of the drivers are of the opinion that the average age of trucks used for transporting petroleum products in Nigeria is between 15 and 20 years. Another 26 (15.3%) believed that the average age of trucks used for transporting petroleum products in Nigeria is between 10 and 15 years old while 11 (6.5%) believed that the average age of trucks used for transporting petroleum products in Nigeria is between 5 and 10 years. Only 5 (2.9%) believed that the age of the trucks is less than 5 years while 14 (8.2%) indicated that they do not know the age of the trucks. From the analysis, there is a strong indication that the trucks used in transporting petroleum products in Nigeria are old trucks which have been used for more than 10 years on the average. Modern trucks are equipped with safety technologies. The result suggests that most of the tanker drivers are not aware of the new safety technologies in modern trucks.

### 5.4.11 Respondents rating of drivers average monthly salary

*Table 31 Average salary of a tanker driver*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | less than N20,000 | 2 | 1.2 | 1.2 | 1.2 |
| | Between N20,000 and N50,000 | 41 | 24.1 | 24.1 | 25.3 |
| | Between N50,000 and N80,000 | 60 | 35.3 | 35.3 | 60.6 |
| | More than N80,000 | 67 | 39.4 | 39.4 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

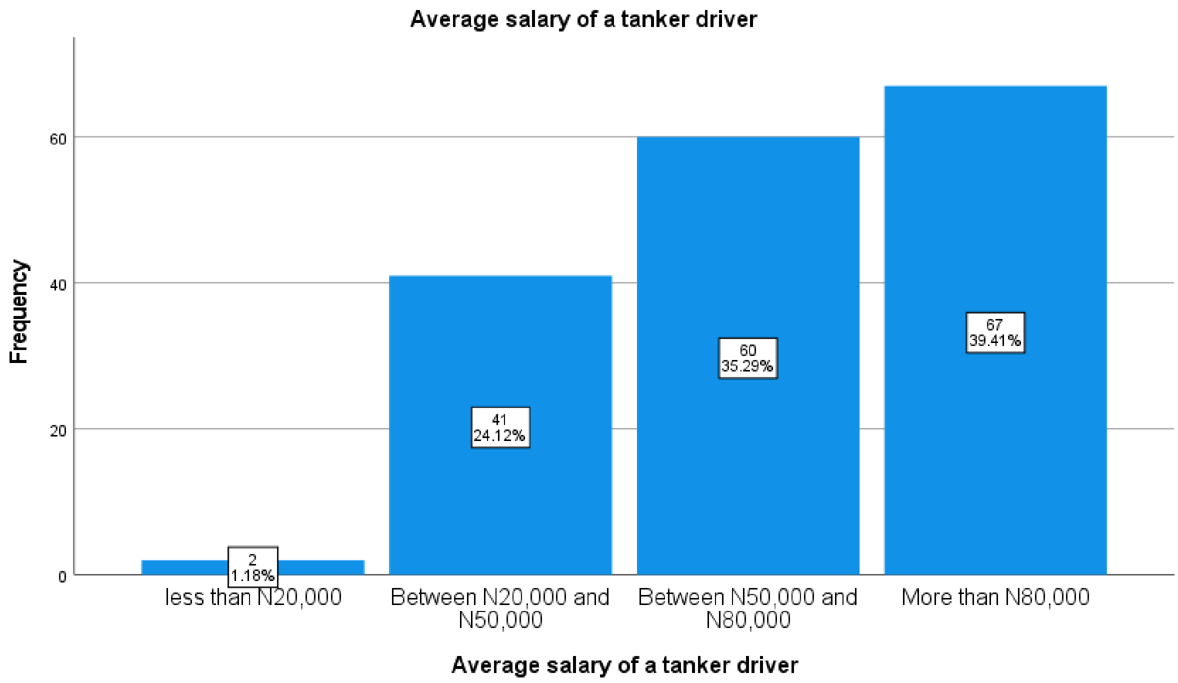



*Figure 35 Average salary of a tanker driver*

As shown in Table 31 and Figure 35 above, 67 (39.4%) tanker drivers out of the 170 who participated in the survey indicated that the average salary of tanker drivers in Nigeria is more than N80,000 while 60 (35.3%) indicated that the average salary of a tanker driver is between N50,000 and N80,000. 4. Further analysis shows that 41(24.1%) indicated that tanker drivers average monthly salary is between N20,000 and N50,000 while only 2 (1.2%) drivers indicated that the average salary of a tanker driver is less than N20,000. The analysis shows that the average monthly salary for a tanker driver in Nigeria is more than N50,000. This amount is nothing compared to what tanker drivers earn weekly in developed countries like the UK and the US. The low wages for tanker drivers in Nigeria have led to diversification of products and also over speeding on the road to make more trips because most drivers are being paid per the trips they make. The analysis suggests that tanker drivers in Nigeria are poorly paid compared to their counterparts in developed nations. Tanker driving is a very risky job and as such they should be well compensated with adequate welfare packages.

5.4.12 Respondents' opinion of average rest time duration

*Table 32 Average rest time for tanker drivers*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | less than 30 minutes | 17 | 10.0 | 10.0 | 10.0 |
| | Between 30 minutes and 1 hour | 84 | 49.4 | 49.4 | 59.4 |
| | Between 1 hour and 2 hours | 51 | 30.0 | 30.0 | 89.4 |
| | More than 2 hours | 18 | 10.6 | 10.6 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

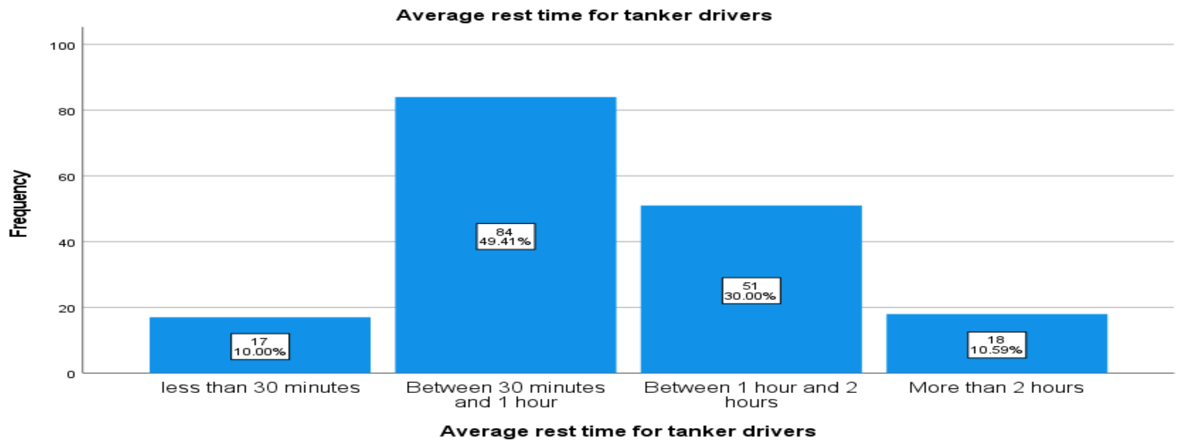



*Figure 36 Average rest time for tanker drivers*

As shown in Table 32 and Figure 36 above, 18 (10.1%) tanker drivers out of the 170 that participated in the survey are of the opinion that the average rest time for drivers transporting petroleum products should be more than 2 hours. 51 (30%) believed that the average rest time should be between 1 and 2 hours. 84 (49.4%) are of the opinion that rest time for drivers should be between 30 minutes and 1 hour while 17 (10%) believed that the average rest time for tanker drivers should be less than 30 minutes. From the analysis, there is an indication that an average rest time of between 30 minutes and 1 hour would be suitable for tanker drivers transporting petroleum products in Nigeria. Rest time is very important after driving for a period of time so that drivers are not fatigued and stressed while driving as these could lead to accidents on the road.

### 5.4.13 Respondent opinion on the use of PPE by tanker drivers

*Table 33 Importance of protective equipment*

| | | **Frequency** | **Percent** | **Valid Percent** | **Cumulative Percent** |
|---|---|---|---|---|---|
| **Valid** | Completely Disagree | 10 | 5.9 | 5.9 | 5.9 |
| | Disagree | 3 | 1.8 | 1.8 | 7.6 |
| | Neither Agree nor Disagree | 13 | 7.6 | 7.6 | 15.3 |
| | Agree | 97 | 57.1 | 57.1 | 72.4 |
| | Completely Agree | 47 | 27.6 | 27.6 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

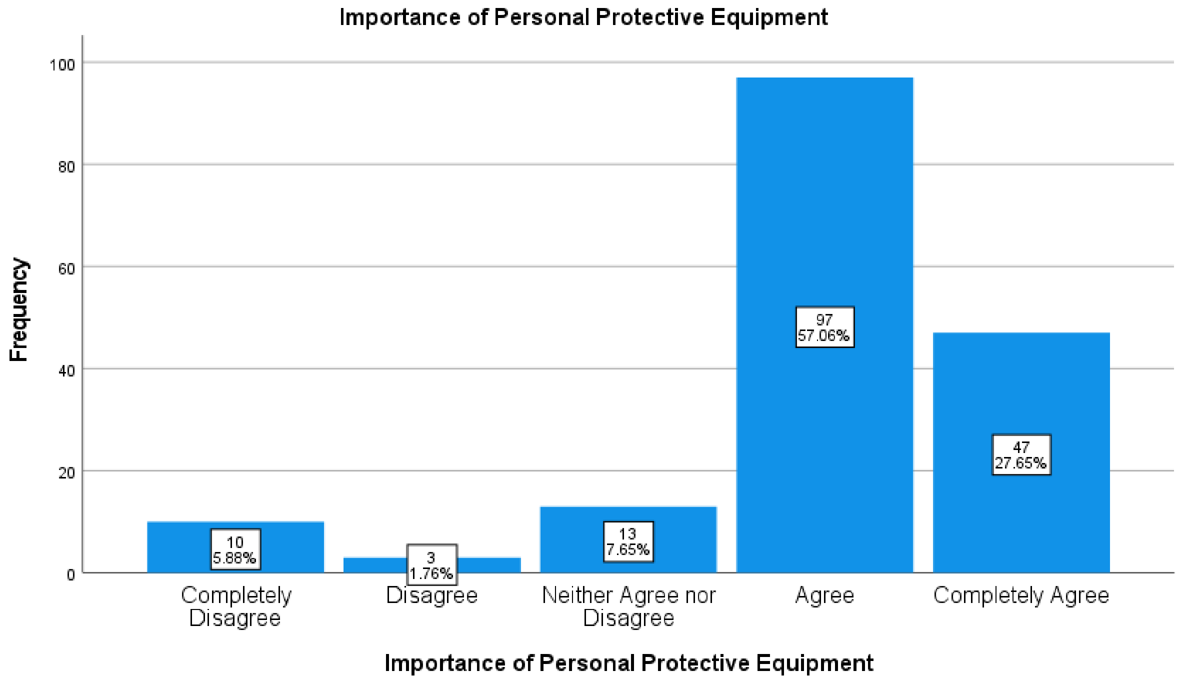



*Figure 37 Importance of protective equipment*

As shown in Table 33 and Figure 37 above, 47 (27.7%) drivers out of the 170 that took part in the survey completely agreed that personal protective equipment (PPE) are necessary for tanker drivers when transporting petroleum products while 97 (57.1%) agreed that PPE are necessary for tanker drivers. 10 (5.9%) drivers completely disagree that PPE are necessary for tanker drivers while 3 (1.8%) drivers disagreed that PPE are necessary for tanker drivers. 13 (1.8%) neither agreed nor disagreed that PPE are necessary for tanker drivers. From the analysis, there is a strong indication that PPE are very necessary for tanker drivers during the transportation of petroleum products.

### 5.4.14 Respondents' opinion between operations of major oil marketers and independent oil marketers

*Table 34 Operations of Major and Independent oil marketers*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Ops of Multinational much safer | 98 | 57.6 | 57.6 | 57.6 |
| | Ops of Multinational slightly safer | 54 | 31.8 | 31.8 | 89.4 |
| | Ops of Multinational equally safer | 15 | 8.8 | 8.8 | 98.2 |
| | Ops of Independent slightly safer | 3 | 1.8 | 1.8 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

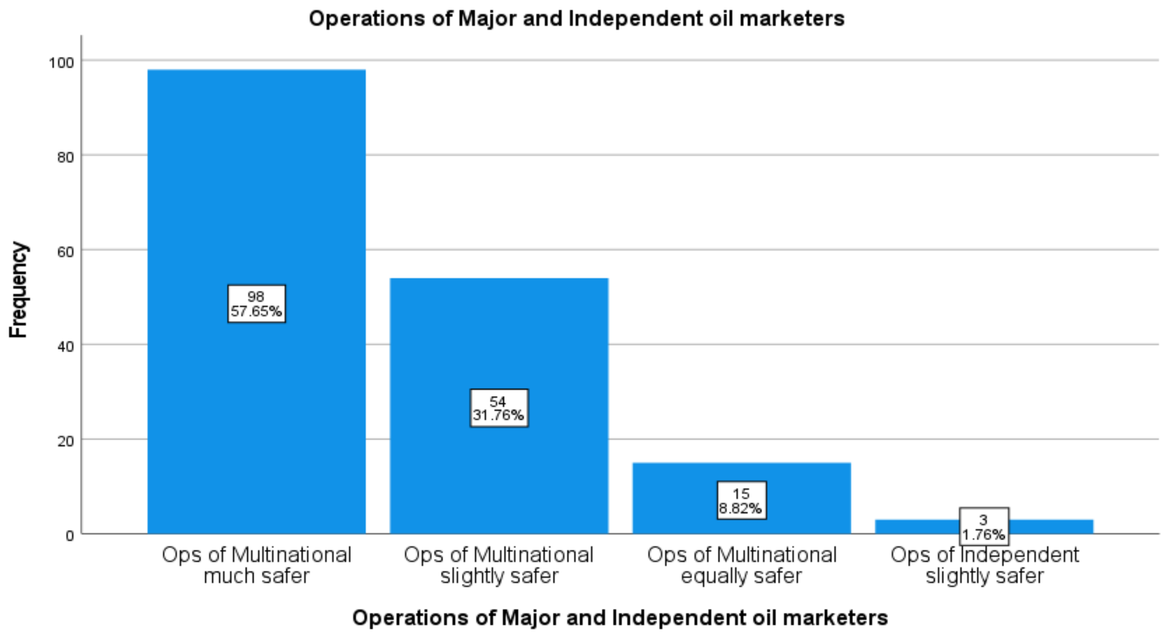



*Figure 38 Operations of Major and Independent oil marketers*

As shown in Table 34 and Figure 38 above, 98 (57.7%) tanker drivers out of the 170 drivers that participated in the survey are of the opinion that the operations of the major oil marketers are much safer than the independent oil marketers. 54 (31.8%) believed that the operations of the major oil marketers are slightly safer than the independent oil marketers. 15 (8.8%) believed that the operations of the major oil marketers are equally safer as the independent oil marketers while 3 (1.8%) are of the opinion that the operations of the independent companies are slightly safer than that of the major oil marketers. From the analysis, there is a strong indication that the operations of the major oil marketers are much safer than that of the independent oil marketers in Nigeria.

5.4.15 Respondents' opinion about cleaning of spilled products after tanker accidents

*Table 35 Spilled products after a tanker accident on the road*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Do not know | 102 | 60.0 | 60.0 | 60.0 |
| | Channelled into a well | 8 | 4.7 | 4.7 | 64.7 |
| | collected by environmental experts | 11 | 6.5 | 6.5 | 71.2 |
| | Nothing is done about spilled products | 49 | 28.8 | 28.8 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

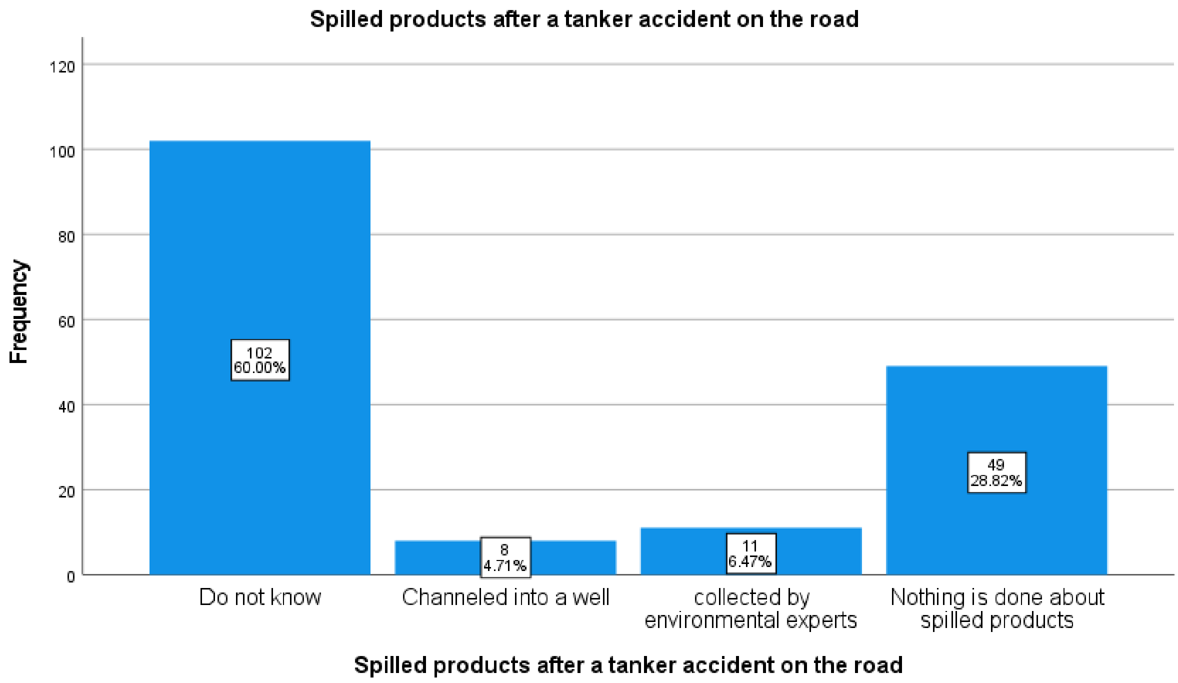



*Figure 39 Spilled products after a tanker accident on the road*

As shown in Table 35 and Figure 39 above, 102 (60%) tanker drivers out of the 170 drivers that participated in the survey do know what happens to spilled products after a tanker accident. 8 (4.7%) drivers are of the opinion that the spilled products are channelled into a well while 11 (6.5%) drivers are of the opinion that the spilled products are collected by environmental experts. 49 (28.8%) are of the opinion that nothing is done about spilled products after a tanker accident. From the analysis, there is a strong indication that tanker drivers in Nigeria do not know what happened to spilled products after a tanker accident. Recent incidents in involving tanker accidents in Nigeria revealed that petroleum products are being scooped by people in the community where a tanker accident happens. This has resulted in fire explosions that have claimed many lives.

## 5.5 Analysis of factors causing road tanker accidents in Nigeria

The aim of this research is to develop a safety framework for accident mitigation during road tanker transportation of petroleum products. The second and third research questions for this study are: 1. What are the contributory factors to the causes of tanker accidents in Nigeria during the transportation and distribution of petroleum products? 2. What are the major challenges faced by tanker drivers during the transportation and distribution of petroleum products? The analysis in this section would be used to answer research questions two and three. To answer these research questions, a descriptive statistic mainly frequency of the respondents rating of the level of importance of factors causing accidents would be performed and presented with a bar chat.

### 5.5.1 Respondents Rating of Lack of Assistive Technologies in Tankers as a Factor Causing Accidents.

*Table 36 Assistive Technologies*

| | | **Frequency** | **Percent** | **Valid Percent** | **Cumulative Percent** |
|---|---|---|---|---|---|
| **Valid** | Not at all important | 9 | 5.3 | 5.3 | 5.3 |
| | Slightly important | 13 | 7.6 | 7.6 | 12.9 |
| | Moderately important | 13 | 7.6 | 7.6 | 20.6 |

| | | | | | |
|---|---|---|---|---|---|
| | Very important | 97 | 57.1 | 57.1 | 77.6 |
| | Extremely important | 38 | 22.4 | 22.4 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

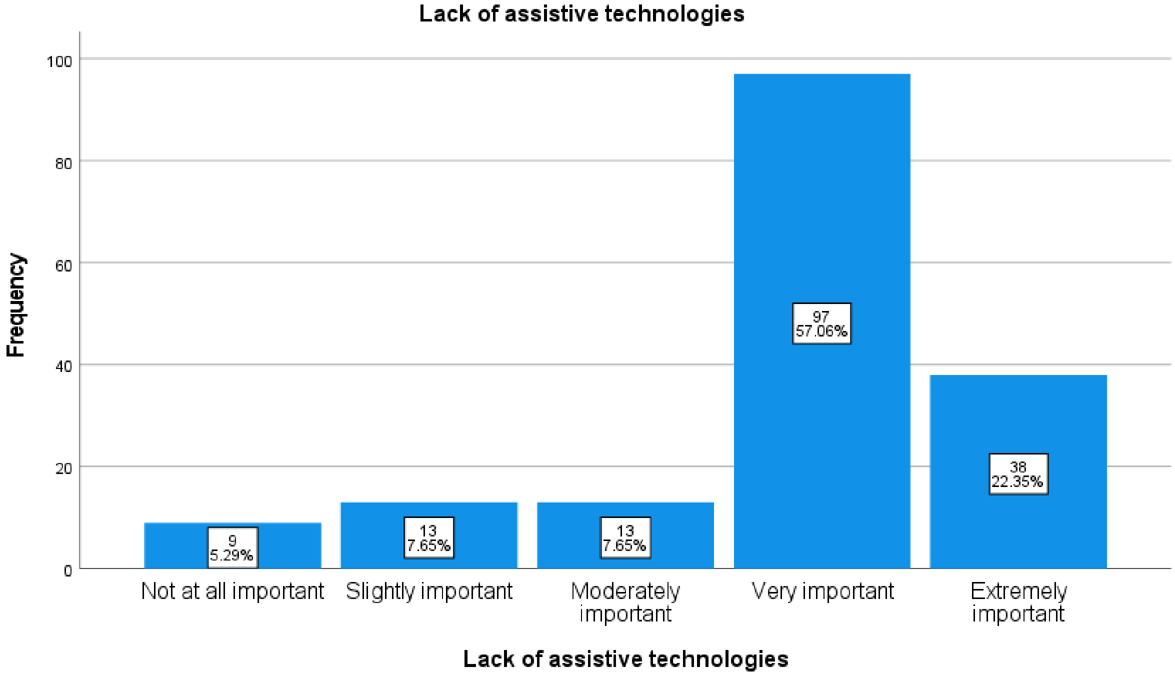



*Figure 40 Assistive Technologies*

As shown in Table 36, and Figure 40 above, 135 respondents representing 79.4% of the total 170 respondents were of the opinion that the lack of assistive technologies is either very important or extremely important as a factor causing accidents in Nigeria. 13(7.6%) respondents and 13(7.6%) respondents were of the opinion that lack of assistive technologies is slightly important and moderately important respectively. Only 9 respondents representing 5.3% were of the opinion that the lack of assistive technologies is not at all important in the causing tanker accidents. From the above analysis, there is a strong indication that the lack of assistive technologies is a causative factor for accidents in Nigeria. According to Olsheski *et., al* (2011) the aim of this technology is to increase driver safety by taking individual cognitive abilities and limitations into account. For instance, this technology was used to assist drivers with traumatic brain injury (TBI) to overcome the impairments that limit driving ability and regain some independence by driving after injury (Olsheski *et. al* 2011). In Nigeria, many drivers have been unable to drive after being affected by serious accident in the course of their job. This kind of technology would help to build confidence in drivers that have been affected by accidents.

5.5.2 Respondents Rating of Poor Road Conditions as a Factor Causing Accidents.

*Table 37 Road Conditions*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Not at all important | 5 | 2.9 | 2.9 | 2.9 |
| | Slightly important | 3 | 1.8 | 1.8 | 4.7 |
| | Moderately important | 6 | 3.5 | 3.5 | 8.2 |
| | Very important | 112 | 65.9 | 65.9 | 74.1 |
| | Extremely important | 44 | 25.9 | 25.9 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

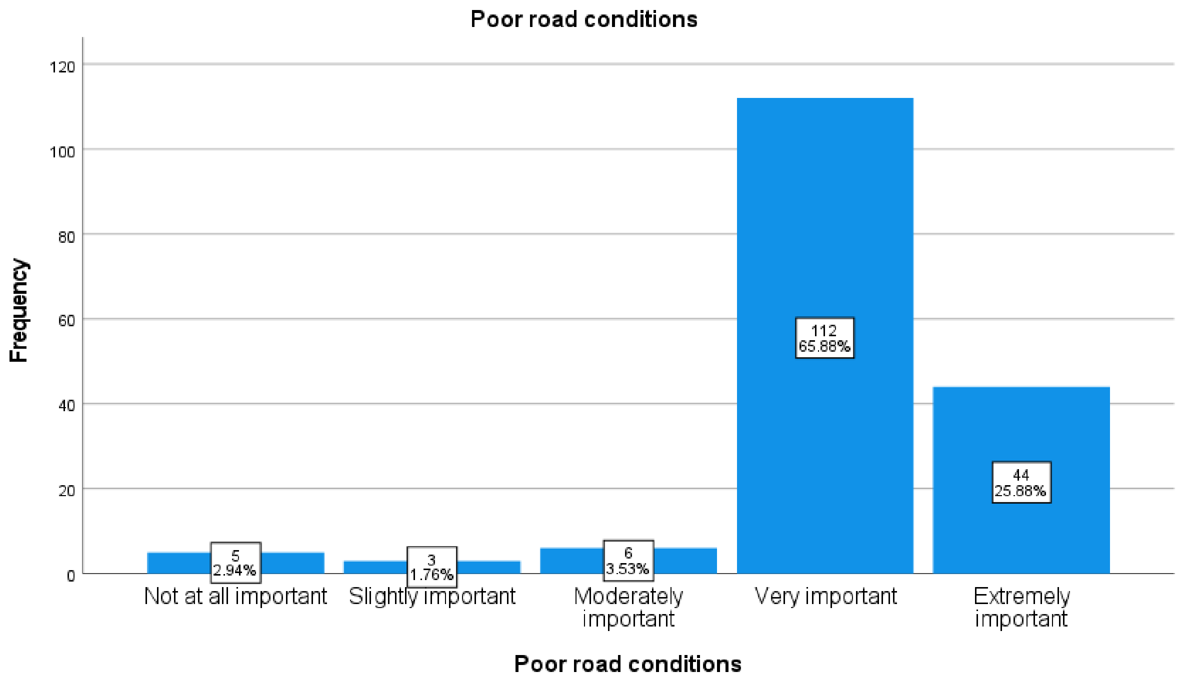



*Figure 41 Road Conditions*

As shown in Table 37 and Figure 41 above, 156 respondents representing 91.8% of the total 170 respondents that completed the questionnaires are of the opinion that poor road conditions is either very important or extremely important as a factor causing road accidents in Nigeria. 3(1.8%) respondents and 6(3.5%) respondents are of the opinion that poor road conditions are either slightly important or moderately important respectively as a factor causing accident while 5 respondents representing 2.9% are of the opinion that poor road condition is not at all important a factor that causes road accidents. From the analysis, there is a strong indication that poor road condition is a factor that causes road accidents in Nigeria. The impact of poor road condition in Nigeria was discussed in the literature review of this study.

### 5.5.3 Respondents Rating of Extreme Weather Conditions as a Factor Causing Accidents.

*Table 38 Weather Conditions*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Not at all important | 28 | 16.5 | 16.5 | 16.5 |
| | Slightly important | 29 | 17.1 | 17.1 | 33.5 |
| | Moderately important | 10 | 5.9 | 5.9 | 39.4 |
| | Very important | 86 | 50.6 | 50.6 | 90.0 |
| | Extremely important | 17 | 10.0 | 10.0 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

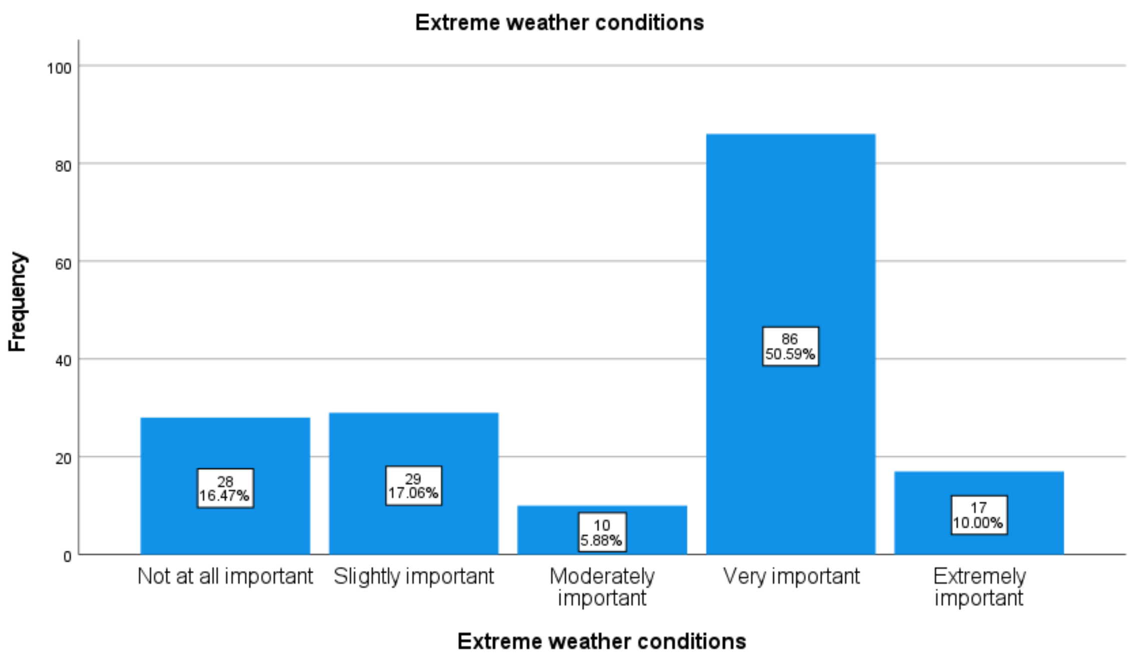



*Figure 42 Weather Conditions*

As shown in Table 38 and Figure 42 above, 103 respondents representing 60.1% of the total 170 respondents are of the opinion that extreme weather conditions are either very important or extremely important as a factor causing road accidents in Nigeria. 29 (17.1%) and 10 (5.9%) are of the opinion that severe weather conditions are slightly important and moderately important respectively as a factor causing accident. 28 respondents representing 16.5% are of the opinion that severe weather conditions are not at all important as a factor causing accident. From the analysis, there is an indication that severe weather conditions could cause accidents on the road. In Nigeria, the weather conditions are mainly of two types: rainy season and the dry season. Both are very harsh conditions. The risk of the weather condition becomes even higher coupled with the bad condition of the roads, leading to accidents on the road. The impact of severe weather conditions has been discussed in the literature review chapter of this research.

### 5.5.4 Respondents Rating of Overloading of Trucks as a Factor Causing Accidents.

*Table 39 Overloading of Truck*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Not at all important | 9 | 5.3 | 5.3 | 5.3 |
| | Slightly important | 36 | 21.2 | 21.2 | 26.5 |
| | Moderately important | 14 | 8.2 | 8.2 | 34.7 |
| | Very important | 89 | 52.4 | 52.4 | 87.1 |
| | Extremely important | 22 | 12.9 | 12.9 | 100.0 |

| | | | | | |
|---|---|---|---|---|---|
| | Total | 170 | 100.0 | 100.0 | |

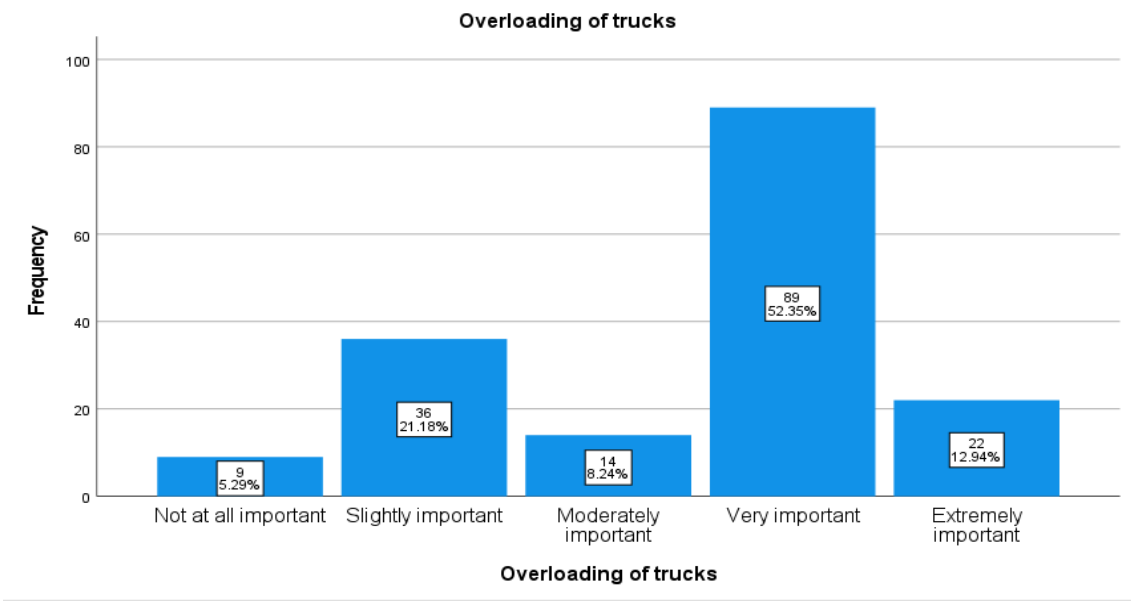



*Figure 43 Overloading of Truck*

As shown in Table 39 and Figure 43 above, 111 respondents representing 48.8% of the total 170 respondents are of the opinion that overloading of trucks are either very important or extremely important as a factor that causes road accidents in Nigeria. 36 respondents (21.2%) and 14 respondents (8.2%) respectively are of the opinion that overloading of trucks are slightly important and moderately important as a factor causing accident. Only 7 respondents (8.8%) are of the opinion that overloading of trucks are not at all important as a factor causing accident. From the analysis, there is an indication that overloading of trucks are a cause of accidents in Nigeria. Aggarwal and Parameswaran (2015) performed a study to observe the relationship between prevalent truck overloading and fatigue damage accumulation as studies suggests overweight trucks could have an impact on the fatigue life of a highway bridge, thus increasing the stress range substantially if trucks are overloaded.

5.5.5 Respondents Rating of Poorly Maintained Truck as Factors Causing Accidents.

*Table 40 Poorly Maintained Trucks*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Not at all important | 4 | 2.4 | 2.4 | 2.4 |
| | Slightly important | 5 | 2.9 | 2.9 | 5.3 |
| | Moderately important | 4 | 2.4 | 2.4 | 7.6 |
| | Very important | 119 | 70.0 | 70.0 | 77.6 |
| | Extremely important | 38 | 22.4 | 22.4 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

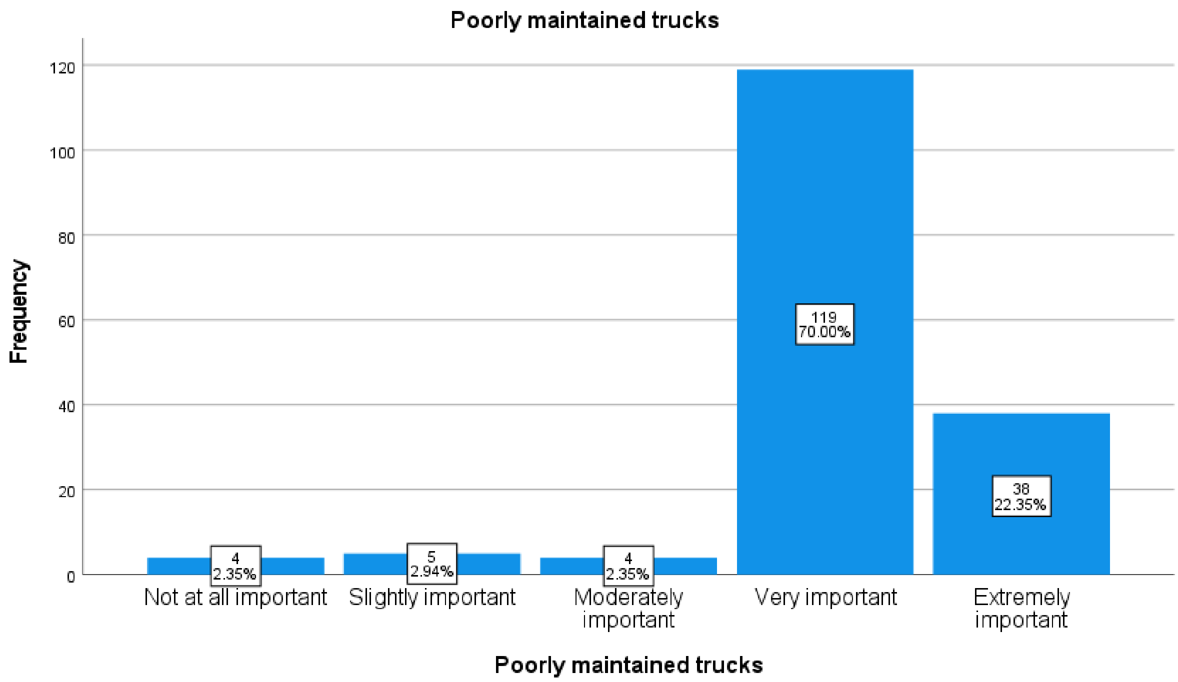



*Figure 44 Poorly Maintained Trucks*

As shown in Table 40 and Figure 44 above, 157 respondents representing 92.4% out of the total 170 respondents are of the opinion that poorly maintained trucks are either very important or extremely important factor that causes accidents in Nigeria. Only 4 respondents representing 2.4%% is of the opinion that poorly maintained trucks are not at all important as a factor causing accident. 5 respondents (2.9%) and 4 respondents (2.4%) are of the opinion that poorly maintained trucks are either slightly important or moderately important as a factor causing accident. From the analysis, there is an indication that poorly maintained trucks are a major cause of accidents in Nigeria. The impact of poorly maintained trucks on road accidents have been discussed in the literature review chapter.

### 5.5.6 Respondents Rating of Insufficient Rest Time during Travel as a Factor Causing Accidents.

*Table 41 Insufficient Rest Time During Travel*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Not at all important | 9 | 5.3 | 5.3 | 5.3 |
| | Slightly important | 16 | 9.4 | 9.4 | 14.7 |
| | Moderately important | 9 | 5.3 | 5.3 | 20.0 |
| | Very important | 102 | 60.0 | 60.0 | 80.0 |
| | Extremely important | 34 | 20.0 | 20.0 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

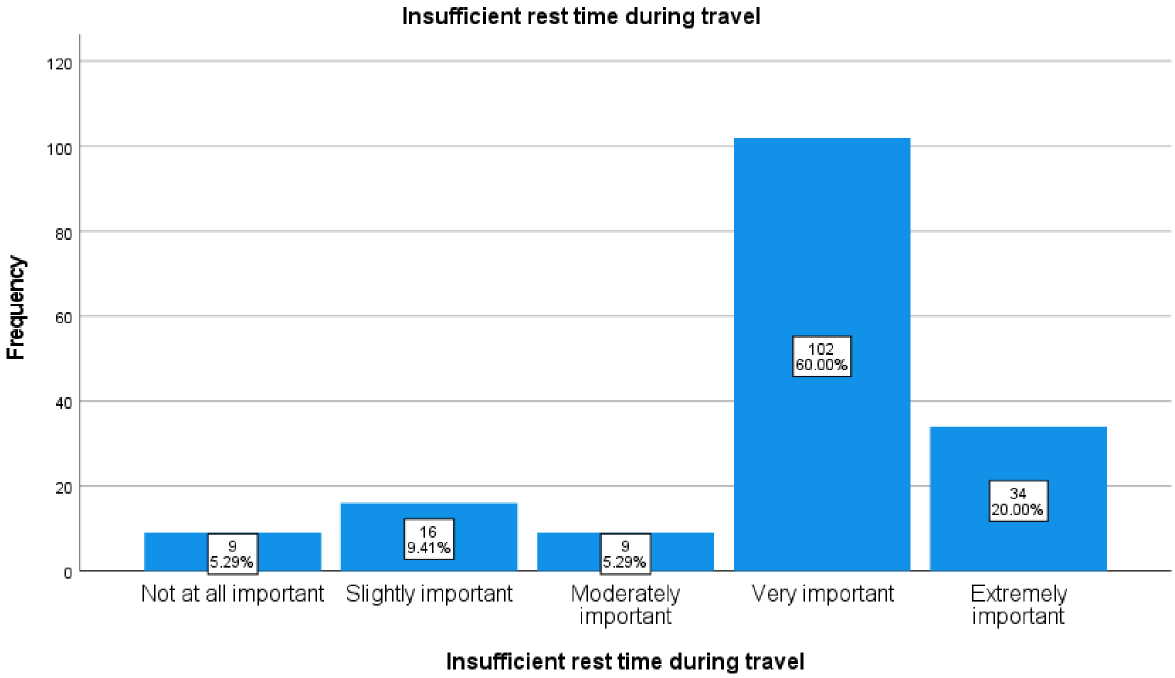



*Figure 45 Insufficient Rest Time During Travel*

As shown in Table 41 and Figure 45 above, 136 respondents representing 80% of the total 170 respondents are of the opinion that insufficient rest time by during travel is either a very or extremely important factor that causes accidents in Nigeria. 16 respondents (9.4%) and 9 respondents (5.3%) are of the opinion that insufficient rest time during travel is slightly and moderately important respectively as a factor causing accident. Only 9 respondents representing 5.3% are of the opinion that insufficient rest time during travel is not at all an important factor causing road accident. From the analysis, there is an indication that insufficient rest time during travel is a factor that causes road accidents in Nigeria. Tanker drivers in Nigeria travel long distances and they do not observe rest time in most cases as they are always in a hurry to get back to the depot and get their trucks loaded with products (see literature review).

### 5.5.7 Respondents Rating of Lack of Regulatory Frameworks as a Factor Causing Accidents

*Table 42 Lack of Regulatory Framework*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Not at all important | 27 | 15.9 | 15.9 | 15.9 |
| | Slightly important | 66 | 38.8 | 38.8 | 54.7 |
| | Moderately important | 16 | 9.4 | 9.4 | 64.1 |
| | Very important | 49 | 28.8 | 28.8 | 92.9 |
| | Extremely important | 12 | 7.1 | 7.1 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

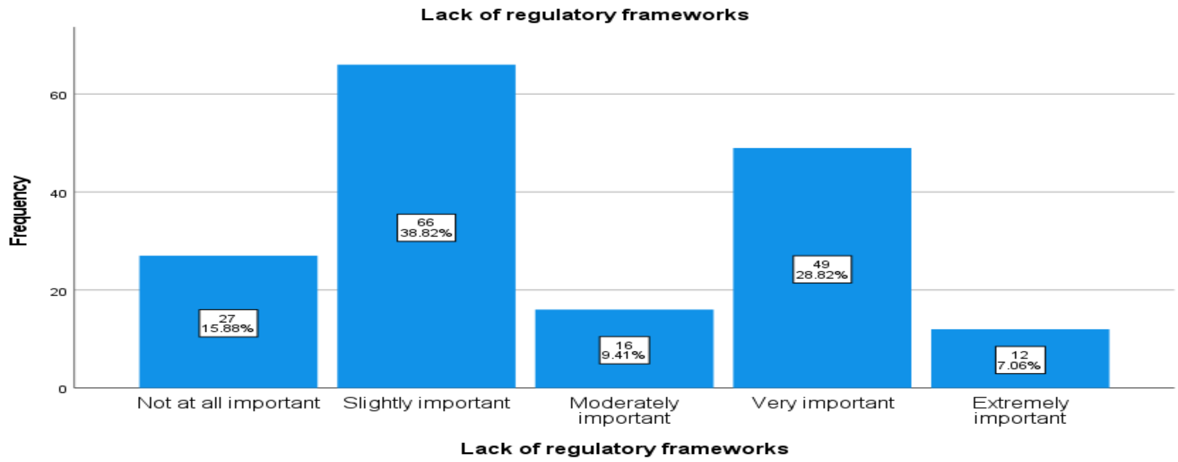



*Figure 46 Lack of Regulatory Framework*

As shown in Table 42 and Figure 46 above, 61 respondents representing 35.9%% of the total 170 respondents are of the opinion that a lack of regulatory frameworks is either a very or extremely important factor that causes accidents in Nigeria. 27 respondents representing 15.9% are of the opinion that a lack of regulatory frameworks is not at all an important factor causing road accidents while 66 respondents (38.8%) and 16 respondents (9.4%) are of the opinion that lack of regulatory frameworks is either slightly important or moderately important respectively as a factor causing accident. From the analysis, there is an indication that a lack of regulatory frameworks is a factor that causes road accidents in Nigeria. The enforcement of regulations as it relates to transportation in Nigeria is very weak. There are no adequate penalties for breaking traffic laws and most drivers do not see anything wrong with it until an accident occur. The literature review of this research discusses the U.S and EU laws governing the transportation of dangerous goods.

### 5.5.8 Respondents Rating of Inadequate Training for Drivers as a Factor Causing Accidents.

*Table 43 Inadequate Driver Training*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Not at all important | 7 | 4.1 | 4.1 | 4.1 |
| | Slightly important | 36 | 21.2 | 21.2 | 25.3 |
| | Moderately important | 11 | 6.5 | 6.5 | 31.8 |
| | Very important | 87 | 51.2 | 51.2 | 82.9 |
| | Extremely important | 29 | 17.1 | 17.1 | 100.0 |

| | | | | | |
|---|---|---|---|---|---|
| | Total | 170 | 100.0 | 100.0 | |

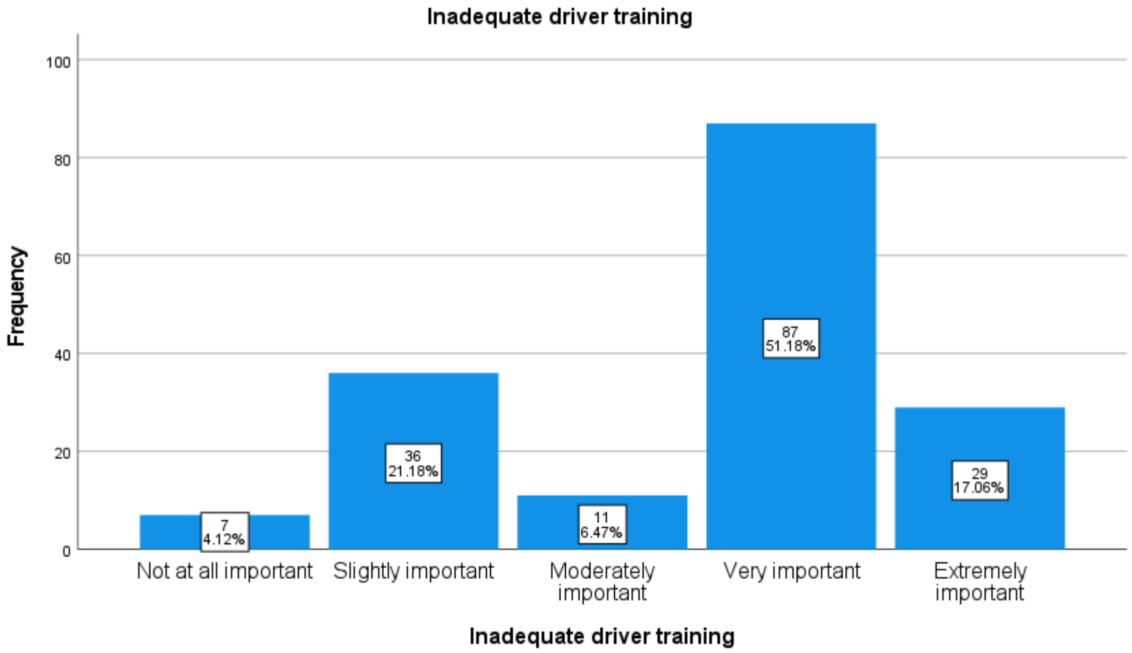



*Figure 47 Inadequate Driver Training*

As shown in Table 43 and Figure 47 above, 116 respondents representing 68.2% of the total 170 respondents are of the opinion that inadequate training for drivers is either a very or extremely important factor that causes accidents in Nigeria. 36 respondents (21.2%) and 11 respondents (6.5%) are of the opinion that inadequate training for drivers is slightly and moderately important respectively as a factor causing accident. Only 7 respondents representing 4.1% are of the opinion that inadequate training for drivers is not at all an important factor causing road accidents. From the analysis, there is an indication that inadequate training for drivers is a factor that causes road accidents in Nigeria. The importance for training for drivers cannot be over emphasized. It is even more important for tanker drivers due to the dangerous nature of the substances they are transporting. For instance, Manzoor (2020) performed a study to identify the essential competencies needed by HAZMAT transportation drivers to deal with emergencies. The study identified six (6) core and 23 sub-competencies of HAZMAT drivers and one of the recommendations from the study was the integration of these competencies into a development and training program for drivers will better enable drivers to handle emergencies in an efficient and effective manner.

## 5.6 Training

### 5.6.1 Drivers' knowledge of hazardous materials

*Table 44 Drivers' knowledge of hazardous materials*

| | | **Frequency** | **Percent** | **Valid Percent** | **Cumulative Percent** |
|---|---|---|---|---|---|
| **Valid** | Not at all concerned | 8 | 4.7 | 4.7 | 4.7 |
| | Slightly concerned | 11 | 6.5 | 6.5 | 11.2 |
| | Moderately concerned | 15 | 8.8 | 8.8 | 20.0 |
| | Very concerned | 102 | 60.0 | 60.0 | 80.0 |
| | Extremely concerned | 34 | 20.0 | 20.0 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

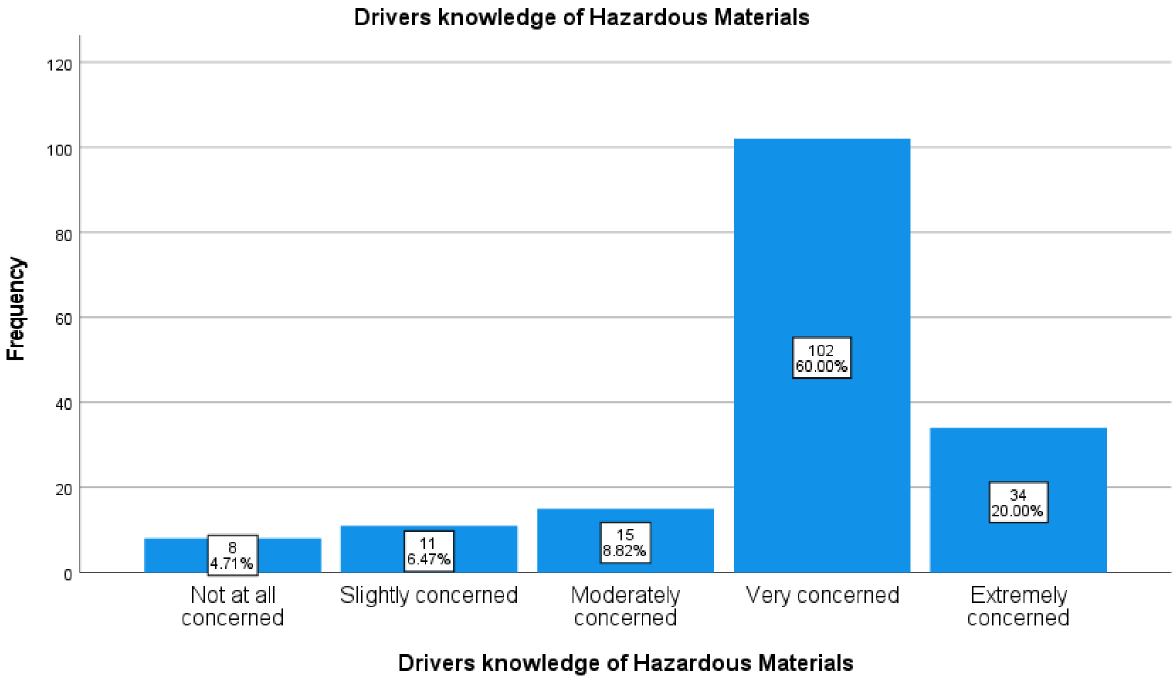



*Figure 48 Drivers' knowledge of hazardous materials*

As shown in Table 44 and Figure 48 above, 136 drivers representing 80% of the total sample are either very concerned or extremely concerned about drivers' knowledge of hazmat. 15 drivers representing 8.8% are moderately concerned about driver knowledge of hazmat while 11 drivers representing 6.5% are slightly concerned about drivers' knowledge of hazmat. Only 8 tanker drivers are responded as "Not at all concern" about drivers' knowledge of hazardous materials. From the analysis, there is a strong indication that drivers are very concerned about hazardous materials and want to gain more knowledge about the products they are transporting. This is a call for all transport operators to ensure that adequate training are given to all the drivers in their fleet.

### 5.6.2 Drivers concerns about knowledge of safety procedures

*Table 45 Driver's knowledge of safety procedures*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Not at all concerned | 6 | 3.5 | 3.5 | 3.5 |
| | Slightly concerned | 8 | 4.7 | 4.7 | 8.2 |
| | Moderately concerned | 12 | 7.1 | 7.1 | 15.3 |
| | Very concerned | 107 | 62.9 | 62.9 | 78.2 |
| | Extremely concerned | 37 | 21.8 | 21.8 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

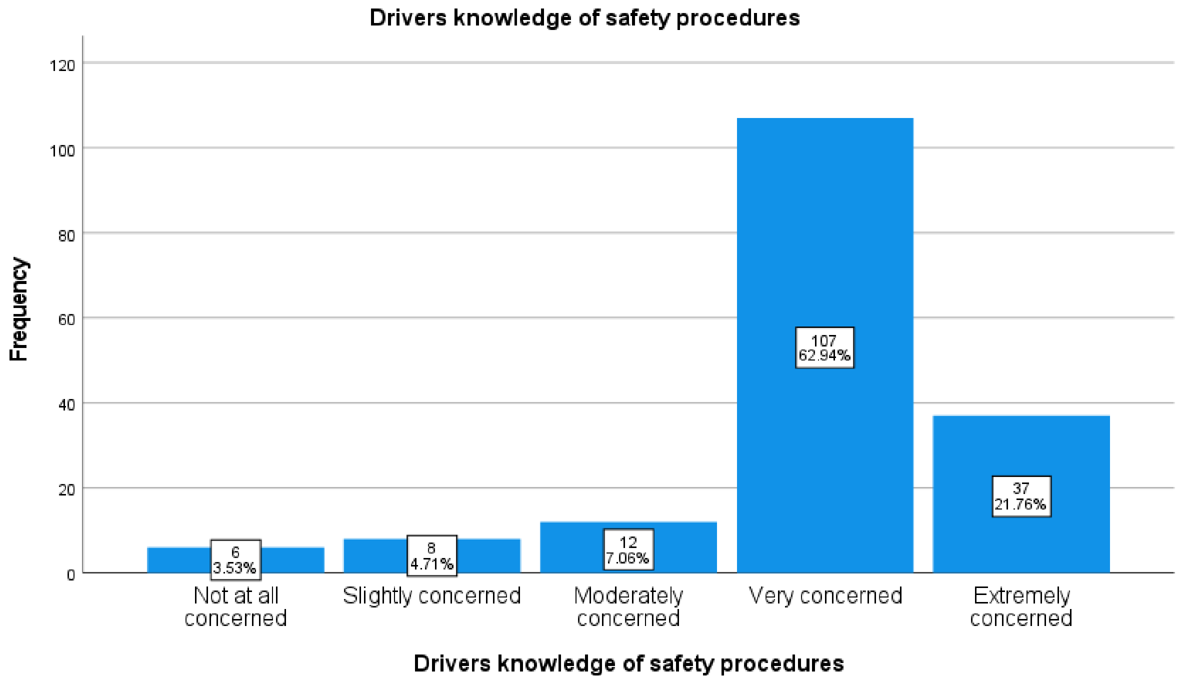



*Figure 49 Driver's knowledge of safety procedures*

As shown in Table 45 and Figure 49 above, 144 tanker drivers representing 84.7% of the total drivers that took part in the survey are either very concerned or extremely concerned about drivers' knowledge of safety procedures. 12 drivers representing 7.1% are moderately concerned about drivers' knowledge of safety procedures while 8 drivers of the drivers representing 4.7% are slightly concerned about drivers' knowledge of safety procedures. The results indicates that drivers are concerned with the knowledge of safety procedures in performing their job.

### 5.6.3 Drivers' opinion about the importance of continuous training

*Table 46 Importance of continuous training for tanker drivers*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Not at all important | 6 | 3.5 | 3.5 | 3.5 |
| | Slightly important | 3 | 1.8 | 1.8 | 5.3 |
| | Moderately important | 4 | 2.4 | 2.4 | 7.6 |
| | Very important | 120 | 70.6 | 70.6 | 78.2 |
| | Extremely important | 37 | 21.8 | 21.8 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

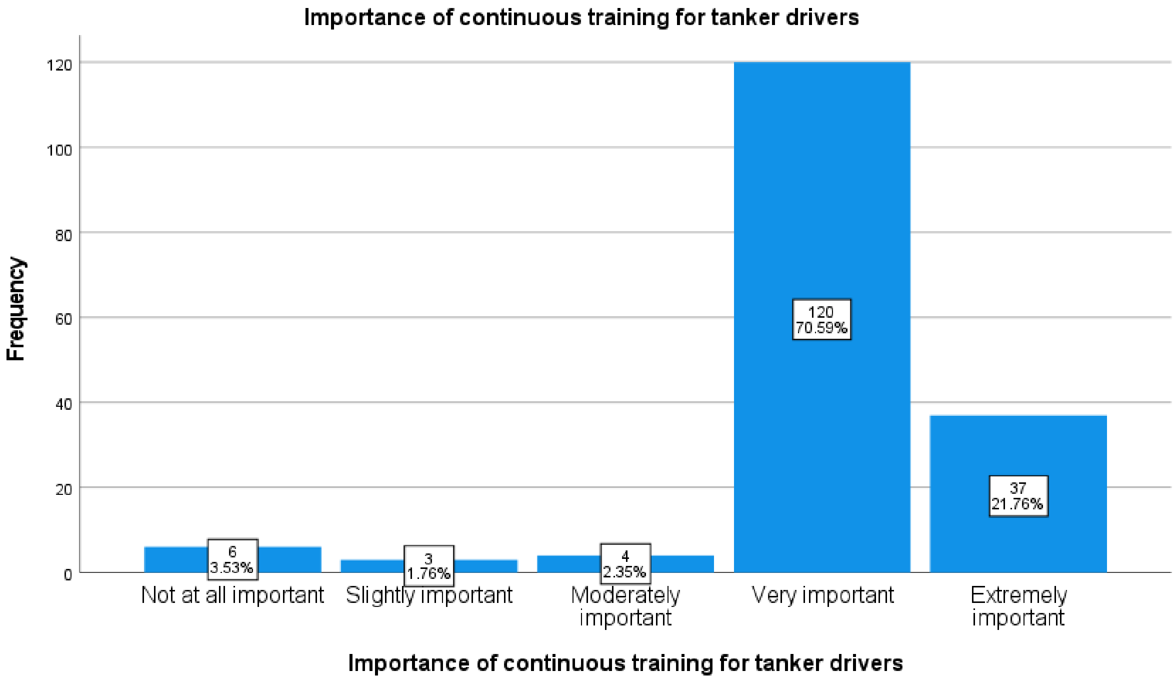



*Figure 50 Importance of continuous training for tanker drivers*

As shown in Table 46 and Figure 50 above, 157 tanker drivers representing 92.4% of the total drivers that took part in the survey are of the opinion that continuous training is either very important or extremely important for drivers transporting petroleum products. This result is a very strong indication that drivers believe in continuous so that their knowledge about hazmat transportation can be regularly updated. The importance of training for hazmat drivers has been discussed in chapter two.

## 5.7 Regulations

### 5.7.1 Drivers' opinion about speed defining maximum speed limits on the road during the transportation of petroleum products?

*Table 47 Defining maximum speed limits for tankers on the road*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Inappropriate | 3 | 1.8 | 1.8 | 1.8 |
| | Slightly inappropriate | 6 | 3.5 | 3.5 | 5.3 |
| | Neutral | 9 | 5.3 | 5.3 | 10.6 |
| | Slightly Appropriate | 72 | 42.4 | 42.4 | 52.9 |
| | Appropriate | 80 | 47.1 | 47.1 | 100.0 |
| | Total | 170 | 100.0 | 100.0 | |

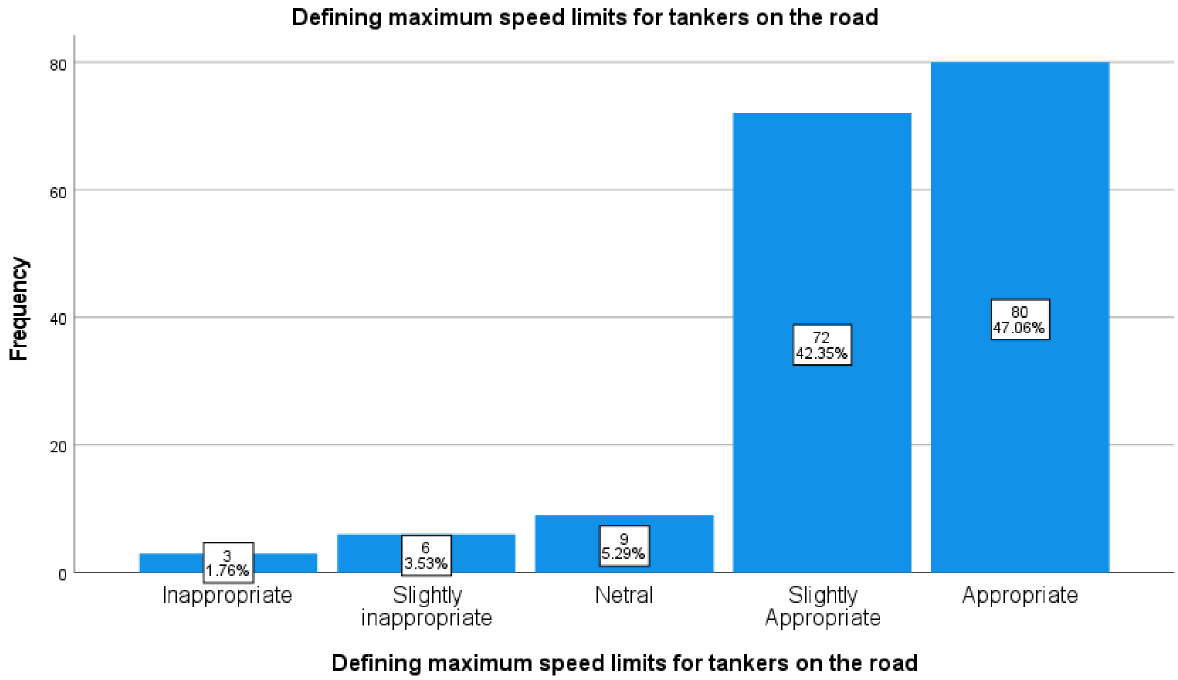



*Figure 51 Defining maximum speed limits for tankers on the road*

As shown in Table 47 and Figure 51 above, 80 drivers representing 47.1% are of the opinion that defining speed limit for tanker drivers is appropriate while 72 drivers representing 42.4% are of the opinion that defining speed limits for tanker drivers is slightly appropriate. 9 (5.3%) are neutral while 6 (3.5%) and 3 (1.8%) are of the opinion that the definition of speed limits for tanker drivers is slightly inappropriate and inappropriate respectively. The results show that drivers are aware of over speeding especially when transporting hazmat, however, drivers do not want to spend time on the road as some of them are paid per the trips they make. This makes drivers to speed and overtake other vehicles on the road to make more trips to earn better wages. This has led to cases of accidents in Nigeria because the roads are in poor conditions.

## 5.8 Correlations Between Variables Using Spearman’s Correlation

This section presents results of the analysis of the relationship between some the key variables identified in the quantitative analysis. This is to test if one variable has a relationship or correlation with another variable. In order to perform this test, the Spearman’s non parametric correlation was used.

### 5.8.1 Relationship between ages of drivers and views on importance of training

*Table 48 Importance of training for tanker drivers*

| | | | **Completely Disagree** | **Disagree** | **Neither Agree nor Disagree** | **Agree** | **Completely Agree** | **Total** |
|---|---|---|---|---|---|---|---|---|
| **Age of drivers** | 20 - 30 years | Count | 1 | 0 | 1 | 16 | 4 | 22 |
| | | % Within Age of drivers | 4.5% | 0.0% | 4.5% | 72.7% | 18.2% | 100.0% |
| | | % Within Importance of training for tanker drivers | 25.0% | 0.0% | 20.0% | 13.8% | 10.0% | 12.9% |
| | | % of Total | 0.6% | 0.0% | 0.6% | 9.4% | 2.4% | 12.9% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 31 - 40 years | Count | 1 | 0 | 0 | 17 | 9 | 27 |
| | | % Within Age of drivers | 3.7% | 0.0% | 0.0% | 63.0% | 33.3% | 100.0% |
| | | % Within Importance of training for tanker drivers | 25.0% | 0.0% | 0.0% | 14.7% | 22.5% | 15.9% |
| | | % of Total | 0.6% | 0.0% | 0.0% | 10.0% | 5.3% | 15.9% |
| | 41 -50 years | Count | 2 | 1 | 2 | 28 | 10 | 43 |
| | | % within Age of drivers | 4.7% | 2.3% | 4.7% | 65.1% | 23.3% | 100.0% |
| | | % Within Importance of training for tanker drivers | 50.0% | 20.0% | 40.0% | 24.1% | 25.0% | 25.3% |
| | | % of Total | 1.2% | 0.6% | 1.2% | 16.5% | 5.9% | 25.3% |
| | 51 -60 years | Count | 0 | 4 | 2 | 52 | 16 | 74 |
| | | % within Age of drivers | 0.0% | 5.4% | 2.7% | 70.3% | 21.6% | 100.0% |
| | | % within Importance of training for tanker drivers | 0.0% | 80.0% | 40.0% | 44.8% | 40.0% | 43.5% |
| | | % of Total | 0.0% | 2.4% | 1.2% | 30.6% | 9.4% | 43.5% |
| | | Count | 0 | 0 | 0 | 3 | 1 | 4 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 61 -70 years | % within Age of drivers | 0.0% | 0.0% | 0.0% | 75.0% | 25.0% | 100.0% |
| | | % within Importance of training for tanker drivers | 0.0% | 0.0% | 0.0% | 2.6% | 2.5% | 2.4% |
| | | % of Total | 0.0% | 0.0% | 0.0% | 1.8% | 0.6% | 2.4% |
| Total | | Count | 4 | 5 | 5 | 116 | 40 | 170 |
| | | % within Age of drivers | 2.4% | 2.9% | 2.9% | 68.2% | 23.5% | 100.0% |
| | | % within Importance of training for tanker drivers | 100.0% | 100.0% | 100.0% | 100.0 % | 100.0% | 100.0% |
| | | % of Total | 2.4% | 2.9% | 2.9% | 68.2% | 23.5% | 100.0% |

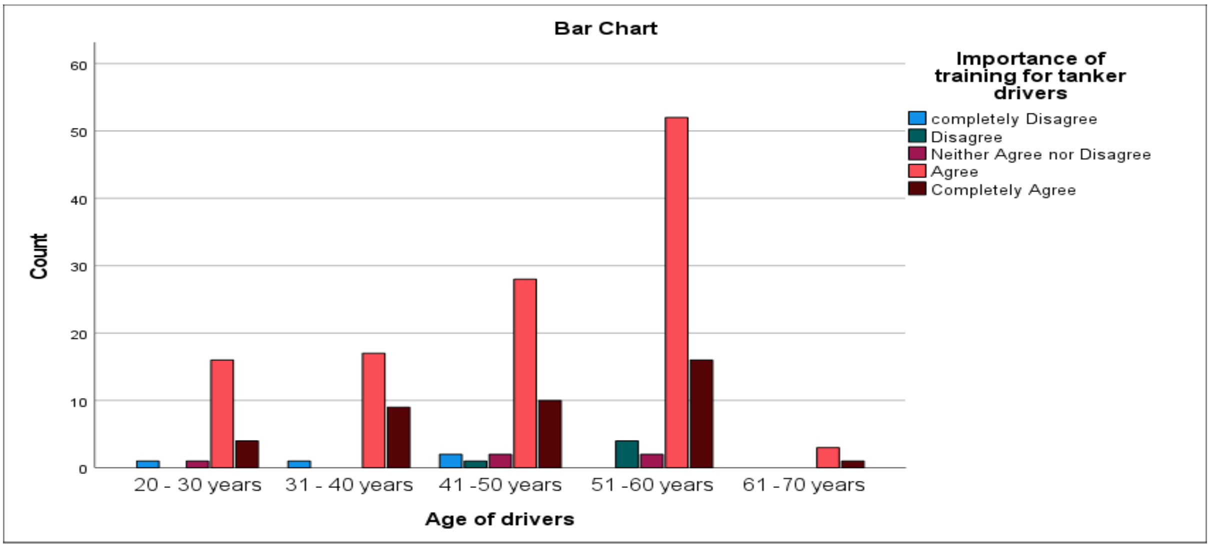


*Figure 52 Importance of training for tanker drivers*

The results on the cross tabulation between the ages of the tanker drivers and the importance of training for drivers as shown in Fig 53 suggests that more drivers in the age groups between 51-60 years (68) and 41-50 years (38) either agree or completely agree to the importance of training for tanker compared to 31 -40 years (26) and 20 – 30 years (20) who either agree or completely agree to the importance of training for tanker drivers. This further suggest that the older drivers see more need for training when compared to the younger drivers. The result is likely due to the fact that the older drivers have more life experience and as such tend to be more safety cautious on the road than the younger drivers who are much more risk takers and, in a hurry, to make more trips. The older drivers therefore see the need for training so that the younger drivers can benefit from it and be more safety cautious on the road.

### 5.8.2 Relationship between drivers' educational qualifications and knowledge of safety procedures.

*Table 49 Symmetric Measures*

| Symmetric Measures | | | | | |
|---|---|---|---|---|---|
| | | Value | Asymptotic Standard Error[a] | Approximate T[b] | Approximate Significance |
| Interval by Interval | Pearson's R | .251 | .071 | 3.365 | <.001[c] |
| Ordinal by Ordinal | Spearman Correlation | .272 | .070 | 3.660 | <.001[c] |
| N of Valid Cases | | 170 | | | |
| a. Not assuming the null hypothesis. | | | | | |

| |
|---|
| b. Using the asymptotic standard error assuming the null hypothesis. |
| c. Based on normal approximation. |

*Table 50 Crosstabulation between Educational Qualifications and Drivers knowledge of Safety Procedures*

| | | | Drivers' knowledge of safety procedures | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | | | Not at all concerned | Slightly concerned | Moderately concerned | Very concerned | Extremely concerned | |
| Educational Qualification | Primary school | Count | 5 | 8 | 10 | 56 | 15 | 94 |
| | | % Within Educational Qualification | 5.3% | 8.5% | 10.6% | 59.6% | 16.0% | 100.0% |
| | | % Within Drivers knowledge of safety procedures | 83.3% | 100.0% | 83.3% | 52.3% | 40.5% | 55.3% |
| | | % Of Total | 2.9% | 4.7% | 5.9% | 32.9% | 8.8% | 55.3% |
| | Secondary school | Count | 0 | 0 | 2 | 37 | 14 | 53 |
| | | % Within Educational Qualification | 0.0% | 0.0% | 3.8% | 69.8% | 26.4% | 100.0% |
| | | % Within Drivers knowledge of safety procedures | 0.0% | 0.0% | 16.7% | 34.6% | 37.8% | 31.2% |
| | | % Of Total | 0.0% | 0.0% | 1.2% | 21.8% | 8.2% | 31.2% |
| | OND/NCE | Count | 1 | 0 | 0 | 14 | 8 | 23 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | % Within Educational Qualification | 4.3% | 0.0% | 0.0% | 60.9% | 34.8% | 100.0% |
| | | % Within Drivers knowledge of safety procedures | 16.7% | 0.0% | 0.0% | 13.1% | 21.6% | 13.5% |
| | | % Of Total | 0.6% | 0.0% | 0.0% | 8.2% | 4.7% | 13.5% |
| Total | | Count | 6 | 8 | 12 | 107 | 37 | 170 |
| | | % Within Educational Qualification | 3.5% | 4.7% | 7.1% | 62.9% | 21.8% | 100.0% |
| | | % Within Drivers knowledge of safety procedures | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| | | % Of Total | 3.5% | 4.7% | 7.1% | 62.9% | 21.8% | 100.0% |

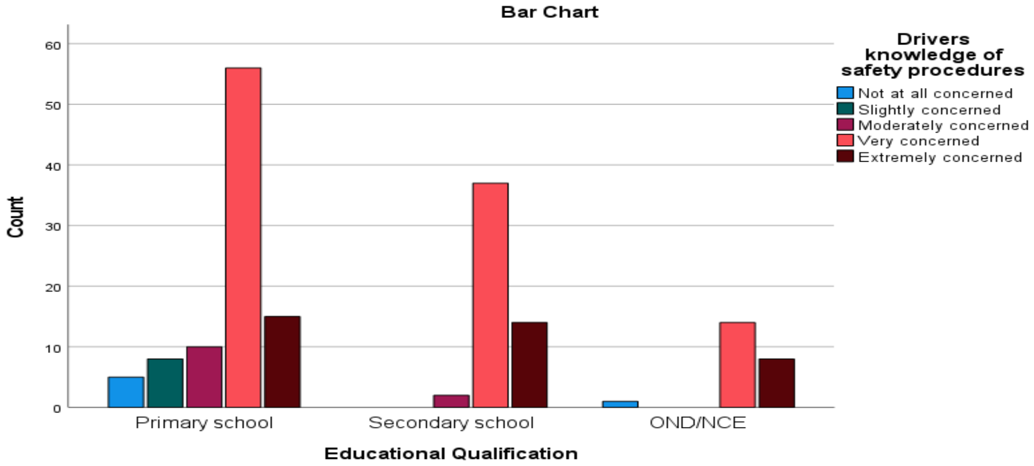



*Figure 53 Driver's knowledge of safety procedures*

The results as shown in Table 50 suggests that educational qualification have little relationship with drivers' knowledge of safety procedures. As seen in the table above, there are more drivers with primary education showing more concerns about knowledge of safety procedures than drivers with secondary and OND/NCE qualifications. Although, the analysis from the table also shows that there are few tanker drivers with OND/NCE qualifications which clearly shows that majority of tanker drivers in Nigeria either has a primary or secondary educational qualification. From this analysis, we can conclude that tanker drivers are concerned with knowledge of safety procedures despite their level of education.

Thus, the Spearman's correlation denoted by r for the above can be reported as:

$$r(df) = .27,\ p = <.001 \qquad \textit{Equation 3}$$

where df = degree of freedom which is N – 2, where N is the total sample size.

Therefore, df = 170 – 2 = 168.

$r(168) = .27$, $p = < .001$ which suggest a little relationship between educational qualification of drivers and their knowledge of safety procedures.

### 5.8.3 Relationship between drivers' educational qualifications and agreement to the use of route planning system technology

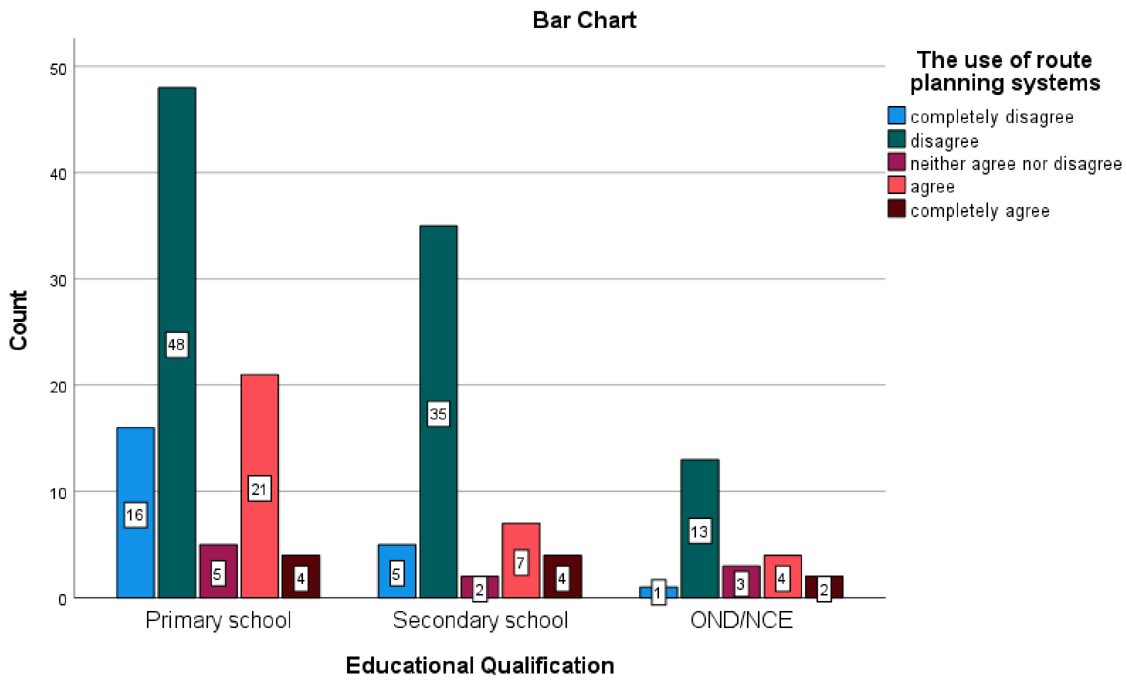



*Figure 54 Use of Route Planning Systems*

*Table 51 Use of Route Planning Systems*

| Spearman's Correlations | | | | |
|---|---|---|---|---|
| | | | Educational Qualification | The use of route planning systems |
| Spearman's rho | Educational Qualification | Correlation Coefficient | 1.000 | .062 |
| | | Sig. (2-tailed) | . | .419 |
| | | N | 170 | 170 |

| | | | | |
|---|---|---|---|---|
| | The use of route planning systems | Correlation Coefficient | .062 | 1.000 |
| | | Sig. (2-tailed) | .419 | . |
| | | N | 170 | 170 |

There is a positive correlation between the drivers' educational qualifications and their agreement to the use of the route planning system technology in trucks for the transportation of petroleum products in Nigeria.

r(168) = .06, p = .419 which suggests there is a relationship between the drivers educational qualification and their perception to the use of the route planning systems.

### 5.8.4 Correlation between Drivers Age and the Overloading of Trucks

*Table 52 Correlation between Drivers Age and the Overloading of Trucks*

**Correlations**

| | | | Age of drivers | Overloading of trucks |
|---|---|---|---|---|
| Spearman's rho | Age of drivers | Correlation Coefficient | 1.000 | .040 |
| | | Sig. (2-tailed) | .073 | .602 |
| | | N | 170 | 170 |
| | Overloading of trucks | Correlation Coefficient | .040 | 1.000 |
| | | Sig. (2-tailed) | .602 | .507 |
| | | N | 170 | 170 |

*Table 53 Crosstabulation between Age of Drivers and Overloading of trucks*

**Age of drivers * Overloading of trucks Crosstabulation**

Count

| | Overloading of trucks | | | | | |
|---|---|---|---|---|---|---|
| | Not at all important | Slightly important | Moderately important | Very important | Extremely important | Total |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Age of drivers | 20 - 30 years | 1 | 5 | 2 | 11 | 3 | 22 |
| | 31 - 40 years | 2 | 10 | 1 | 10 | 4 | 27 |
| | 41 -50 years | 3 | 6 | 2 | 28 | 4 | 43 |
| | 51 -60 years | 3 | 13 | 8 | 39 | 11 | 74 |
| | 61 -70 years | 0 | 2 | 1 | 1 | 0 | 4 |
| Total | | 9 | 36 | 14 | 89 | 22 | 170 |

As shown in Table 52 above, there is a positive correlation between the ages of tanker drivers and the overloading of trucks. The Spearman's correlation result is .04 while the p-value is .602. This result from Table 53 suggests that the older drivers between the ages of 51 – 60 years (50) and 41 – 50 years (32) are of the opinion that overloading of trucks is either an extremely or very important factor that causes accidents compared to the younger drivers between 20 – 30 years (14) and 31- 40 years (14).

### 5.8.5 Relationship between the Ages of the drivers and their perception of the impact of severe weather conditions when transporting petroleum products

*Table 54 Correlation between the Ages of tanker drivers and their perception of severe weather impact*

**Age of drivers * Extreme weather conditions Crosstabulation**

Count

| | | Extreme weather conditions | | | | | |
|---|---|---|---|---|---|---|---|
| | | Not at all important | Slightly important | Moderately important | Very important | Extremely important | Total |
| Age of drivers | 20 - 30 years | 6 | 4 | 2 | 7 | 3 | 22 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 31 - 40 years | 5 | 8 | 1 | 10 | 3 | 27 |
| | 41 -50 years | 3 | 7 | 2 | 26 | 5 | 43 |
| | 51 -60 years | 13 | 9 | 5 | 41 | 6 | 74 |
| | 61 -70 years | 1 | 1 | 0 | 2 | 0 | 4 |
| Total | | 28 | 29 | 10 | 86 | 17 | 170 |

*Table 55 Spearman's correlation*

**Symmetric Measures**

| | | Value | Asymptotic Standard Error[a] | Approximate T[b] | Approximate Significance |
|---|---|---|---|---|---|
| Interval by Interval | Pearson's R | .090 | .082 | 1.167 | .245[c] |
| Ordinal by Ordinal | Spearman Correlation | .056 | .081 | .723 | .471[c] |
| N of Valid Cases | | 170 | | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

As shown in Table 55 above, there is a positive correlation (r = .06 with a p-value of .471) between the ages of the tanker drivers and their opinions on severe weather conditions as a factor that causes accident during the transportation of petroleum products. Also, the results in Table 54 above, suggests that the older drivers of ages between 51 – 60 years (47) and 41 and 50 years (31) are of the opinion that severe weather conditions are either extremely or very important factor causing accidents on the road when compared to the younger drivers between 20 – 30 years (10) and 31 – 40 years (13).

## 5.9 Reliability of Research Findings

According to Bryman and Bell (2007), the reliability of research depends on ensuring consistency in terms of the measurement of the key concepts. This was achieved in this research by ensuring a consistent instrument for collecting data was designed. In analysing and presenting the data in section, every care was taken to ensure the research led to reliable results. The questionnaire is clearly understood by the respondents and free of any ambiguity.

## 5.10 Summary of Chapter Five

This chapter has analysed and discussed the results of the quantitative data collected for this research. From the analysis of the data, it is evident that most tanker drivers are not educated to understand how dynamic the petroleum industry is in terms of best practices relating to the transportation of petroleum products. In Nigeria most people see driving of trucks as a job for people who are not educated and as such would prefer to go into other kinds of professions. Results from the analysis shows that drivers are not familiar with safety technologies in vehicles. Some of these modern trucks have inbuilt modern technologies but due to lack of training and education, it is difficult for the drivers to know about these technologies and how they work. The results suggest that poor road conditions, extreme weather conditions lack of regulatory frameworks, insufficient rest time during travel among others are some of the factors that lead to accidents on the road. The correlational statistical test performed using the Spearman’s Ranked Correlation also revealed that the older drivers are more concerned about factors like overloading of trucks and severe weather conditions than the younger drivers. The next chapter presents the results on the qualitative data collected through the use of interviews, done concurrently with the quantitative data. Information in the next chapter is expected to help shed more light on the issues presented in this chapter.

# 6 QUALITATIVE DATA ANALYSIS AND DISCUSSION

## 6.1 Introduction

This chapter concentrates on the analysis of the qualitative data obtained through the interviews. The third objective of the research is to investigate the challenges faced by stakeholders across the value chain involved in the transportation of petroleum products.

The qualitative research was conducted to shed more light on the results from the quantitative research. In doing this, questions similar to that of the quantitative research were posed to interviewees, this time not with tanker drivers but some other stakeholders in the petroleum industry with more educational and knowledge background to see if they can shed more light to key questions that would be used to address the objectives of this research as discussed in chapter one. Issues such as drivers challenges and causes of accidents as it relates to road tanker transportation of petroleum products in Nigeria were key to addressing the research objectives (objectives 2, 3 and 4) in chapter one. After, the researcher carried out a comparison to ascertain if there is any gap in the answers provided by the tanker drivers during the quantitative survey. In order to address these objectives, this chapter presents an analysis of the data obtained through the qualitative study. The findings along with that of the quantitative survey will be used to develop a safety assessment framework for the transportation of petroleum products in Nigeria. The questions in the interview were carefully designed to mirror that of the quantitative survey. A draft of the interview questions is attached as appendix 2.

## 6.2 The Data Collection

The data collection for the qualitative interview was collected to compliment the quantitative survey. The quantitative and the qualitative survey were carried out one after the other to investigate the challenges facing the downstream petroleum industry in Nigeria. As discussed in Chapter Four, interviews were used in conducting the qualitative study. According to Schostak (2006), an interview can provide insights into the experiences, beliefs, values, knowledge, interests, and concerns of the other, as well as being a means of assessing their reasoning and actions. Therefore, to address the research objectives, interviews were considered to be an appropriate method for data collection. Semi-structured interviews were conducted to obtain the primary data for this research study. The interviews were carried out with 10 professionals from both the public and private sector of the downstream sector of the oil and gas industry including other government agencies that work in collaboration with the petroleum downstream sector, and the Federal Road Safety Commission of Nigeria (FRSC). The selection criteria for the interview participants were on the basis of professional position and knowledge relating to the transportation of petroleum products and road safety. For instance, questions relating to information relating to accidents and road safety were directed to FRSC officials while questions relating to depot loading operations and offloading at retail stations were directed to depot managers and petrol station managers respectively. The semi-structured interview for this research was conducted through telephone calls. The interviewees were notified through emails and phone calls prior to the interviews. The researcher used the telephone call methods to conduct the interview because of the impact of the Covid-19 pandemic and travel restrictions in many parts of the world.

Since the research involved developing a safety framework for the petroleum industry in Nigeria, the interview requires inputs in the form of approaches and descriptions from the participating oil professionals. As a result, flexibility was needed in the interviews in terms of following up questions. Hence semi structured interviews were selected, as they provide much needed flexibility while maintaining the overall structure of the interview themes.

## 6.3 Profile of the Interviewees

The interviews were conducted among professionals in the downstream sector of the oil and gas industry, the FRSC officials and other government agencies that work in collaboration. This research is about investigating the challenges facing the transportation of petroleum products in Nigeria in order to develop a safety framework that would help to mitigate accidents on the road during the tanker transportation of petroleum products in Nigeria. As such, the interview was conducted with professionals who know about petroleum products transportation and road safety. In this case, my interviewees as shown in Table 46 were Depot Manager (R1), Transport Manager (R2), Petrol Station Manager (R3), FRSC Area Commander (R4), Health and Safety Manager (R5), DPR Depot Inspector Officer (R6), Fire Fighting Engineer (R7), Laboratory Scientist (R8) Vehicle Inspection Officer (R9) and Road Maintenance Engineer (R10).

The responses to the interview questions were transcribed and coded by the researcher as shown in Table 57 below.

*Table 56 Profile of Interviewees*

| Respondent | Years of Experience | Position |
|---|---|---|
| R1 | 6 | Depot Manager |
| R2 | 10 | Transport Manager |
| R3 | 7 | Petrol Station Manager |
| R4 | 12 | Area Commander FRSC |
| R5 | 9 | Health and Safety Manager |

| | | |
|---|---|---|
| R6 | 13 | DPR Depot Inspector |
| R7 | 8 | Fire Fighting Engineer |
| R8 | 5 | Laboratory Scientist |
| R9 | 10 | Vehicle Inspector Officer (VIO) |
| R10 | 7 | Road Maintenance Engineer |

*Table 57 Thematic cross-content analysis of semi-structured interview with regulators*

| **Drivers' challenges & causes of tanker accidents** | **Technology** | **Risk management** | **Regulation and standards.** | **Environment** | **Training** |
|---|---|---|---|---|---|
| Poor road conditions. (R1, R2, R3, R4, R5, R9, R10). | Lack of safety technologies in vehicles. (R1, R2) | Lack of rest time for drivers. (R4, R5) | Non-compliance with the use of PPE. (R1, R3, R4, R9) | Lack of good road designs. (R1, R2, R4) | Drivers lack of regular training on hazardous materials transportation. (R2, R5, R10) |
| Lack of parking spaces for tankers. (R3, R5, R7). | Use of outdated vehicles in transporting petroleum products (R1, R2, R4, R9). | Poor knowledge of risk management in the petroleum industry (R3, R4, R5). | Lack of enforcement of standards and regulations. (R1, R2, R3, R4, R7, R9, R10). | Lack of effective drainage systems (R4, R5, R10). | Importance of continuous training for drivers. (R1, R2, R3, R4, R5, R6, R7, R8) |

| | | | | | |
|---|---|---|---|---|---|
| Over speeding. (RI, R2, R3, R4, R5, R6, R7, R8, R9, R10) | Lack of infrastructures (R1, R2, R3, R4, R5, R6, R7, R8, R9, R10). | Vehicle maintenance (R1, R2,) | Corruption in the system (R1, R2, R3) | Trees are too close to the roads. (R4, R9) | Training for new technologies in vehicles. (R1, R2, R3, R4, R5, R7,) |
| Overloading of trucks. (R4, R5, R9) | Lack of vehicle parts to carryout repairs (R1, R2) | | Lack of speed limits on the roads. (R2, R4, R5, R9, R10). | | |
| Poor welfare packages for drivers. (R3, R5, R10) | | | Lack of rest time specification for drivers. (R3, R4, R5). | | |

## 6.4 Drivers Challenges and Causes of Tanker Accidents

As shown in Table 57, R1, R2, R3, R4, R5, R9, and R10 are of the opinion that poor roads conditions are the major challenges faced by tanker drivers during the transportation and distribution of petroleum products in Nigeria. According to R1 "*Most of our drivers consider the state of the road to be very bad which makes driving of trucks to be very difficult*" R2 and R3 added that "there *are many gullies on the road and each time the truck driver wants to avoid the gullies to avoid crashing, the truck would rollover in most cases posing high risk for other vehicles on the road. Sometimes, other vehicles run into it and causes fire explosion claiming lives and damaging properties worth huge amount*". The views of R3, R5 and R7 is that there is no parking space for the tankers on the road. All the respondents are of the opinion that over speeding is a factor that causes accidents on the road during the transportation and distribution of petroleum products in Nigeria.

## 6.5 Welfare Packages for Tanker Drivers

As shown in Table 57 above, R3, R5, R10 are of the opinion that the welfare packages for tanker drivers should be improved as one of the reasons why they overspeed on the road is for them to make more trips and get more money. *According to R5, "when you compare the wages of what some taker drivers to the cost of living in Nigeria, you will not blame them if they try to work many hours without taking a break"*. R3 and R10 maintained that many tanker drivers also diversify products for sale in the black market. R10 also stated that the major oil marketing companies have better welfare packages for their drivers compared to the private and independent oil marketers.

## 6.6 Technology

R1, R2 are of the opinion that most of the trucks used to transport petroleum products in Nigeria do not have safety technologies such as the GPS and route planning systems. R1, R2, R4, R9 are of the views that most of the tankers used in Nigeria are outdated and have been used for many years before they were imported to Nigeria. According to them "*Most of the trucks imported to Nigeria for the transportation of petroleum products have been used for many years in the countries they were manufactured; as such, they are not as effective as modern trucks. Also, because they are very old, maintenance become very challenging as most of the parts are not available for repairs and maintenance thereby increasing the possibility of them involving in road accidents".*

## 6.7 Lack of Infrastructures and Vehicle Spare Parts

R1, R2, R3, R4, R5, R6, R7, R8, R9, R10) are of the opinion that new trucks imported into Nigeria have safety technologies but lack of infrastructures to support these technologies are lacking in the Nigerian transport system. The roads are very bad and this affects the trucks in terms of driving effectively. Also, the technologies that came with these trucks cannot be sustained due to lack of parts for their maintenance. It is very expensive to bring some of these parts into the country due to import duties that are very expensive. It becomes a problem when the original technology that came with the trucks is damaged and could not be replaced. Most trucks are driven without adequate safety technologies which results in accidents causing injuries, deaths and environmental damage**.** According to one of the respondents, **"***As we speak, some trucks have been used for many years because that is the only way the private investors can ensure they maintain their fleets of trucks on the road*".

## 6.8 Age of Trucks

*Trucks that have been used for a number of years overseas before importing them to Nigeria cannot perform like the new trucks. In terms of inspection, the imported trucks are not properly inspected by vehicle safety professionals before they are used to transport volatile products like petrol and diesels. Some of the trucks have been damaged and so they leak products which constitute fire hazards. Government has not done enough to regulate the importation of trucks into Nigeria and this gap has made over used and over aged truck to be imported into Nigeria.*

## 6.9 Risk Management and Safety

R3, R4, R5 are of the opinion that the attitude of tanker drivers towards risk management in Nigeria is very worrying. According to one of the respondents "*There was a case of a tanker* *accident that happened in a remote area of this country. Although, the driver was not injured in the incident, but he left the scene without reporting to the necessary quarters. In a nut shell, most accidents are not reported and this is why risk management information are very difficult to access in the Nigeria transport industry".*

## 6.10 Regulations and Standards

"R1, R3, R4, R5 and R9 stated that "*Although, the trucks of both companies drive thorough the same roads to transport and distribute petroleum products across the country, however, the drivers of the major oil companies are more safety cautious on the road"*. They tend to observe adequate rest after driving for certain period of time and the trucks are newer compared to the independent operators". R5 mentioned that the recruitment process for drivers in major oil companies is very rigorous and thorough compared to the ways drivers are recruited by independent operators. In terms of training, R5 said regular training for drivers in major oil marketing companies is not taken for granted. "*The independent operators hire truck drivers whose driving skills are not known to their employers. The drivers of the independent operators can also temper with products as most of the trucks are not tracked. Overall, there are more risk with the independent operators compared to the major oil marketers*".

According to R4"*There are standards and regulations in terms of hazmat transportation in Nigeria. However, drivers do not comply with the regulations because of the way the system is being operated. Most drivers are of the opinion that even when they break traffic rules and regulations, they can always have their ways because of corrupt officers who will take money from them and let them go free without any penalty. This is the reason why most road safety rules and standards are not obeyed. The FRSC and other government agencies whose tasks* *are to implement these standards are not doing their jobs properly. Drivers who violate speed limits do not get adequate penalties, rather they bribe the officials and it becomes a habit"*.

The introduction of speed limit would help to reduce accidents on our roads but the roads need to be fixed because they are dangerous. Speed limits for vehicles including trucks would be meaningful only when the roads are fixed. "*The way it is now, you have to chase a truck to stop when you observe they are over speeding. Most times, they increase their speed and starts to drive dangerously to scare officials away. If you are lucky, they stop and they are being given fines to pay. But the biggest problem is the fixing of the roads.*"

## 6.11 Perception of Drivers towards the use of PPE

According to R1, R3, R4, and R9, *"Most tanker drivers do not use the personal protective equipment (PPE) provided for them when they are discharging petroleum products at petrol stations. They rarely wear their hand gloves or helmets. Most times, you see tanker drivers not wearing adequate safety shoes at loading and offloading sites. When you check inside their trucks, you will find PPE like helmets, safety boots and hand gloves which are never worn. They prefer to do things their own way because they are not properly supervised"*. According to him, training on the use and importance of PPE should be given to truck drivers and also, there should be a penalty for not using adequate PPE according to the station supervisor.

## 6.12 Vehicle Maintenance

"R1 and R2 stated that vehicle maintenance is very important. According to them *"Most of our truck drivers are trained on how to carryout appropriate checks and also report problems. Before the start of every shift, we ask our drivers to check tyres, lights, brakes, steering, horns, and indicators. However, some of our trucks have not been in service for a long period of time* *because of lack of skilled professionals to carryout repairs on them. This is because most of the technologies and vehicle parts cannot be sourced in Nigeria. This is one major problem we face as a transport company. When there are no tankers to distribute products, there will be shortage of products at the petrol station which often leads to petrol scarcity and rise in pump price. We are facing a big problem in this country and government should do something to save the truck industry. Trucks need adequate maintenance to function properly".*

## 6.13 Impact of Severe Weather Conditions

"According to R4, R5, R10, *"The state of the Nigerian roads is very bad. When it rains, it becomes difficult for vehicles to drive smoothly on the road. Potholes are covered with water because there is no adequate drainage system to deal with the problem of water erosion. During heavy wind, trees are broken by winds and they fall across major roads and become hazards that could cause road accidents. Many accidents involving tankers in Nigeria have been as a result of severe rainfall and heavy winds. Sometimes, drivers find it very difficult to see clearly during heavy downpour and heavy winds. Even when they try to park along the road side, there is a possibility they could fall into potholes. I would suggest that trucks don't travel under these kinds of weather conditions especially during the rainy season in this country".*

## 6.14 Training

"R1, R2, R3, R4, R5, R6, R7, and R8 mentioned that *"Training of drivers is very important because truck driving is different from the driving of other vehicles on the road. Drivers must go through training from skilled professionals so as to make sure they can handle the risk that comes with driving a truck. Modern trucks have safety technologies built in them and when* *drivers are trained, they would know what to do when faced with emergency situations. They must understand how the truck functions and also have knowledge of the cargo they are transporting. Drivers must be trained on how to behave on the road when driving trucks. They must understand basic safety principles of transporting hazardous materials and know how to manage emergency. Training for drivers promotes safety on the road".*

According to R1, R2, R3, R4, R5 and R7, *the training of drivers for new technologies is very important to ensure that they drive safely on the road. Most modern trucks are equipped with technologies like the crash preventing systems, driver's behaviour monitoring systems and cargo tampering prevention systems. All these systems are built in the truck to promote safety and the driver must understand how they work and what their function is. Driving of trucks should be made very competitive to attract knowledgeable people into the industry. This would enhance safety on the road and also take the industry to another level".*

## 6.15 Implications from the findings

The aim of the interviews was to get more insight into the problems facing the transportation of petroleum products in Nigeria in order to achieve the objectives for this research. The analysis of the interview would be used by the researcher as a mechanism for validating the framework that would be developed from this research due to the way the interviewee responded to the questions. Also, the results from the interview were similar to the results of the quantitative survey which suggests that the tanker drivers and the regulators of the petroleum industry in Nigeria are speaking with one voice in terms of the challenges facing the downstream oil sector and the causes of tanker accidents in Nigeria. From the analysis of the literature review, quantitative survey and the qualitative data analysis, objectives 1- 4 of this research have been achieved. Findings from the interview and questionnaire survey would be used to develop the Safety Assessment Framework (SAF) in the downstream petroleum industry in Nigeria to address the aim of the research. Rules and standards are to be created for SAF in the petroleum industry and a level of compliance should be ensured by the government as practiced in countries such as the UK and the US. To support this, a SAF awareness group should be formed. To further strengthen the awareness level, SAF should be introduced into the curriculum of schools especially in universities at undergraduates' level and other organisations that teaches road safety such as the FRSC and the society of safety professionals in Nigeria (SSP). From the research findings, key areas have been identified to help in the development and implementation of SAF in the downstream sector of the petroleum industry. These areas are briefly discussed below. (A detailed discussion of the key implications of the research results from interviews and questionnaire are presented in chapter 7 which deals with the development and implementation of SAF for the downstream sector of the petroleum industry).

### 6.15.1 The Need for a SAF Awareness Campaign Group

From the results discussed in this chapter, creating a SAF awareness group will help to spearhead government efforts to improve the performance of the downstream oil and gas industry through the adoption and implementation of SAF. The awareness group can help set the agenda, decide timelines and put in place measures to help the industry achieve its SAF objectives.

### 6.15.2 The Need for Infrastructural Development

The analysis of data also indicates that the downstream sector of the petroleum industry in Nigeria lacks the infrastructure required to implement SAF. This is one of the main barriers to SAF in the Nigerian petroleum industry. The way forward is for the government to investment in infrastructures in order to ensure the success of SAF implementation in the petroleum industry.

### 6.15.3 The Need for Education and Training

From the analysis, education and training are seen as a key requirement for the petroleum industry to achieve its aims. Due to the low level of awareness and the lack of skills in best practices, SAF implementation in the petroleum industry could become a challenge, providing education and training for transport personnel in the petroleum industry will help to bring the industry to the level required for implementing and adopting SAF.

### 6.15.4 Collaboration and Communication

The research findings shows that collaboration and communication are key requirements for implementing SAF. Any effort to ensure the industry adopts SAF should therefore place an emphasis on ensuring a cultural change in the way the industry communicates and collaborates. Collaboration and communication should therefore form a key part of any strategy to implement SAF.

## 6.16 Summary of Chapter Six

The interviews explored the relevance of SAF to the petroleum industry in Nigeria and looked at factors that could hinder the implementation of SAF in the petroleum industry. The findings from the interviews cut across different professionals in the oil and gas industry, road safety officials, and other stakeholders in the petroleum industry (see section 6.4.7). Furthermore, the respondents were of the opinion that SAF would bring many benefits to the petroleum industry, as practised in European countries and America, and so identifying the barriers and the main actors in the industry playing their key roles would help the implementation of SAF. However, all the benefits identified with SAF were positive in relation to the accident mitigation in the petroleum industry. Awareness campaign groups has been identified as one way the government can support the implementation of SAF. Also, another strategy is for SAF to be integrated into school's curriculum in Nigeria as this would help in creating the skills and knowledge to implement SAF in the petroleum industry. Ensuring that rules and standards are set and enforced would be good for the benefits of SAF to be reflected in the transport industry. The next chapter is the development of SAF for the downstream petroleum industry based on the results of the study.

# 7 SAFETY ASSESSMENT FRAMEWORK (SAF) FOR THE NIGERIAN PETROLEUM INDUSTRY

## 7.1 Introduction

Based on the results of this research discussed in the previous chapters, there is a clear indication that Nigeria as a nation can benefit from the proper implementation of SAF in the petroleum industry. To achieve this, there is a need for a strategic approach to SAF implementation which will take into consideration the local factors within the country, combined with best practices captured from other countries around the world where SAF implementation is at a much more developed level. The aim of this chapter, therefore, is to bring together the different elements of the framework identified in the research to develop a safety assessment framework (SAF) for the petroleum downstream industry in Nigeria. The chapter also identifies the key parties in the implementation process of SAF and the specific roles to be played by these parties. The strategic framework is developed as a contribution by this research towards road safety in the petroleum industry. Information for developing this framework is taken from all the stages of the research from the background issues raised in the introductory chapter to the results gathered from the collection of data.

## 7.2 Components of the Framework

The results of the quantitative research helped to understand the current state of the issues plaguing the downstream sector of the oil and gas industry in Nigeria. From the results of the quantitative and qualitative study, the causes of tanker accidents during the transportation of petroleum products were identified. Also from the mixed research approach, the barriers to the implementation of SAF were identified which can help in shaping the core of the framework and in particular understanding the general perception of people in the industry and the gaps in their understanding of risk assessment and management. The outcome of the quantitative and qualitative research in identifying the issues of lack of technology in trucks, causes of tanker accidents on the road and low level of education among tanker drivers would help to understand the need to import modern trucks to Nigeria, improve road infrastructures, and improve upon the education of the drivers in relation to petroleum products transportation. Results from the qualitative research also indicates the need for cooperation and collaboration among the different stakeholders in the supply chain network for hazmat transportation. Lack of government regulations and standards were also found to be some of the main barriers that could face the implementation of SAF. As such, one of the recommendations is for the government to set up an awareness campaign group to help promote awareness of SAF among all professionals involved in the transportation and distribution of petroleum products in Nigeria. From the analysis of the quantitative and qualitative research, there was need for the improvement of road designs and suggestions that tanker operators should put weather conditions into consideration before they start their journey. Also, from the analysis, it can be seen that truck drivers do not observe rest time during travel; however, this has been hinged on the poor welfare packages for tanker drivers in Nigeria especially drivers who work for private transport companies. It was also found from the interview that there is no clear roadmap in terms of risk management for the transportation of petroleum products from a loading depot to the retail outlet in Nigeria.

## 7.3 Safety Assessment Framework (SAF) for tanker operations in the petroleum industry

The safety assessment framework that would be developed for this research would be called SAF. The risk mitigation initiatives discussed in this framework were inspired by key findings from risk assessment frameworks discussed in chapter 2 and findings from the quantitative and qualitative survey analysis. The framework as shown in Figure 7.1 presents an approach through which key issues identified within the current transport system in the petroleum industry can be addressed to enhance risk management for safe petroleum products transportation in Nigeria. It is designed to be utilised by both regulators and operators and considers stakeholder contextual interest and collaboration, the need for commitment to change, and enhancing knowledge of hazards and risks identification as critical factors in accident mitigation and safety. The framework supports ‘action’ as an important element of risk management and should comply with regulatory requirements.

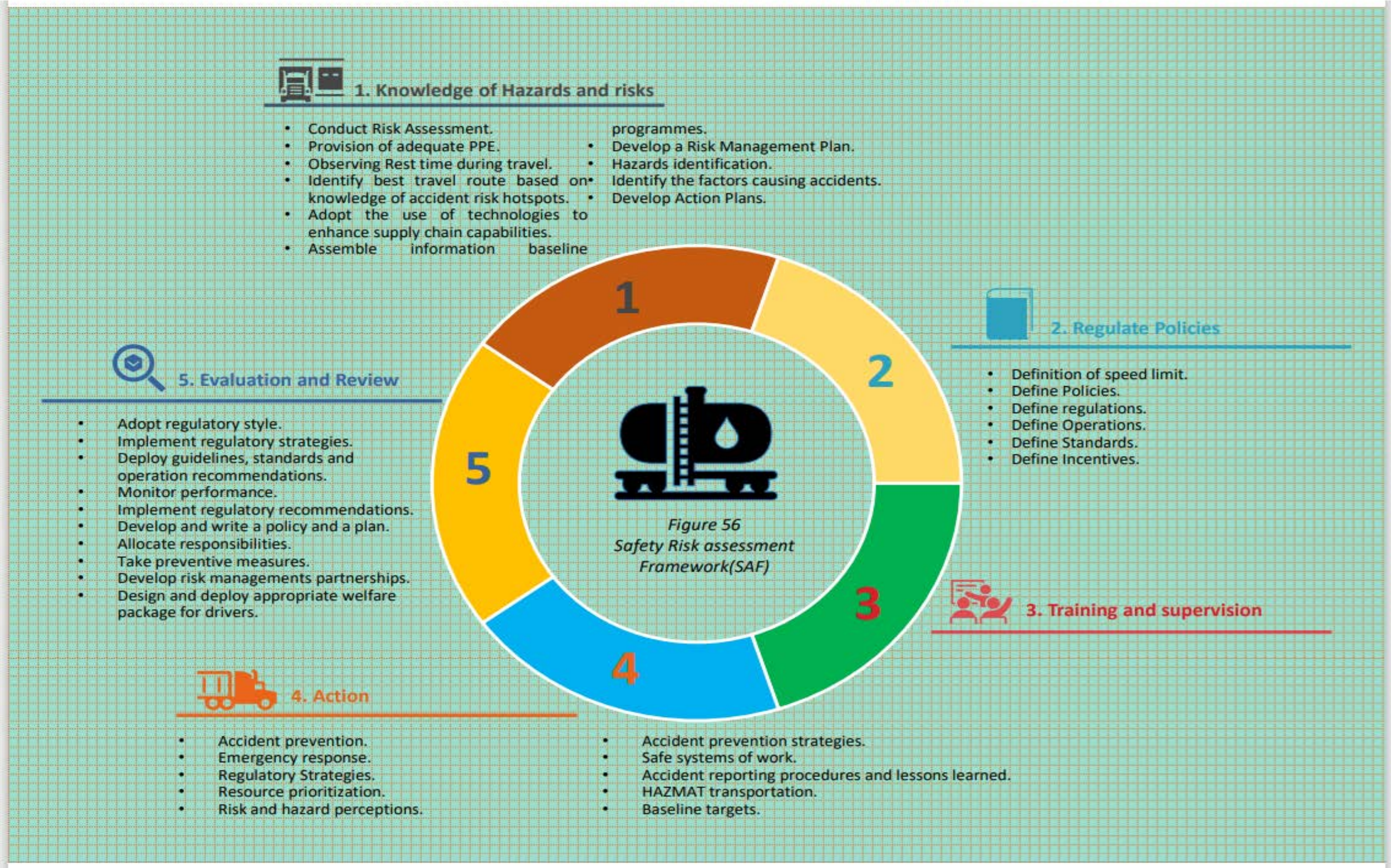



*Figure 55 Safety Assessment Framework*

### 7.3.1 Drivers' Challenges

One of the areas identified as a challenge facing tanker drivers in Nigeria is their poor remuneration for truck drivers. package. The need of prioritising driver welfare within the truck transport systems cannot be overemphasized. An investment in the welfare packages for drivers should be seen as one of the strategies for action that will contribute directly to an improvement of the safe driving attitude on the road. Also, the working conditions for drivers should be improved as well as their allowances. There were concerned raised among the interviewees concerning the remunerations for drivers as this could be related to safety concerns in the petroleum industry. For instance, in a bid to make more trips so as to increase reward, drivers tend to drive above required speed limits which can lead to accident. Also, the activity of diverting products could be as a result of poor welfare packages for drivers. Products diversion has led to many unsafe acts like selling of petrol in the "black markets" and the resultant effects of fuel shortages in the country.

### 7.3.2 Risk Management and Safety

In the literature review, quantitative and qualitative sections of this research, good knowledge of risks and hazards involved in trucking operation is lacking. One of the interviewees (see 6,4.7, R1) cited a case where a tanker driver was watching people in the community where a tanker carrying petrol rolled over without taking any action. This can be argued as a lack of risk management knowledge and awareness. Hence, the framework recommends that operators should provide staff with relevant information through routine risk assessment in the form of material safety data sheets and clearly labelled trucks with standardised FRSC classifications. In terms of emergency management, FRSC, NOSDRA, NEMA and the fire service department should ensure that there is communication regarding risk at all time so that action can be quickly taken in case of an emergency. This would help to improve emergency preparedness, accident response and spill clean-up operations. Operating companies can also design driving training manuals and integrate considerations for these risk prone locations. Also, tankers inspection should be made mandatory before products are loaded at the depot.

### 7.3.3 Training and Supervision

The importance of training for tanker drivers cannot be overemphasized. This is a key component of SAF. In many developed countries, there is a training program for hazmat operators and everyone involved in hazmat transportation. For instance, the U.S. Department of Transportation's Research and Special Programs Administration (RSPA) in compliance with the Hazardous Materials Transportation Uniform Safety Act of 1990 has ruled that interstate carriers that transport any quantity of hazardous materials must conduct appropriate training and testing of hazmat employees (dock workers, drivers, safety supervisors of handling/shipping, and clerks who document hazmat freight). RSPA also requires that everyone must be re-trained every 2 years. This Act can be adopted by transport operators in the petroleum industry in Nigeria to enhance tanker drivers' awareness and knowledge regarding hazmat transportation. Also, a leadership-based intervention model as designed in Zohar (2002) can be used for supervisory monitoring and rewarding safety performance. Here, supervisors receive weekly feedback based on repeated intervallic interviews with subordinates concerning the cumulative frequency of their safety-oriented interactions.

### 7.3.4 Regulations

In the EU, there is the ADR regulation for carriage of dangerous goods (ADR 2015). The ADR regulation was discussed in chapter 2. ADR provides structured approach to hazmat classification, packing and tank provision, consignment procedures (including documentation and vehicle marking) construction and testing of vehicles, as well as loading, unloading and handling. All the regulatory elements covered in ADR are very relevant to the limitations of petroleum transportation illustrated in this study. Hence, with this approach, it is possible to obtain a holistic regulatory method that can deal with the issues of substandard tanker construction in Nigeria as well as proper consignment documentation during loading and offloading of petroleum product in refineries and retail stations (Ambituuni et al., 2015). Also, the regulators in the petroleum industry in Nigeria can emulate the United Kingdom where it is mandatory for drivers to have ADR licence before they are qualified to drive tankers (see session 5.2.1). In the develop nations, regulations play a key role in achieving high safety standards in the transportation of hazardous materials.

### 7.3.5 Technology

This component of the framework recommends that tankers to be imported into Nigeria for petroleum products transportation must meet the minimum standard of trucks used in other parts of the world. The operators and regulators of transport in the petroleum industry should ensure that the SAN works with DPR to ensure standard and modern truck with safety technologies such as the crash prevention systems and cargo tampering prevention systems are imported to Nigeria. For this framework to work manage risk effectively, modern trucks with safety technologies must be provided for drivers in the petroleum industry in Nigeria.

### 7.3.6 Environment

From the analysis gathered from literature review, quantitative and qualitative research, the Nigerian road network is not well managed in term of designs and maintenance. Hence, this has been greatly linked to the causes of accidents during the transportation and distribution of petroleum products. For this framework to work effectively, roads must be fixed to high safety standards. The designs of roads should allow the manoeuvring of large vehicles. Many truck rollover incidents have been related to trucks trying to manoeuvre through bends. Also, technologies that warn drivers when approaching bends should be embedded in trucks to mitigate accidents. Severe weather conditions should be considered by both regulators and operators as a risk management strategy in the transportation of petroleum products. As discussed in chapter 2, severe weather conditions like heavy rainfall could lead to lead to tanker accidents in Nigeria. One of the interviewees for this research suggested that petroleum products should be transported at night probably to avoid traffic both in terms of vehicular traffic and human traffic because most houses are very close to the roads where tankers ply and this poses some risk concerns.

### 7.3.7 Actions

The underlying philosophy of this framework emphasises "action" as the backbone for effective risk management. At this point, regulators and operators need to actually implement all written plans developed. Both parties need to realise that analysis of risks need to be backed by actions as analysis only provides information needed for decision making and planning but does not by itself reduce risk (ICF, 2000).

### 7.3.8 Communication and Collaboration

In Nigeria, policies are not adequately communicated across the supply chain network of the petroleum industry. The major oil marketers have a blame in this. For instance, some of the tankers used by private marketing companies for the transportation of petroleum products carries the logo of the major oil marketing companies such as NNPC and Mobil. These private companies have poor safety culture and most of their drivers do not conform to minimum safety standards and regulations. This is another contributory factor to accidents. Regulators should make it mandatory that all major oil marketing companies who franchise their tankers with other smaller companies should be made to give the drivers the same training that they give to their own staffs. Training on risk management should be uniform and communicated to everyone involved in the transportation of petroleum products in Nigeria. There should also be collaboration among all the various stakeholders in the petroleum industry in the area of risk management and safety. For trucks integrity, SAN should collaborate with DPR, and NNPC to ensure standard trucks with modern technologies are brought into Nigeria.

## 7.4 Summary of Chapter Seven

This chapter presented the various elements that make up the safety assessment framework that would be implemented in the downstream petroleum industry. The framework was developed based on findings from the review of literature, quantitative survey and interview analysis. It also reveals the problems within the context of road transportation of petroleum products in Nigeria. Thematic interview analysis and analysis of the socio-technical road truck transport system revealed a number of contributory factors to regulatory and operational deficit including limited regulatory resources, poor accident reporting and investigating culture, poor driver welfare, and corruption and rent seeking culture, etc. A risk management framework was, therefore, proposed. The framework is designed to be utilised by both regulators and operators in Nigeria and adheres to principles of commitment to change, collaboration, organisation and communication, enhancing knowledge of hazards and risks, and continues improvement.

# 8 IMPLEMENTATION OF THE SAFETY ASSESSMENT FRAMEWORK (SAF)

## 8.1 Introduction

Chapters 7 presents the safety assessment framework that would be used to mitigate accident and promote safety in the downstream oil and gas sector. Some barriers to the implementation of the framework were identified in chapter 6, however, the framework has been designed to withstand such limitations if it is well utilised. This chapter presents how SAF would be implemented by the various stakeholders in the Nigerian supply chain industry in order to actualise its benefits. The next session discusses the implementation of SAF.

## 8.2 SAF Implementation

In order to effectively sustain product supply across the Nigeria, SAF was developed such that it operates as a risk management guideline for transporter of hazardous materials in the Nigerian petroleum industry to ensure optimised product supply. SAF would be instrumental in ensuring safety within the downstream context of petroleum industry operations in Nigeria because truck tanker transportation currently remain the most viable method of product distribution. The framework integrates a risk mitigation approach that both operators and regulators can utilise to prevent and respond to accidents involving truck tankers. Therefore, risk in this context is the risk of accident on road and within loading and off-loading facilities.

Before loading of petroleum products at the depot, the factors that could lead to accidents on the road must be checked. From the analysis of the questionnaires and interviews, there is need for depot operators to ensure that a risk assessment is performed before and after the loading of a truck with petroleum products. The truck that must be used for the transportation of petroleum products must have safety technologies such crash preventing systems, route planning systems and other safety technologies that were analysed in the data analysis of this research (see chapters 5 and 6). The vehicle should also be inspected before it leaves the depot. Tyres, brakes, mirrors and seat belts must all be in good conditions. Leaks from the body of the tanker should be inspected too and if any leaks are found, the products should be offloaded into another truck while the faulty trucks is taken for repairs by trained professionals. The following risk countermeasures should be carried out before a truck leaves the depot:

- Develop a site- specific security assessment and security plan for each location/terminal of the organisation, unique to its layout, design etc.
- Develop procedures to segregate hazmat cargo in a separate and secure area that limits and control employee access.
- Have law enforcement a facility risk assessment.
- Communicate security procedures regarding restricted hazmat areas and sensitive/confidential records with all employees.

Once the trucks get on the road, it has to be monitored from the base to ensure that the driver and the products being transported are safe. Weather warning alerts should be sent to drivers so they can park at designated parking areas until weather situation improves and the driver can start his journey.

DPR is responsible for monitoring all petroleum industry operations in refineries, storage depots and retail outlets. These are the facilities where petroleum products are loaded into trucks and/or offloaded from trucks. Also, ensuring the safe movement of vehicles, including petroleum trucks on Nigerian roads is the statutory responsibility of the FRSC. This make DPR and FRSC the lead stakeholders in regulation of trucking operations in Nigeria, and therefore the two agencies should jointly own the designed SAF. Therefore, both DPR and FRSC and have a big role to play in the implementation. For SAF to be effectively implemented, there must be collaboration between DPR and FRSC from a regulator's viewpoint. They are the main regulators that would communicate SAF to other stakeholders in the petroleum industry. Other stakeholders like the IPMAN and MOMAN also have major roles to play because they are the two main petroleum marketing organisations in Nigeria. Research has shown that IPMAN and MOMAN have good National coverage with branches at local, state and regional levels. Since all petroleum marketers in Nigeria belong to either of the two trade unions, this makes them ideal for developing and improving risk management capabilities and welfare programmes for drivers. As such, the trade union should aim at developing and training member companies using guidelines that can improve operations and optimise their safety performance. Such guidelines need to be in alignment with the statutory requirements by FRSC and DPR.

The risk assessment procedures at the loading depots should be regulated by the DPR while the safety of the tanker on the road should be regulated by DPR. The purpose of developing SAF is to ensure that petroleum products are safely transported between a loading depot and a retail station. Therefore, SAF involves risk management between these two points. The identification of hazards should start from the depot and DPR must make it a rule that before any trucks leaves the depot, it must be certified road worthy and the driver of such truck must have been certified as qualified to drive a truck and also have knowledge of hazardous materials and risk management. Information about such truck and the driver can be sent to DPR in the form of certified truck with certified drivers. By doing this, only trucks that are road worthy and drivers who are qualified would be on the road. This is one aspect of SAF to mitigate accident on the road. Also, to ensure that the trucks used to transport petroleum products maintains good safety standards, there should be a compulsory requirement for developing safety cases by truck operating companies to identify specific hazards and risk from their operations, describe how the risks are controlled and define the safety management systems in place to ensure the controls are effective and consistently applied. FRSC should then assess the safety cases and if it is satisfied that the arrangements set out in the document demonstrate that the risk will be reduced to ALARP, FRSC can then issue safety licence and pass on the list of qualified companies to DPR. DPR will then ensure that they are the only companies allowed to load products from refineries, depots and tank farms. Also, DPR can also carryout unannounced inspection on vehicles within their jurisdiction to monitor the application of safety case in practice.

Finally, DPR should oversee the unloading operations at the retail stations. The drivers must be able to identify the hazards that could pose risk during offloading of products and how to mitigate such risk. Drivers should wear appropriate PPE during the off-loading of petroleum products at retail stations and DPR must ensure that all truck companies provide adequate PPE for their drivers.

## 8.3 Guidelines for the use of the Safety Assessment Framework (SAF)

The safety Assessment Framework (SAF) is designed to mitigate tanker accidents between a loading depot and a retail station. The Framework was designed taking the following factors into consideration:

- Drivers’ challenges
- Technology
- Risk management and safety

- Regulations
- Environment
- Training

In order to implement the framework, the guideline in the table below must be followed so as to ensure that the implementation of the framework gives the required results which is to mitigate accidents during the transportation of petroleum products in the downstream sector of the Nigerian petroleum industry.

*Table 58 Guidelines for the use of the Developed Safety Assessment Framework (SAF)*

| **Loading depot** | **Tanker drivers on the road** | **Offloading station** |
| --- | --- | --- |
| ▪ Conduct a risk Assessment. | ▪ Ensure that drivers are in good health condition. | ▪ Ensure retail station is aware of product delivery to perform adequate risk assessment. |
| ▪ Ensure that tankers are checked for leaks before loading. | ▪ Ensure that drivers are driving trucks within specified speed limits. | ▪ Tankers must be well parked for dipping and offloading operations. |
| ▪ Ensure that vehicle is in good working condition before loading products e.g., brakes, tyres and mirrors are checked. | ▪ All drivers of petroleum truck tankers should be mandated to attend an approved basic training course. | ▪ Allow time for tanker to settle after arriving a retail station. |
| ▪ Ensure tanker/trucks are equipped with | ▪ Ensure that drivers observe rest time | ▪ Ensure there are no naked flames or |

| | | |
|---|---|---|
| modern safety technologies such as the crash prevention systems and cargo tampering monitoring systems. | after driving for more than 2 hours at a stretch. | smoking around where truck is parked. |
| ▪ Reduce the problem of overloading of trucks at the depot. | ▪ Ensure that drivers have the appropriate qualification and licence to transport hazardous materials. | ▪ Ensure that pumps connected to tanks where products would be delivered are turned off and the areas free of obstructions. |
| ▪ Ensure the vehicle has a fire extinguisher. | ▪ Ensure that drivers are provided with adequate PPE. | ▪ Ensure adequate PPE are used by all staffs involved in the offloading of petroleum products. |
| ▪ Periodically evaluate and review the effectiveness of the risk management strategies. | ▪ Ensure drivers have adequate knowledge of hazardous materials being transported. | ▪ Ensure that all documentations are done by both parties during and after delivery. |
| ▪ Ensure that tanker drivers are provided with the Material Safety Data Sheet (MSDS) for every product being transported. | ▪ Ensure drivers have knowledge of accident reporting. | ▪ Safety checks must be carried out at the retail stations before products arrive for offloading. |
| ▪ Ensure that tankers used to transport petroleum products are designed to give low emissions in other to reduce pollution and protect the environment in | ▪ Ensure that roads are regularly maintained for hazmat transportation. | ▪ Emergency respondents should be strategically positioned on the road and at offloading station to tackle any emergencies that |

| | | |
|---|---|---|
| line with the Sustainable Development Goals (SDGs) | | could arise during hazmat transportation. |
| ▪ Ensure that driver's behaviour can be monitored on the road when transporting petroleum products. | ▪ Tanker drivers should be able to take all necessary measures for their own safety and that of the public and the environment to limit the effects of any incident that does occur. | ▪ All retail station must adopt a Non-smoking policy |
| | ▪ Tanker drivers' welfare should be improved to reduce poverty and ensure sustainability of a balanced work and family life. | |

## 8.4 Summary of Chapter Eight

This chapter discusses how the framework developed from this research would be implemented in the petroleum industry. The main point in the implementation of SAF is for the regulators and the operators (DPR, FRSC, IPMAN, MOMAN etc) to acknowledge the need for communication and collaboration amongst themselves to ensure that the benefits of implementing SAF is achieved in the Nigerian petroleum industry. Government too has a role to play by ensuring they give enforcement backing to DPR and FRSC. Also, this chapter outlined the guidelines and steps to follow in order to use the framework to successfully achieve its aims.

# 9 CONCLUSION AND RECONMMENDATIONS

## 9.1 Introduction

The overall conclusion of the study is presented in this chapter. The conclusions are based on the research aim, objectives and strategies taken to answer the research questions. The chapter also presents the contribution of the research to optimising the safety performance of petroleum operations within the Nigerian petroleum sector and the contribution to the development and advancement of the knowledge of risk management. The chapter concludes by reflecting on the research methods used and makes recommendations for further research.

## 9.2 Contribution of Research

This research has provided an insight into the mitigation of accident and promoting safety on the road during the transportation of petroleum products in Nigeria by investigating the current factors leading to road tanker accidents. Although previous research has presented information on the causes of hazmat accident in other countries, however, no information has been published in the public domain regarding the factors specific to Nigeria that impact safe transportation of petroleum products using road tankers, thus providing the knowledge for improving safety through risks management in Nigeria and also in the West African sub region. It is believed that the framework developed by this research forms a good basis for deepening the current body of knowledge on HAZMAT accident mitigation in Nigeria and elsewhere within the West African sub region. By reviewing and capturing data on the existing challenges facing the petroleum industry in Nigeria, this research provides the knowledge required for understanding the current problems and taking the necessary steps to improve. Below are the contributions of this research:

- The main contribution of this research is the development of a safety assessment framework for the transportation of flammable petroleum products for accident mitigation. This framework integrates all the components of safety to enhance the safe transportation and distribution of petroleum products in Nigeria.
- Adoption of the framework will open up channels for information flow between stakeholders within the freight transportation industries and technology consultants for the provision of adequate technological solutions for tanker accidents in Nigeria.
- Implementation of the framework will further enhance safety culture amongst depot and retail station operators for the loading of petroleum products at the depots all through to offloading at retail outlets.
- This research has created a roadmap for safety in the Nigerian petroleum downstream sector by identifying the need for collaboration between all stakeholders in the petroleum industry.
- Adoption of this framework will help the petroleum industry regulators in Nigeria to develop focussed policies and programmes to enhance risk management applications.

## 9.3 Achievement of the Research Aim and Objectives

The overall aim of the study is to develop a safety assessment framework for the transportation and distribution of petroleum products in Nigeria. The research focused on assessing the risks associated with road tanker transportation of petroleum products in Nigeria in order to mitigate accident and promote road safety. The main findings from each of the chapters, which address individual objectives are discussed below.

**<u>Objective Number One:</u>**

The first objective was **to perform a literature review on the Nigerian downstream petroleum industry.** To satisfy this objective, an in-depth review of literature was conducted in Chapters 1 and 2. The literature discusses the function of the NNPC which oversees the operations of all the petroleum companies in Nigeria. This chapter also discusses the challenges the petroleum industry is facing as it relates to the transportation of petroleum products. Also, it discusses the various participating organs that support the NNPC such as the PPMC which oversee the transportation and distribution of petroleum products in Nigeria. The current status of the refineries in Nigeria was also discussed and it also discusses how petroleum products transportation is being caried out in other parts of the world. The chapter was used to answer the first research question which is: **What is the status of hazmat transportation globally? In Nigeria**?

**<u>Objective Number Two:</u>**

The second objective was **to investigate the causes of road accidents involving tankers transporting petroleum products in Nigeria**. To satisfy this objective, an in-depth literature review was performed in chapter 2 to identify the various causes of accident especially as it relates to tanker transportation of petroleum products. The main findings on the causes of accident were classified into human, mechanical and environmental factors. Also, the results from the analysis of the quantitative and qualitative research in chapters 5 and 6 was also used to satisfy this objective. We can therefore conclude that chapters 2, 5, and 6 was used to answer the second research question which is: **What are the contributory factors to the causes of accidents during the transportation of petroleum products in Nigeria?**

**Objective Number Three:**

The third objective of this research was **to investigate the challenges faced by stakeholders across the value chain involved in the transportation of petroleum products. To** satisfy this objective, a literature review was performed in chapter 1 and 2. The findings include poor road designs which was linked to tanker accidents, pipelines vandalism, lack of depots maintenance, lack of functioning refineries etc. The results from the analysis of the quantitative and qualitative research in chapters 5 and 6 was also supports the findings from the literature review. We can therefore conclude that chapters 1, 2, 5 and 6 was used to answer the third research question which is: **What challenges do tanker drivers face in the downstream sector of the petroleum transport industry?**

**Objective Number Four:**

The fourth objective was to **evaluate the suitability of measures that can be implemented for the mitigation of tanker transportation accidents.** To satisfy this objective, an extensive literature review was performed on risk management frameworks and accident causation models in chapter 2. Also, a review of EU and the U.S laws concerning the transportation of hazardous materials was also performed to see how such can be adopted in Nigeria to help mitigate accidents involving the transportation of hazmat. We can therefore conclude that chapter 2 was used to answer research question 4 which is: **What measures could be implemented to mitigate tanker transportation accidents?**

**Objective Number Five:**

The fifth objective was **to develop a framework for road safety during Hazmat transportation considering safety legislation and standards for tanker operations in Nigeria.** To satisfy this objective, chapter 7 presented a safety assessment framework that was developed with the aim of mitigating accident during the transportation of petroleum products in Nigeria. The framework was developed based on the results from analysis of literature review, interviews and quantitative research.

**Objective Number Six:**

The sixth objective was to validate the developed framework by capturing user requirements and user acceptance data from selected members of the supply chain and from stakeholders in different organisational and governmental levels, thereby identifying areas requiring improvements and modifications. This objective was achieved in chapter 6 through the interviews conducted. The output of the interview was used as a mechanism to validate the framework.

**Research Question Five:**

**What is the perception of drivers toward training as it relates to petroleum products transportation?**

This research question was answered from the results of the analysis of the qualitative and quantitative research.

**Research Question Six:**

**What possible benefits could the Nigerian oil and gas transport sector achieved by implementing the safety assessment framework?**

This research question was answered in chapter 8. Chapter 8 presents the implementation of the framework and discussed its benefits to the petroleum industry.

## 9.4 Overall Conclusion

- This thesis focussed on the transportation of petroleum products using road tankers and it presented strategies which can be used to mitigate accidents involving tankers by developing a safety assessment framework.

- This thesis revealed the problems facing the Nigerian petroleum industry. The study also shows that the petroleum sector would require a complete overhauling for any meaningful investment in terms of road safety to yield positive results.
- The main finding from this research is that the attitude towards safety in the downstream sector of the petroleum industry is very poor. There are no risk management initiatives among the various stakeholders. This is the first time a study would explore risk management concepts to address the causes of accidents involving road tankers and include the opinions of drivers in order to investigate the challenges they face during the transportation of petroleum products in Nigeria.
- This research has revealed that the problems in the petroleum industry stems from governmental and regulatory levels down to operational and work levels. The study also revealed that the main problems facing the transportation of petroleum products in Nigeria is attributed to bad roads, lack of infrastructures, and poor safety attitudes of drivers.
- The study reveals that new initiatives are needed to address challenges in infrastructural development and the government and private investors should be ready to assist in building functioning transport infrastructure that would welcome the deployment of ITS to support hazmat transportation in Nigeria.
- From the study carried out in this research, it obvious that the Nigerian government does not have means of monitoring losses incurred during tanker accidents and as such they do not know what the country stands to benefit from the effective implementation of a risk management framework.
- The study reveals that most tanker drivers in Nigeria are not educated to the extent of understanding the concepts of risk management. Their presentation toward the

quantitative survey shows that many of the drivers does not know what safety technology means. This is a wake-up call for the government and transport operators and regulators to invest in safety awareness campaigns.

- The study reveals that the unsafe attitudes of tanker drivers on the road are being influenced by poor organisational and operational safety attitudes, and lack of risk management capabilities. This revealed the need for development and deployment of risk management strategies that target behavioural change and improve safety awareness.
- Also, the research finding suggests that the concept of risk management will provides viable approach to accident prevention and response within the context of petroleum transportation and distribution despite the limitations observed in downstream regulations in Nigeria. However, for the concept to be successful, meaningful policies need to be designed, implemented and monitored.

## 9.5 Limitations of Research

The research combined both qualitative and quantitative data and also made use of mixed methods for data analysis. The mixed method was adopted for this research based on the aim of the study which is to develop a safety assessment framework for the transportation of petroleum products to mitigate accidents involving tankers in the downstream petroleum industry in Nigeria. The researcher also envisaged that inputs from stakeholders will be critical to successful design of risk mitigation strategies for road tanker operations. The type of data derived from semi-structured interviews cannot be obtained from structured questionnaires, participant observation or analysis of the literature (McIntosh and Morse, 2015). It is an in-depth data about a phenomenon which can be answer from the participants' experience. Based on this, the researcher decided to compliment the analysis of the responses from the tanker drivers with those of some professionals in the downstream petroleum industry to get more information in other to investigate the causes of tanker accidents during the transportation and distribution of petroleum products in Nigeria, hence the need for a qualitative study.

Below are some of the limitations of the overall study:

- Conducting interviews with the stakeholders was perhaps the most challenging aspect of the interview due to the covid-19 pandemic. The researcher travelled to Nigeria for data collection but was unable to meet with stakeholders because of the pandemic. At the end, the telephone interview was adopted with its own challenges.
- During the telephone interview, most of the stakeholders were secretive with sharing some information as they try to play safe. This is also a challenge when the researcher visited the FRSC office in Abuja and Lagos state.
- During the telephone interview, there was too much network issues from Nigeria and some of the information could not be captured by the researcher. This can also impact on the reliability of the qualitative research.
- It was very challenging to obtain comprehensive data for this study due to the secretive nature of the petroleum industry in Nigeria (Amundsen, 2010). Most of the data are fragmented and inadequate.
- Most of the tanker drivers who completed the questionnaires have low level of education and needs assistance to understand the questions in the questionnaires. Also, their motivation was very low as one of them stated that they have assisted researchers in the past with completing questionnaires but the impact of such exercises is not felt as the conditions of the road remains very poor and no improvement in their welfare packages.

- It is very difficult for researchers to have access to most of the many of the companies for data collection due to heavy security at the gates and demanding visit protocols. They do not take research too seriously in Nigeria.
- The cost of travelling to all the NNPC oil depots in Nigeria for data collection was too much for the researcher as the research was self-funded. With limited resources, the researcher was only able to visit three depots in different geographical regions of the country. This could affect the reliability of the quantitative study.
- Another limitation of this research is the scope of the research. The scope of this research was initially to cover the nine classes of hazardous materials. However, this could not be achieved because of the cost implications and also because the research was self-funded. As such, only the class 3 hazardous materials were used for this research. A better research finding would have emerged if all the classes of hazmat were used for the study.
- Many of the respondents took the questionnaires home to complete but fail to return them as promised thus affecting the sample size of the survey.

## 9.6 Recommendations

The following recommendations have been made during the course of this study:

**Recommendations for stakeholders:**

- There is an urgent need to put Nigeria transport infrastructure in good shape to attract investors into the petroleum industry. This is why the government must single out infrastructure as a major priority and focus developmental effort on it in relative terms.
- Tanker accidents will continue to be on the increase in Nigeria unless a bold step is taken by the government and the various stakeholder in the oil and gas sector to set up an effective body comprising of transport experts to look at the problem facing the Nigerian transport industry and develop a model that would accommodate the setting

up of a modern transport structure. This is what most advanced countries have done to promote safety on the road and mitigate accidents.

- There should be a culture of proper maintenance of roads like what is being done in most developed countries otherwise, any accident mitigation project would remain a mirage.
- There should be proper training for tanker drivers and there must be a taskforce to ensure that tanker drivers are properly trained and licensed before they are made to drive tankers. Also, there should be huge penalties for those who fault the rules and regulations.
- The Standard Organisation of Nigeria (SON) must work in collaboration with DPR and FRSC to ensure that the specifications of tankers to be imported into Nigeria are well defined.
- It would be recommended that tankers should be made to travel at night hours, therefore reducing accidents rate because the roads would be less congested at nights. Alternatively, the creation of dedicated lanes for heavy duty vehicles would be strongly recommended and the government can generate some income for its maintenance by collecting tax duties in form of toll gates from other road users. This is being done in most developed countries.

**Recommendations for future research:**

- There is need for more research on hazmat transportation in Nigeria.
- The Nigeria government should create a curriculum for transport studies in every institution in the country so as to create room for the breeding of more transport professionals to manage transport activities and researches in Nigeria.
- Future research should be undertaken on other classes of hazardous materials.
- Further research should be undertaken to determine the actual cost of tanker accidents during the transportation of petroleum products in Nigeria.
- Additional research should be carried out at wider level to focus on the actual challenges faced by tanker drivers.
- Further research should be undertaken to **validate** the framework developed as part of this research work.

- Further research should be undertaken to determine the technologies tankers should have that would assist to mitigate tanker accidents during the transportation of petroleum products.

## 9.7 Summary of Chapter Nine

Chapter 9 presented how the objectives in this study were achieved, the summary of findings, overall conclusions, recommendations and contributions to knowledge drawn from the entire research. Each of the objectives in the study was restated while reporting the method(s) employed to achieve it. The report was then briefly presented under the overall conclusion section to put forward all the research findings in a summarized form. To conclude the chapter, some recommendations and contributions to knowledge were also presented.

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# APPENDIX 1 QUESTIONNAIRE AND COVER LETTER

23rd July, 2017

[e-mail address redacted]

My name is Augustine Odogun and I am a PhD research student of the University of Wolverhampton, UK. I am researching an area of Transportation, under the supervision and guidance of Dr Panos Georgakis and Professor Cristopher Nwagboso. I am currently in the process of gathering data for my research entitled: **Developing a Safety Framework for the Transportation of Petroleum Products: A case study of the Nigerian Petroleum Downstream Sector.**

I would therefore be grateful if you could spare a few minutes to complete this questionnaire. The questionnaire is estimated to take about 10 – 15 minutes to complete.

Please note that all information gathered will be treated with the strictest confidence. Information from the completed questionnaire is anonymous and will not be disclosed to anyone. The collected data will be kept secure to ensure confidentiality.

Kindly return the completed questionnaire to me in person. If you need any help or want to know more about the research project, please feel free to contact me using the contact details below:

Email: [e-mail address redacted]

Tel: (00) 44 [number redacted]

The questions in this survey are categorised into the following areas related to the transportation of petroleum products:

- Technological
- Drivers' challenges
- Environment
- Risk management and safety
- Regulations
- Training

## DEMOGRAPHICS

Please tick as applicable

1. What is your age?
   - 20 - 30 years
   - 31 - 40 years
   - 41 - 50 years
   - 51 - 60 years
   - 61 – 70 years
   - 70 and above

2. How long have you been a tanker driver?
   - 1 – 5 years
   - 6 – 10 years
   - 11 – 15 years
   - 16 – 20 years
   - 21 – 26 years
   - 26 and above

3. Please indicate your educational qualification (please tick)?
   - Primary Education
   - Secondary Education
   - OND/Diploma
   - University Education

TECHNOLOGICAL

1. Please state your level of agreement in the use of the following technologies by tankers on the road during the transportation and distribution of petroleum products in Nigeria.

| Technologies | Completely Disagree | Disagree | Neither agree nor disagree | Agree | Completely agree |
|---|---|---|---|---|---|
| **Vehicle location monitoring systems** | ○ | ○ | ○ | ○ | ○ |
| **Vehicle condition monitoring systems** | ○ | ○ | ○ | ○ | ○ |
| **Route planning systems** | ○ | ○ | ○ | ○ | ○ |
| **Driving behaviour monitoring systems** | ○ | ○ | ○ | ○ | ○ |
| **Crash preventing systems** | ○ | ○ | ○ | ○ | ○ |
| **Freight status monitoring systems** | ○ | ○ | ○ | ○ | ○ |
| **Weight-In-Motion systems** | ○ | ○ | ○ | ○ | ○ |
| **Cargo tampering prevention systems** | ○ | ○ | ○ | ○ | ○ |

2. Speed cameras on Nigeria roads have the potential to reduce tanker accidents by:

- O ≤ 20%
- O 20 - 40%
- O 60 - 80%
- O More than 80%
- O Do not know

3. To your knowledge, what is the average age of trucks used for transporting petroleum products in Nigeria?

- O < 5 years
- O Between 5 and 10 years
- O Between 10 and 15 years
- O Between 15 and 20 years
- O More than 20 years
- O Do not know

DRIVERS CHALLENGES

4. What are the major challenges faced by drivers on the road when transporting petroleum products in Nigeria? (Please tick all that apply)

- ☐ Poor road conditions
- ☐ Extreme weather conditions
- ☐ Over loading of trucks
- ☐ Poorly maintained trucks

☐ Insufficient rest time during travel

☐ Other (please specify) ……………………………………….………………

5. In your opinion, how important are the following factors in causing road tanker accidents?

| **Factors** | **Not at all important** | **Slightly important** | **Moderately important** | **Very important** | **Extremely important** |
|---|---|---|---|---|---|
| Lack of assistive technologies | ○ | ○ | ○ | ○ | ○ |
| Poor road conditions | ○ | ○ | ○ | ○ | ○ |
| Extreme weather conditions | ○ | ○ | ○ | ○ | ○ |
| Over loading of trucks | ○ | ○ | ○ | ○ | ○ |
| Poorly maintained trucks | ○ | ○ | ○ | ○ | ○ |
| Insufficient rest time during travel | ○ | ○ | ○ | ○ | ○ |
| Lack of regulatory frameworks | ○ | ○ | ○ | ○ | ○ |
| Inadequate driver training | ○ | ○ | ○ | ○ | ○ |
| Others (Please specify) ………………………………… | ○ | ○ | ○ | ○ | ○ |
| ………………………………… | ○ | ○ | ○ | ○ | ○ |

**6.** What is the average monthly salary (Naira) of a tanker driver in Nigeria?

- O < N20,000
- O Between N20,000 and N50,000
- O Between N50,000 and N80, 000
- O More than N80,000

RISK MANAGEMENT AND SAFETY

7. Personal Protective Equipment (PPE) such as helmets, hand gloves and safety shoes are necessary for tanker drivers when transporting petroleum products on Nigeria roads.

- O Completely disagree
- O Disagree
- O Neither agree nor disagree
- O Agree
- O Completely agree

8. In your opinion, how important is the specification of rest time in the legislation for tanker drivers when transporting petroleum products in Nigeria?

- O Not at all important
- O Slightly important
- O Moderately important
- O Very important
- O Extremely important

9. In your opinion, what should the average rest time be for tanker drivers when transporting petroleum products over long journeys?

O < 30 minutes
O Between 30 minutes and 1 hour
O Between 1 hour and 2 hours
O More than 2 hours

ENVIRONMENTAL

10. In your opinion, how satisfied are you with the conditions of the roads in Nigeria?

O Not at all satisfied
O Slightly satisfied
O Moderately satisfied
O Very satisfied
O Extremely satisfied

11. How concerned are you about the impact of severe weather conditions on tanker drivers when transporting petroleum products in Nigeria?

O Not at all concerned
O Slightly concerned
O Moderately concerned
O Very concerned
O Extremely concerned

12. What happens to spilled products after a tanker accident on Nigeria roads?

O Channelled into a well
O Products are collected by environmental experts

O Nothing is done about spilled products
O Other (please specify) ……………………………………….....
O Do not know

REGULATIONS

13. In your opinion, is it appropriate to define maximum speed limits on the different roads for tankers transporting petroleum products?

O Inappropriate
O Slightly inappropriate
O Neutral
O Slightly appropriate
O Appropriate

14. Who inspects the tankers before and after loading of petroleum products? (Please tick all that apply)

☐ Drivers themselves
☐ Depot officers
☐ Environmental Officers
☐ Police officers
☐ Other (please specify) ………………………………………….

15. In your opinion, how would you compare the operations of the multinational companies and the independent oil companies in terms of safety of tanker operations in Nigeria?

O Operation of multinational companies is much safer than that of independent companies

- O Operation of multinational companies is slightly safer than that of independent companies
- O Operation of multinational companies is equally safe to that of independent companies
- O Operation of independent companies is slightly safer than that of multinational companies
- O Operation of independent companies is much safer than that of multinational companies

TRAINING

16. How concerned are you about driver's knowledge of hazardous materials?

- O Not at all concerned
- O Slightly concerned
- O Moderately concerned
- O Very concerned
- O Extremely concerned

17. How concerned are you about driver's knowledge of safety procedures?

- O Not at all concerned
- O Slightly concerned
- O Moderately concerned
- O Very concerned
- O Extremely concerned

18. Adequate training can improve driver's behaviour on the road.

- O Completely disagree
- O Disagree

- O Neither agree nor disagree
- O Agree
- O Completely agree

19. In your opinion, how important is the continuous training for tanker drivers transporting petroleum products in Nigeria?

- O Not at important
- O Slightly important
- O Moderately important
- O Very important
- O Extremely important

# APPENDIX 2 DRAFT INTERVIEW QUESTIONS FOR QUALITATIVE RESEARCH

A. Drivers Challenges

In your opinion, what do you think is the most important challenge to do drivers during the transportation of petroleum products?

In your opinion, what is the relationship between drivers' wages and road safety during the transportation of petroleum products?

B. Technology

How has trucks equipped with safety technologies assisted in reducing road accidents during the transportation of petroleum products in Nigeria?

Do you believe that your fleet of trucks use state-of-the art technology in terms of safety?

How does the age of a truck impact accident during the transportation and distribution of petroleum products in Nigeria?

C. Risk Management and Safety

In your opinion, in the context of safety, how would you compare the operations of major oil marketers to that of independent oil marketers during tanker transportation and distribution of petroleum products?

What is your perception on compliant to the use of PPE by tanker drivers?

In your opinion, what is your take on vehicle maintenance in your organisation?

D. Environment Conditions

What is your opinion of severe weather conditions as a factor impacting the tanker transportation and distribution of petroleum products in Nigeria?

E. Regulations

In your opinion, do you think there are strict standards and regulations in term of hazmat transportation in Nigeria?

In your opinion, what do you think about the introduction of speed limits on the roads?

What is your take on rest time specification and how would this help to mitigate accidents?

F. Training and supervision

How important do you consider training of drivers as part of your risk management process to reduce accident during the transportation of petroleum products?

How important do you consider training drivers for new technologies?

Do you believe that tanker drivers have adequate knowledge and training before they are employed to transport petroleum products?

G. Framework Development and Implementation

1. What is your opinion about the development of a framework for the transportation of petroleum products in Nigeria?