A risk management framework for downstream petroleum product transportation and distribution in Nigeria

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Abstract

In Nigeria, downstream transportation and distribution of petroleum products is mainly done using pipelines and truck tanker transport systems. These systems have been linked to substantial accidents/incidents with consequences on human safety and the environment. This thesis proposes a risk management framework for the pipelines and road truck tanker transport systems. The study is based on a preliminary review of the entire downstream petroleum industry regulations which identifies key legislations and stakeholder interests within the context of accident prevention and response. This was then integrated into tailored mixed method risk assessment of the pipeline and truck transport systems. The risk assessment made use of accident reports and inputs from semi-structure interviews and focus group discussion with relevant stakeholder organisations.

For the pipeline systems, 96.46% of failure was attributed to activities of saboteurs and third party interference. The failure frequency of the pipeline (per km-year) was found to be very high (0.351) when compared to failure frequencies in the UK (0.23×10^{-3}) and the US (0.135×10^{-3}). It was discovered that limitations in pipeline legislations and national vested interests limits regulatory and operational capabilities. As a result the operator lacks the human and technical capability for pipeline integrity management and surveillance. Similarly the finding from the truck system revealed that 79% of accidents are due to human factors. The tanker regulators have no structured approach in dealing with the regulation of petroleum road trucking. Also, operating companies poorly adhere to safety standards. From an accident/incident response perspective, it was discovered that local response capability is lacking and the vulnerability of affected communities increases due to poor knowledge of the hazards associated with petroleum products.

A framework was proposed for each of the transport systems. For the pipeline system, the framework leverages on the powers of the Petroleum Minister to provide best practice pipeline risk management directives. It also proposes strategies which combine the use of social tactics for engaging host communities in pipeline surveillance with technical tactics to enhance the pipeline integrity. For the truck risk management framework, control points for prevention of truck accidents were identified. It adheres to principles of commitment to change, and regulatory/peer collaboration for deployment of management actions. Suitable policy recommendations were made based on regulatory and operational interest of stakeholder organisations.

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List of Abbreviations

AGO	Automotive Gas Oil
ALARP	As Low As Reasonably Practicable
BBC	British Broadcasting Corporation
CEA	Cost-Effectiveness Analysis
CONCAWE	Oil Company European Organisation for Environment Health and Safety
CP	Code of Practice
CSR	Corporate Social Responsibilities
DPR	Department of Petroleum Resources
EGASPIN	Environmental Guidelines and Standards in the Petroleum Industry in Nigeria
EGPDI	Environmental Guidelines for Petroleum Distribution Installations
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Assessment
EU	European Union
FEPA	Federal Environmental Protection Agency
FFSD	Federal Fire Service Department
FG	Focus Group
FME	Federal Ministry of Environment
FRSC	Federal Road Safety Commission
GIS	Geographic Information Systems
HAZOP	Hazard and Operability
HHK	House Hold Kerosene
HSE	Health Safety and Environment
ICF	Inter City Fund
IITS	Information, Instruction, Training and Supervision
IPMAN	Independent Petroleum Marketers Association of Nigeria
IR	Individual Risk
LEMA	Local Emergency Management Committee Agency
LFN	Laws of the Federation of Nigeria

LOC	Loss of Containment
MOMAN	Major Marketers Association of Nigeria
NEMA	National Emergency Management Agency
NESREA	National Environmental Standards and Regulations Enforcement Agency
NNOC	Nigerian National Oil Corporation
NNPC	Nigerian National Petroleum Corporation NNPC
NOSDRA	National Oil Spill Detection and Response Agency
NPE	National Policy on Environment
OPEC	Organisation of Petroleum Exporting Countries
PEF	Petroleum Equalization Fund
PHA	Process Hazard Analysis
PID	Petroleum Industry Bill
PMS	Premium Motor Spirit
PPMC	Pipeline Product Marketing Company
PPPRA	Petroleum Products Pricing Regulatory Agency
PRMF	Pipeline Risk Management Framework
PTDF	Petroleum Technology Development Fund
QaRA	Qualitative Risk Assessment
QRA	Quantitative Risk Assessment
RMF	Rasmussen’s Risk Management Framework
ROW	Pipeline Right of Way
SEMA	State Emergency Management Committee Agency
SEMC	State Emergency Management Committee
SR	Societal Risk
SUPPORT	SUPporting POlicy relevant Reviews and Trials
TRMF	Truck Tanker Risk Management Framework
UK	United Kingdom
UKOPA	United Kingdom Onshore Pipeline Operators
UNEP	United Nations Environment Programme
WHO	World Health Organisation

1 CHAPTER ONE: INTRODUCTION

1.1 Background

The concepts of safety, risk and environmental management are currently receiving considerable attention in the global petroleum industry due to the potential of operational accidents/incidents with devastating consequences to human safety and the environment (Eduljee, 2000; Hopkins, 2012). The 2010 Deepwater Horizon accident involving BP in the Gulf of Mexico (Deepwater Horizon Study Group, 2011) is a typical reminder of risks posed by petroleum industry operations. However, this is not to say that the global petroleum industry is only known for its troubles as the industry have been supplying the energy demands of mankind. The challenge faced by the global petroleum industry is striking a balance between the critical need for supply of energy with safe and sustainable operations.

Like many oil producing countries, the Nigerian economy is heavily dependent on the petroleum industry. According to International Monetary Fund (2012), the industry accounts for over 95% of export earnings and over 90% of government revenue. However, the industry has been blamed for poor safety performance, air, land and water pollution leading to poor ecological quality. Poor safety and environmental management within the industry has been attributed to poor technical infrastructures, accidents and vandalism (Zabbey, 2009; UNEP, 2011; Adewuyi and Olowu, 2012; Cbukwudi, 2012).

Similarly to the global classification of petroleum industry operations, the Nigerian petroleum industry consist of two streams of operations, upstream and downstream. The upstream operations includes: exploration; evaluation and appraisals; development; production and transportation of crude oil and untreated gas (Charles, 1999). Conversely, downstream operations are crude oil refining, transportation, distribution and product retailing. All of these activities can potentially cause harm to human safety and the environment. Yet, research attention tends to focus more on accidents emanating from the upstream petroleum industry operations in Nigeria (Zabbey, 2009; Kadafa *et al.*, 2012), and focusses more on environmental pollution occurring during exploration and production of oil and accidental or deliberate crude spillage. The reason for the high attention given to upstream risk research may be attributed to the perceived importance of the upstream subsector and involvement of big multinational companies and the relatively late cohesion of the downstream operations in Nigeria (Emeseh, 2006; Adefulu, 2008; Emeseh, 2012; Ambituuni *et al.*, 2014). Safety and risk management research within the downstream context has often been neglected and, till date, no satisfactory generally accepted risk management framework has been developed for measuring, assessing, interpreting and mitigating safety and environmental risks from accidents in operations within the downstream sector of the Nigerian petroleum industry. As such, when accidents occur within downstream operations, they lead not only to major economic losses but also record serious safety and environmental consequences.

1.2 Downstream petroleum industry operations Nigeria

The current downstream Nigerian petroleum industry structure is shown in figure 1-1. Within the structure there is a combination of different operations (including refining, transportation and distribution, and retailing) with different stakeholders with various interest. Downstream operations in Nigeria only became more cohesive in 1965.

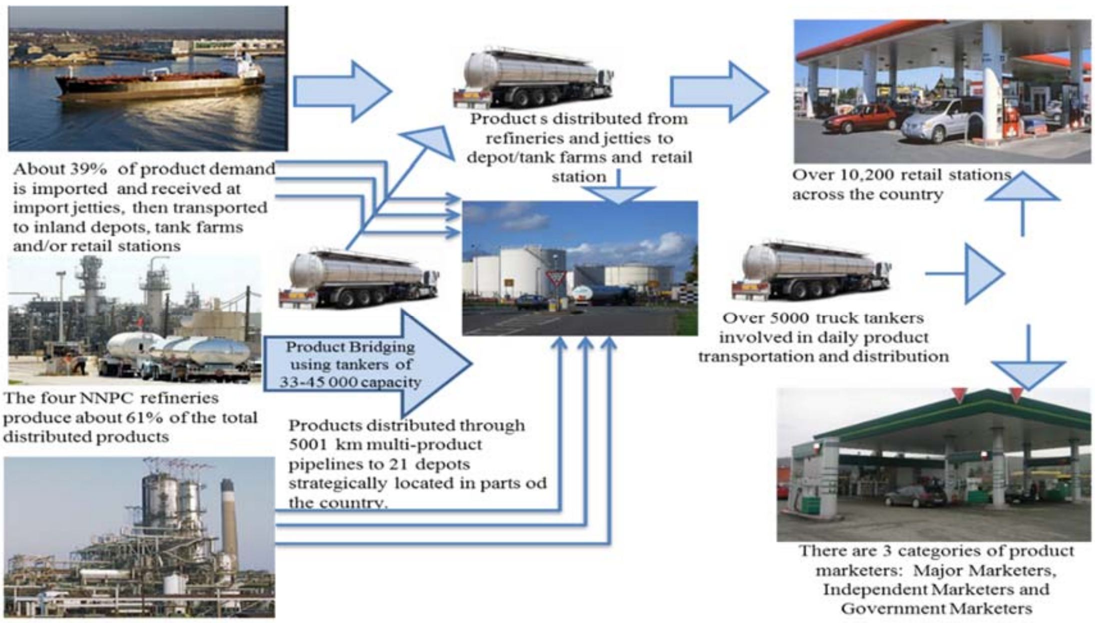

Figure 1-1. Downstream structure of Nigerian petroleum industry

Prior to 1965, domestic downstream requirements of petroleum products in Nigeria were met entirely through importation under a deregulated environment and completely in the hands of the private sector (Kupolokun, 2004). However, the Organisation of Petroleum Exporting Countries' (OPEC) Resolutions (1960 and 1971) ushered a significant change in the ownership structure of the entire petroleum industry in Nigeria. In accordance with the Resolutions which urged member countries to participate in oil operations by acquiring ownership in the concessions held by foreign companies, the Nigerian government began to develop a more coherent approach in its participation in the downstream sector. Thus, in 1971 the government established the Nigerian National Oil Corporation (NNOC now Nigerian National Petroleum Corporation NNPC) by Decree Number 33. The NNOC was empowered to acquire any asset and liability in existing oil companies on behalf of the Nigerian government and to participate in all phases of the petroleum industry (Akinjide-Balogun, 2001).

As a consequence of the need to participate in downstream activities, the first Nigerian government wholly owned refinery was commissioned in 1978. Afterward, 3 other refineries, 21 depots and over 5000km of strategically located product pipelines were later commissioned to aid product availability.

Currently, there are 4 refineries in the country, one each in Kaduna and Warri, and two in Port Harcourt, with a nameplate capacity of 438,750 billion b/d. These refineries, however, routinely perform below their capacities due to poor management and maintenance policies. For instance, records show (see figure 1-2) refining capacity of the Kaduna refinery to be as low as 0.67% in January 2011 (NNPC, 2011). It is unclear to what extent this poor management relates to safety and environmental performance. However, Vivan *et al.* (2012) reported issues of environmental pollution and adverse health problems within the host community of the Kaduna refinery.

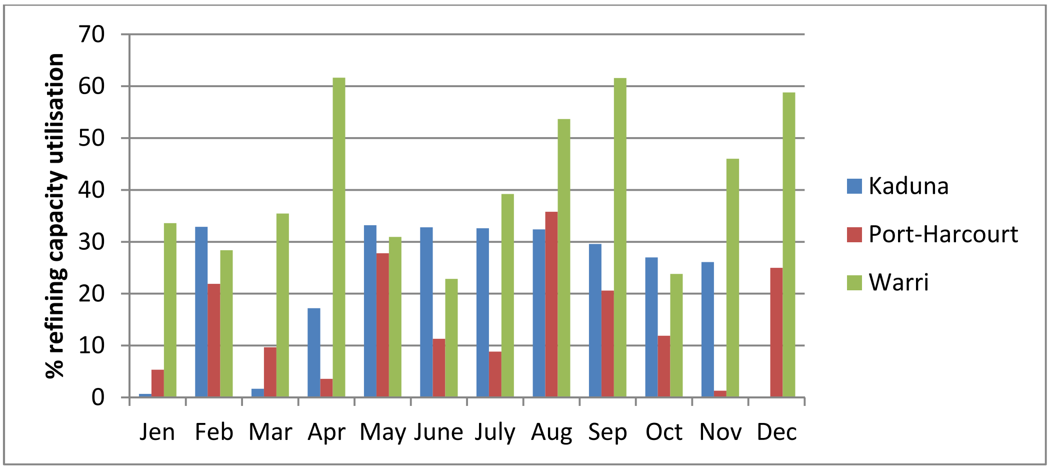

Figure 1-2. 2011 Domestic Refining Capacity Utilisation (%) (Source: NNPC, 2011)

The Nigerian government is a key participant (both regulation and commercial operations) in downstream operations including petroleum product transportation and distribution (Akinlo, 2012). There is however some limited private sector participation. Nevertheless, generally, most local private companies are small, fragmented and unable to adhere to global best practices. Thus, downstream activities are characterised by:

1. Complete and exclusive domination of the supply chain structure of the downstream sector by government via the NNPC through ownership of all the existing refineries, distribution pipelines, depots and oil import jetties (as shown in figure 1). It is only in the marketing sub-sector that government has loosened its vice-like grip on the industry. Here, 6 major marketers (Oando Nig. Plc, Mobil Oil Nig. Plc, Total Nig. Plc, Forte Oil Nig. Plc, MRS Nig. Plc, and Conoil Plc) control a 25.47% share of the fuels retail market; over 3800 Independent Marketers control 51% of the fuels retail market; while the NNPC controls 23.43% of the retail market.
2. Scarcity of petroleum products leads to long queues at service stations all over the country. As noted in section 1.3 below, this has fuelled poor safety practices and high level of environmental pollution as people take extreme measures, including illegal activities to supply or obtain products.

1.3 Safety and environmental issues in the downstream operations

The absence of a risk management framework within the Nigerian downstream petroleum operations has contributed to deficiency in guidelines for setting and achieving safety and environmental management goals that should incorporate a balance of technical information and stakeholder input. This typifies the challenges faced in Nigeria in the quest to harmonise the conflict between safety and the environment with petroleum operations through the concept of sustainable development (Emeseh, 2006) especially in pursuit of modern management (Yanting and Liyun, 2011). Perhaps this is the reason the downstream operations are characterised by poor safety and environmental standards. For instance, refinery underperformance results in fuel scarcity in Nigeria (Bazilian and Onyeji, 2012). Fuel scarcity contributes to petroleum elevated accident risks in the country owing to such factors as the prevalence of adulterated petroleum products in the "black market" during periods of scarcity; sabotage and siphoning of products from

NNPC facilities for sale in the black market; illegal refining; unsafe storage and transportation of petroleum products by consumers; and importation of substandard refined products into the country (Onuoha, 2007; UNEP, 2011).

Due to the total collapse of rail infrastructure and absence of inland water transportation, pipeline and truck systems are the main medium of petroleum product transportation and distribution. Like many pipeline system around the globe, in Nigeria, transmission pipelines carrying liquid petroleum products are not on secure industrial sites but are routed across the land, i.e., busy city, remote locations or network of highways. Consequently, there is ever-present potential for third parties to interfere with the integrity of these pipelines. In addition, the combination of third-party interference and pipeline route might suggest that people around the pipelines are subject to significant risk from pipeline failure. And although in many countries pipeline infrastructure presents the most effective, safe and environmentally friendly means of transportation for petroleum products over long distances, this is not the case in Nigeria, as vandalism and pipeline interdiction has been liked to catastrophic disasters. This is the reason why there is considerably high road haulage operations for petroleum products.

It is estimated that about 95 percent of total product volume transported by road is done using truck tankers of about 33,000litre capacity. On average, 5,000 tankers are involved in the daily product cargo haulage and 1,500 trailers in dry cargo haulage on poorly maintained Nigerian roads (FRSC, 2011). Similar to the pipeline system, road-truck transportation contributes to safety and environmental issues as documented by Dare *et al.* (2009), BBC (2012) SAVAN (2002) and Anomohanran (2011).

Both nodes of product transportation and distribution (pipeline and road-trucking) are characterised by rampant occurrence of accidents, vandalism and related fire disasters. Some examples of accidents involving petroleum product distribution include:

1. Onitsha petrol tanker accident claims 69, including a pregnant woman: 31st May, 2015. Reported by Channels TV (2015). The tanker loaded with petrol, was said to have lost control and ran into Asaba Motor Park at upper Iweka, in Onitsha before exploding.

2. December 26, 2006 pipeline explosion in Ilado-Odo around Lagos in Nigeria, which killed more than 250 people. This was amongst the 14 different cases reported in Omodanisi *et al.* (2014) between 1998 and 2006.

3. Pipeline explosion at Jesse community on 15 October, 1998 resulted in large scale pollution of nearby rivers and farmlands, and killed over 1,500 people including women and children (Emeseh, 2006).

4. Other accidents reported by Dare *et al.* (2009) included: Fuel tanker crash in 6 November, 2000 killing over 100 people and destroying farmlands and polluting nearby river. Fuel tanker crashed with bus on the 12th of October 2000, killing up to 50 people and damaging properties worth millions.

These accidents have exposed the lack of accident/incident prevention and emergency management structure within the downstream petroleum product transportation and distribution systems in Nigeria.

As can be gleaned, the safety and environmental impact of pipeline and road-truck operations are critical concerns and, therefore, require the attention of risk professionals. This is mainly because it is at this point that ordinary individuals who may have little or no industry expertise and training on handling products come into contact with volatile petroleum products, thereby increasing accident/incident risks. Since injuries, contamination of the environment and loss of investment all depend on the controls of physical processes, the lack of control within these operations increases safety and environmental vulnerability. There is, therefore, a need to define novel means of mitigating the risk associated with these operations by balancing technical processes with human involvement for a holistic management of risks.

Balancing technical and human involvement in risk management is especially important for the Nigerian context due to the operational context and characteristics of stakeholders and legislations within the downstream sector. For example, (and as discussed in chapter 3) many safety and environmental regulatory failures in Nigeria are largely attributed to weakness and looseness of the legislation and the related government unwillingness to enforce laws, deferring priority within the tiers of government, absence of technical knowhow, and low literacy rate (Ambituuni *et al.*, 2014). Stakeholders are therefore faced with the enormous complexity of these limitations and the critical task of ensuring that petroleum supply chain operations remain functional for optimisation of supply of products to fuel the Nigerian economy. The challenge, therefore, is to ensure that risk prone petroleum operations such as pipeline and trucking operations remain safe and within acceptable risk limits.

While the impact of petroleum pipeline failure and truck tanker accidents in Nigeria have been reported mostly in newsprints and as unpublished reports, specific effects of these disasters are rarely known and the approach for preventing and responding to such accidents is not well researched. Except for the study by Anifowose *et al.* (2012) which provides a quantitative analysis of the reason for pipeline failure and Fadeyibi *et al.* (2011) which provided information on different degrees of burns suffered by the victims of the pipeline related disaster in Nigeria. These studies do not provide an approach for managing the problems of accidents and disasters from hazardous petroleum operations from a holistic view of risk management.

Even though the concept of risk management has long been applied by researchers and industry practitioners in the developed world to find solutions to the challenges of ensuring safety petroleum operations, this concept has not been applied to the problem instance of downstream petroleum transportation and distribution in Nigeria. Notably, the risk management frameworks used in the developed world integrates technical and human elements (at all levels of regulations and commercial operations) in developing proactive and reactive strategies for accidents and incident prevention and response. Some well-known frameworks with this approach are discussed in section 1.4 below.

1.4 Application of risk management concept for downstream operations in other countries

Developed countries are increasingly adopting risk management concepts to suite the specifics of such countries and used for managing safety and environmental risks from downstream petroleum operations in the context of accident risk reduction and response. The concepts are also used as means of achieving specific regulatory targets, whilst also balancing risk perception and business profitability with stakeholders involved in petroleum operations in the country. Some examples include: United Kingdom (Energy Institute, 2007), United States (ICF, 2000) and Italy (Bubbico *et al.*, 2006).

In the UK, the Environmental Guidelines for Petroleum Distribution Installations (EGPDI) by the Energy Institute (2007) is a typical example of a risk based framework that forms part of the guideline for petroleum distribution operations developed with the aim of optimising safety and environmental performance. Specifically, the guideline outline technical and managerial practises for the prevention of leaks and spills that may adversely affect surface and groundwater, and soil with complete integration into a regulatory framework.

Motivated by regulatory frameworks on control of environmental hazards such as: EU Groundwater Directive 80/68/EEC; EU Natural Habitats Directive 92/42/EEC; EU SEVESO II Directive 92/82/EEC; and EU Water Framework Directive 200/60/EC, EGPDI was designed to meet the need for good environmental performance and effective actions to minimise the release of hydrocarbons to the environment, and improvement in safety performance as required in the work place. The fundamental principle used to develop the guideline is: wherever possible, “prevention is better than cure”. Thus, the principal outlined methodology takes a proactive approach to managing risk from petroleum distribution installations by raising the level of understanding of personnel within such facilities on how to operate existing equipment and facilities to get the best performance.

EGPDI emphasises the importance of risk assessment as a key tool in safety and environmental management. The importance of risk assessment was identified as a tool used to:

- Identify hazards posed by facility and activities within,
- Measure the probability of hazards and accident/incident occurring,
- Evaluating the corresponding consequences of hazards if they do occur,
- Deciding what can be done to reduce the probability of the hazard occurring, and
- What can be done to mitigate the consequences of the hazard occurring.

Accordingly, EGPDI suggested the utilisation of a conceptual model in understanding the site under review. The model is aimed at providing a pictorial representation of contaminating agent(s), source, pathway and receptors, and how they interact with the environment (groundwater, surface water and land). The result of such assessment is then used in: establishing operational and engineering control measure requirements; implementing appropriate operational management system and controls/monitoring processes; and preparing emergency plans/procedure throughout the life of the facility. The methodology suggested for the risk assessment is an iterative process that allows for review and thereby enabling different risk reduction options to be incorporated in a practicable and cost effective manner.

In terms of transportation and distribution of petroleum and hazardous products, in the US, the Inner City Fund (ICF) developed a risk management framework which has been adopted by the US-Department of Transport. The underlying philosophy of the framework is "action informed by analysis". Based on this principle, analysis of risks, costs, benefits, technical feasibility, and other items is necessary for effective risk management, particularly within a system as complicated as hazardous materials transport, but analysis should not become an end unto itself. Hence, risk analysis provides the information needed for decision-making and planning but does not by itself reduce risks. Therefore, the decisions and actions on risk management by integrating both technical and human capabilities should be informed by results of analysis.

Similarly, Bubbico *et al.* (2006) presented a framework for managing accident risks from land transportation of hazardous materials in Sicily, Italy. The framework makes use of a specialist software called TrHazGis and GIS application for accident risk assessment. Based on the result of the assessment, risk management initiatives can be developed and rapidly evaluated for decision on possible mitigation actions.

The above discussed risk management frameworks are valuable strategies to learn from, but cannot be directly applied to the Nigerian context because risk management is not generic (Rasmussen, 1997) and can only be applicable to the context to which it was developed. Moreover, for risk management initiatives to be effective, it must adhere to the regulatory principles of the country and the scope it is designed for. This is the reason why this research sets out to a design risk management framework based on the regulatory requirement and stakeholder interest within the scope of downstream petroleum transportation and distribution operations in Nigeria. It is based on this scope that the research aim, objective and research questions were designed in section 1.6.

Risks in this study will be investigated from the context of safety and the environment as affected by the two mean medium of transportation and distribution of petroleum products in Nigeria i.e. pipeline and road-truck systems. The focus will be on prevention and response to accidents with potential safety and environment consequences. Throughout this study, safety will be used to mean safety to human, safety to the environment and safety to petroleum assets. Similarly, ‘‘environment’’ in this research will cover key components such as human and ecological entities; including plants, animals, air, water and land as defined by UNEP (2011).

Being the two main medium of product transportation in Nigeria, pipeline and road-truck systems are critical infrastructure that play vital roles in the supply of energy. An overview of the two systems under consideration is given in 1.5 below.

1.5 Overview of pipeline and truck transport systems in Nigeria

1.5.1 Pipelines system

The pipelines covered within this research is the 5001km transmission system for liquid petroleum products in Nigeria. The system moves large quantity of products from either refinery or import jetties to local distribution depots as shown in figure 1-3. Mainline pipes, pumps, and compressor and buster stations, and other facilities that form the transmission system are all considered within the terminology “pipeline system”.

The pipeline system is strategically located across the county and classified into five regions of operations. The Nigerian National Petroleum Corporation (NNPC) own and operate the asset via its subsidiary the Pipeline Product Marketing Company (PPMC). Each of the pipelines links the refineries/import jetties with depots. The Kaduna refinery is also linked to the Escravos terminal through Warri by a crude oil supply pipeline. The pipelines are divided into 2 phases depending on the period of their construction:

- **Phase 1**: These pipelines commissioned in 1979, consists of systems 2A, 2B, 2C, 2D, and 2E.

  System 2A = Warri - Benin - Ore - Moisimi line

  System 2B = Moisimi - Lagos Sattelite - Atlas Cove, and Moisimi - Ibadan - Ilorin

System 2C = Warri - Abudu - Auchi - Lokoja - Abaji - Izom - Sarkin Pawa - Kaduna.

System 2D = Kaduna - Gombe

System 2E = Port Harcourt - Aba - Enugu – Makurdi

- **Phase 2:** These pipelines commissioned in 1998 consists of the 2CX, 2EX West, 2EX East, and 2DX systems

  2CX = Auchi - Suleija - Minna and Suleija – Kaduna

  2EX West = Port Harcourt – Enugu –Auchi -Benin

  2EX East = Port Harcourt - Enugu - Makurdi - Yola.

  2DX = Jos - Gombe

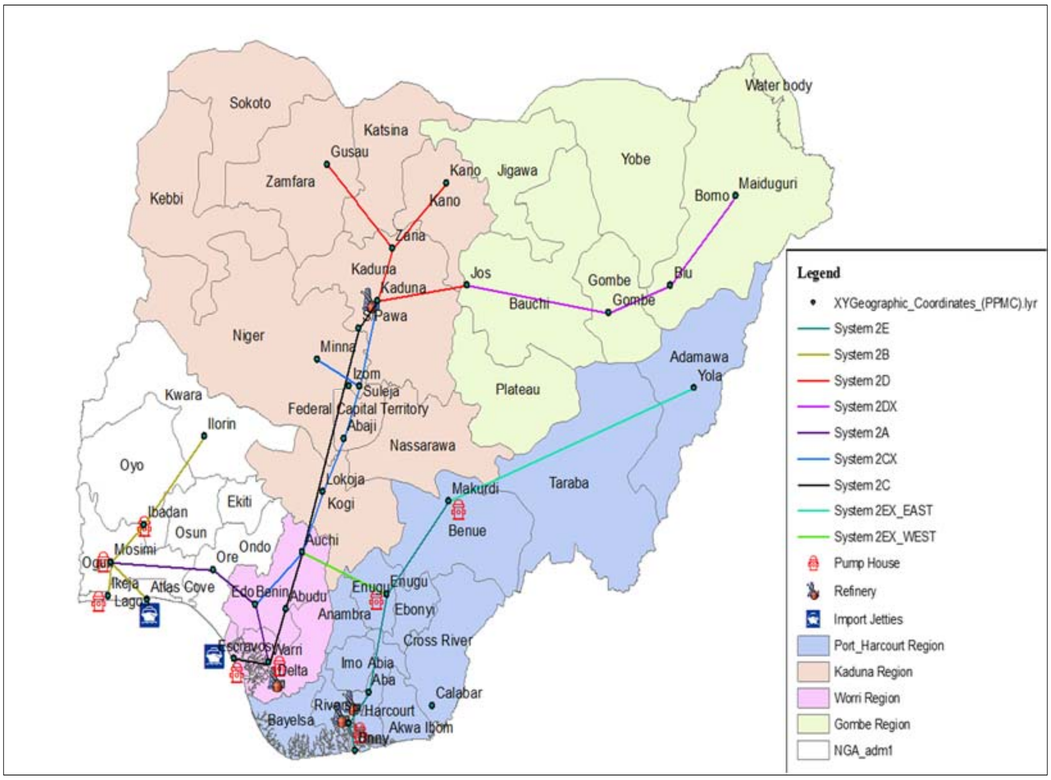

Figure 1-3. Map of Nigeria showing pipe network and petroleum depots. (Source; Anifowose et al. (2012); NNPC (2012); and PPPRA (2006))

The pipelines are made up of multiproduct systems for the supply of Premium Motor Spirit (PMS), House Hold Kerosene (HHK) and Automotive Gas Oil (AGO). To ensure safe operation of the pipeline, the operator buried the pipes at about 1m depth. Similarly, the Nigeria Oil Pipeline Act (Chapter 338, LFN, 1990) stipulates a 47.5m wide right of way (ROW) buffer around pipeline where human activities including buildings and farming are expected. However, recent experience have shown that these safety measures have been compromised, resulting in rampant cases of pipeline sabotage, third party interference and large scale accidents (Onuoha, 2008).

1.5.2 Road-truck system

Figure 1-4 represents the typical flow of products using the truck transport system in Nigeria. The system was ideally designed for short distance transportation of products from fixed storage facilities which should receive products via the pipelines. However, with the constant failure of the pipeline systems, trucking has become the most viable transport mode. It now transports products from refineries/jetties to depots and from depots to depots as well as supplying to retail stations. Further description of this supply chain phenomenon and its connectivity to the pipeline system is given in section 1.5.4.

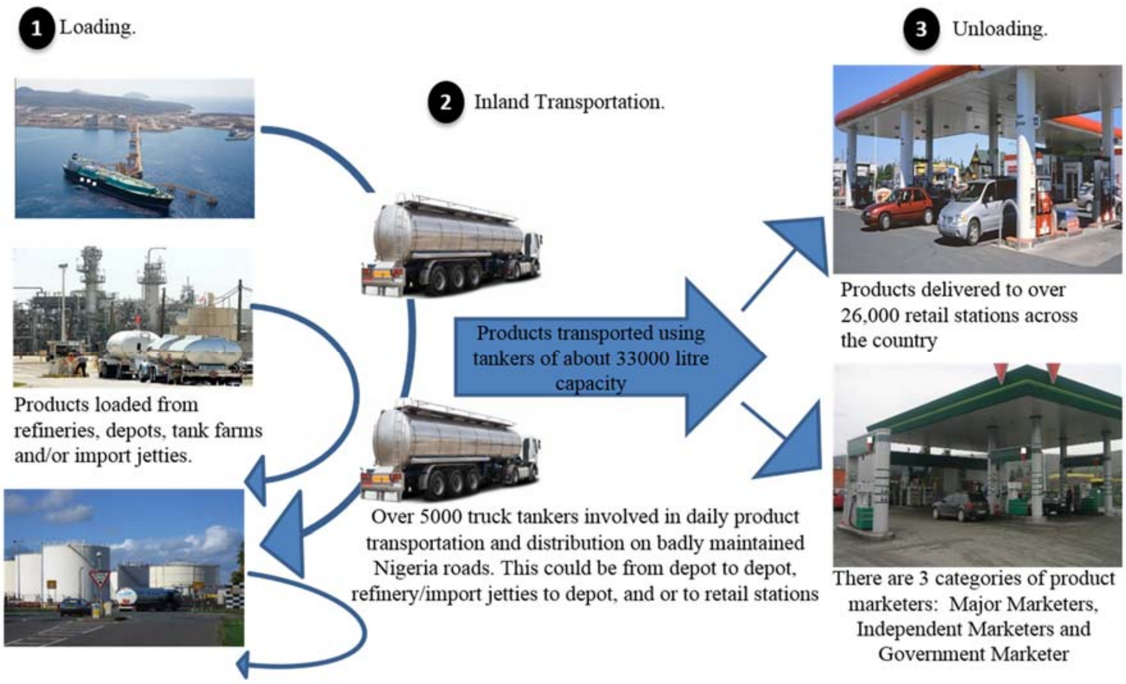

Figure 1-4: Supply nodes for petroleum truck tanker operation in Nigeria.

Currently, over 95% of petroleum product land transportation is done on the road (FGN, 2010)and there is a steady growth in number of road tanker vehicles. However, accidents, bad roads, poor road networks and various hindrances such as armed attacks and hijacking obstructs the effectiveness of truck operations. Also, trucks transportation are most times the source of product adulteration as some drivers siphon products and replace the volume with a comparably cheaper product without considering the product quality. Tankers are also often involved in diversion of petroleum products to illegal destinations even across the Nigerian borders and are also used by vandals for evacuation of products from vandalised pipelines. The challenges for safe operation and regulation of truck tanker transportation is therefore enormous and requires an innovative risk management approach.

1.5.3 Pipelines and trucking as inter-multi-nodal systems

Refined petroleum products are ideally supposed to be transported from the refineries and import jetties through a network of pipelines to the 21 regional storage/distribution depots with a total capacity of 1,422,000 cubic metres, spread across the country (as earlier shown in figure 1-4). It is from these depots that the marketing companies are supposed to obtain their supplies using road trucks to distribute to retail stations. This system barely operates as designed due to constant failure within the pipeline systems. In order to address the shortfall (created by pipeline failure) in petroleum product supply through transport pipelines, the concept of bridging was introduced by the PPMC and its management was later transferred to the Petroleum Equalization Fund (PEF) in 1998. Bridging is a process that involves road trucks transporting petroleum products over long distances (usually over 450 km) e.g. from the refinery or depot to another depot that may be experiencing a shortfall in supply (Anifowose *et al.*, 2011). However, this transport mode has recently become the essential mode of transport, due in part, to the increasingly recurrent damages to the downstream pipeline network and the low capacity utilization of the four refineries in the country. This is the current context of inter-nodal connectivity between the pipeline and truck systems of transportation and forms the context of full-circle petroleum transportation in Nigeria.

As can be deduced from this product transport structure, failures caused by accidents in the two mediums of distribution can go beyond safety and environmental impact as such failure can cut short the supply of petroleum products which plays a vital role in the economic and socio-political spheres in Nigeria. The importance of petroleum products can be seen in every facet of life (Iwayemi, 2008). According to AGUSTO (2008), petroleum products account for the bulk of energy source in Nigeria, estimated at 68.5%

of the total energy consumed in the country (Energy Information Administration, 2012). Therefore, failure in the systems of transportation and distribution can be of adverse effect to other sociotechnical infrastructures.

Figure 1-5 shows the interconnection between the two distribution medium and between the webs of complex socio-technical infrastructures in Nigeria. This interconnectivity is known as infrastructure interdependency. Infrastructure interdependency is defined as a physical, logical and functional connection from one system to another, where the loss or severing would affect the operation of the dependent infrastructure (Pederson *et al.*, 2006). In the figure, each web represent a sector or subsector. At the top web is the energy sector with a detailed representation of the supply chain structure of petroleum products within the domain of energy demand. The nodes within the webs represents infrastructure components, while the dotted line illustrates the flow of energy.

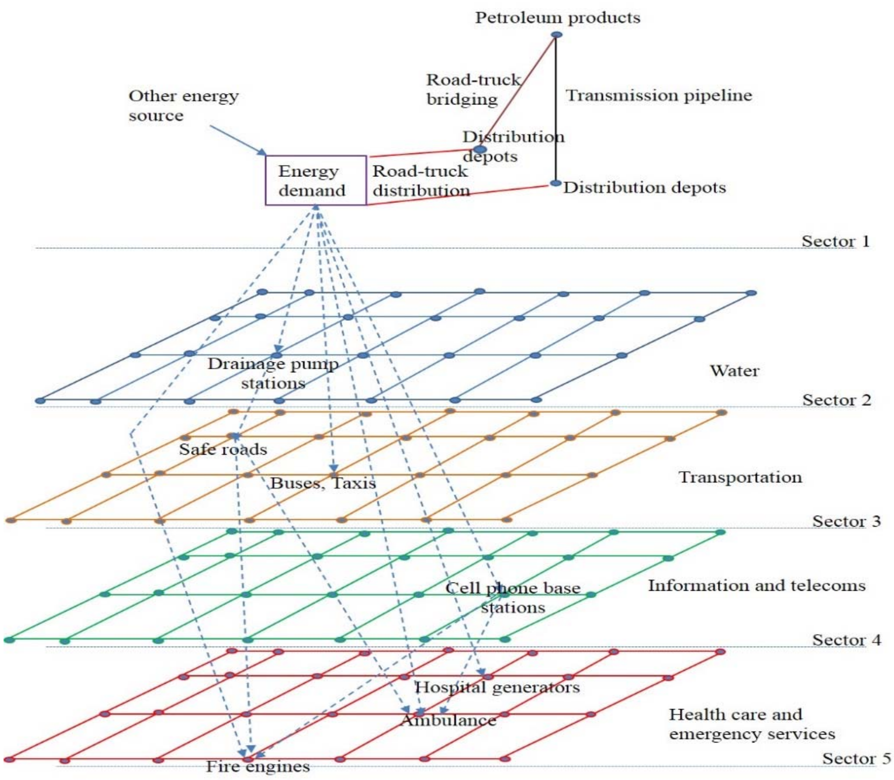

Figure 1-5. Petroleum product distribution and infrastructural connections. Diagram adopted from Pederson *et al.* (2006)

To put the importance of safe and optimised running of the petroleum distribution systems (especially road-truck and pipeline systems) into a realistic context, one can recall the December 26, 2006 pipeline explosion in a rural community (Ilado-Odo) (Omodanisi *et* *al.*, 2014). In addition to the safety and environmental consequence, the accident had a negative impact on the entire socio-economic activities in Nigeria. In such case, disruption on a main transmission pipeline will result in shortfall in supply. This may consequently have effects on the workability of sociotechnical infrastructure interdependency in two scenarios. First is the direct impact resulting in shortage of petroleum products required to run key infrastructural components such as ambulances, hospitals, telecommunications, etc. Second is the indirect impact, e.g., unavailability of telecommunications infrastructure to call emergency services.

It can therefore be seen that in addition to the need for a safety and environmental risk management framework for petroleum product distribution, this study will benefit optimisation of the complex sociotechnical infrastructure interdependency by proposing accident risk reduction strategies within the two main medium of product distribution.

1.5.4 Properties of petroleum products under consideration

Although the overall principles of this study can be applied to distribution of all types of petroleum products, the main products considered for both pipeline and road-truck distribution systems are liquid hydrocarbons which are mainly used as sources of energy in Nigeria. The specification given below are the standard properties recommended by the regulator in Nigeria, i.e., the Department of Petroleum Resources (DPR):

Premium Motor Sprit (PMS): a lightweight hydrocarbon that flows easily, spreads quickly, and may evaporate completely in a few hours under temperate conditions. It poses a risk of fire and explosion because of its high volatility and flammability, and is more toxic than crude oil. PMS also known as gasoline or petrol is amenable to biodegradation, but the use of dispersants is not appropriate unless the vapours pose a significant human health or safety hazard. The specific characteristics provided by regulatory authorities are shown in table 1-3

Table 1-1 Properties of petroleum products

	PMS	**HHK**	**AGO**
Appearance	Clear and bright	Clear and bright	Clear and bright
colour	Ox-blood	Saybalt (min) +20	ASTM(Max) 3.0
Specific gravity at 15 °C	0.720-0.780	0.775-0825	0.820-0.870
Acidity	-	0.01	-
Boiling point °C	210	300	385
Flash point °C (min)	43	45	66

House Hold Kerosene (HHK): a lightweight hydrocarbon that flows easily, spreads rapidly, and evaporates quickly. HHK also called Kerosene is easily dispersed, but is also relatively persistent in the environment. Kerosene is the third product of the refinery stream. It is mainly used as a cooking fuel in Nigeria.

Automotive Gas Oil (AGO): a complex mixture of hydrocarbons produced by mixing fractions obtained from the distillation of crude oil with brand-specific additives to improve performance. Under normal conditions it is a liquid with a characteristic odour. It is produced by blending straight-run middle distillates (minimum 40%) with varying proportions of straight-run gas oil, light vacuum distillates, light thermally-cracked distillates and light catalytically-cracked distillates. Also known as diesel, automotive gas oil is ideal for road vehicles (trucks, buses, vans, and cars) powered by diesel engines. It is also used to power generators.

1.6 Research aim, objectives and research questions

The need for application of risk management in preventing and responding to accidents/incidents involving downstream petroleum transportation and distribution operations informed the aim of this study. Consequently, this research is aimed at *'developing a risk management framework for transportation and distribution of petroleum products in Nigeria'*. To achieve this aim, the following research objectives (1 to 5) were designed and presented below. Figure 1-6 shows the corresponding chapters in which the objectives were addressed.

Objective 1: *Develop an approach for risk management research within the context of petroleum product transportation and distribution in Nigeria.*

- RQ 1.1: What research philosophy and methodology best suits the context of risk management research?
- RQ 1.2: What accident analysis model can be best used for causal factor analysis?
- RQ 1.3: What methods for data collection and analysis are suitable for risk assessment and development of mitigation strategies?

Objective 2: *Analyse the safety and environmental regulatory framework for downstream petroleum industry operations in Nigeria.*

- RQ 2.1: What are the laws governing the entire downstream petroleum industry operations and specifically petroleum transportation in Nigeria?
- RQ 2.2: Who are the stakeholders? What are their interests and areas of participation?
- RQ 2.3: What problems and prospects, if any, does the regulatory framework hold?

Objective 3: *Develop a risk management framework for pipeline operation with complete integration of legislative requirement.*

- RQ 3.1: What model can be used of the pipeline risk assessment?
- RQ 3.2: What are the risks associated with the pipeline systems?
- RQ 3.3: What factors contribute to the frequencies of pipeline failure and the consequences of such failure?
- RQ 3.4: How best can stakeholder interests be integrated for the deployment of the designed risk mitigation strategies?

Objective 4: *Develop a risk management framework for road truck tanker operations with complete integration of legislative requirement.*

- RQ 4.1: What are the risks associated with the road trucking of petroleum products?
- RQ 4.2: What model can be used of assessment truck tanker accident risks?
- RQ 4.3: What causal factors within the complex socio-technical structure of tanker operations contribute to accidents?
- RQ 4.4: What structured approach can be integrated with stakeholder interests for accident risk mitigation?

Objective 5: *Discuss and analyse how best the risk management frameworks can be deployed.*

- RQ 5.1: What possible policy directions can be used for implementing the risk mitigation strategies developed?
- RQ 5.2: What implementation challenges should be expected?

1.7 Thesis structure.

The chapters of the thesis are set out such that each chapter addresses one of the research objectives and its corresponding reserch questions. This is illustrated in Figure 1-7. The figure shows the objectives addressed within each chapter, the research activities carried out and the data used.

Chapter 2 provides a general framework for the reseach methods used throughout the thesis. However, the method sections in Chapters 4 and 5 provide the specific methods and risk assesment models used to address the context of petroleum transportation operations under consideration.

Chapter 3 provides analysis of the pieces of legislations across the downstream structure of the Nigerian petroleum industry in other to develop understanding of the effectiveness of the downstream regulations in general and with respect to product transportation and distribution. The chapter identifies relevant laws, stakeholder organisation and their risk management interests. This grounds the risk management propositions made throughout the thesis. The chapter also discusses the limitation of the laws.

Chapter 4 addresses objective 3. It provides an assessment of the risks of the downstream pipelines and proposes risk mitigation strategies based on the regulatory context established in chapter 3. Similarly, **Chapter 5** presents an assessment of the risks of transportation and distribution of petroleum products by road. The chapter also develops a risk management framework based on regulatory and stakeholder interests.

In **Chapter 6,** objective 5 was addressed. The chapter discusses strategies for implementation of the proposed frameworks in chapters 4 and 5. The chapter presents some policy briefs and discusses the role of key stakeholders within the briefs. The also highlights some possible challenges to expect in the policy implementation.

Chapter 7 is the conclusion. It provides the summaries of the main findings of the research and also assesses the contribution of the research to the development and advancement of the knowledge of risk management and the petroleum industry. The limitations and possible areas of future research was identified.

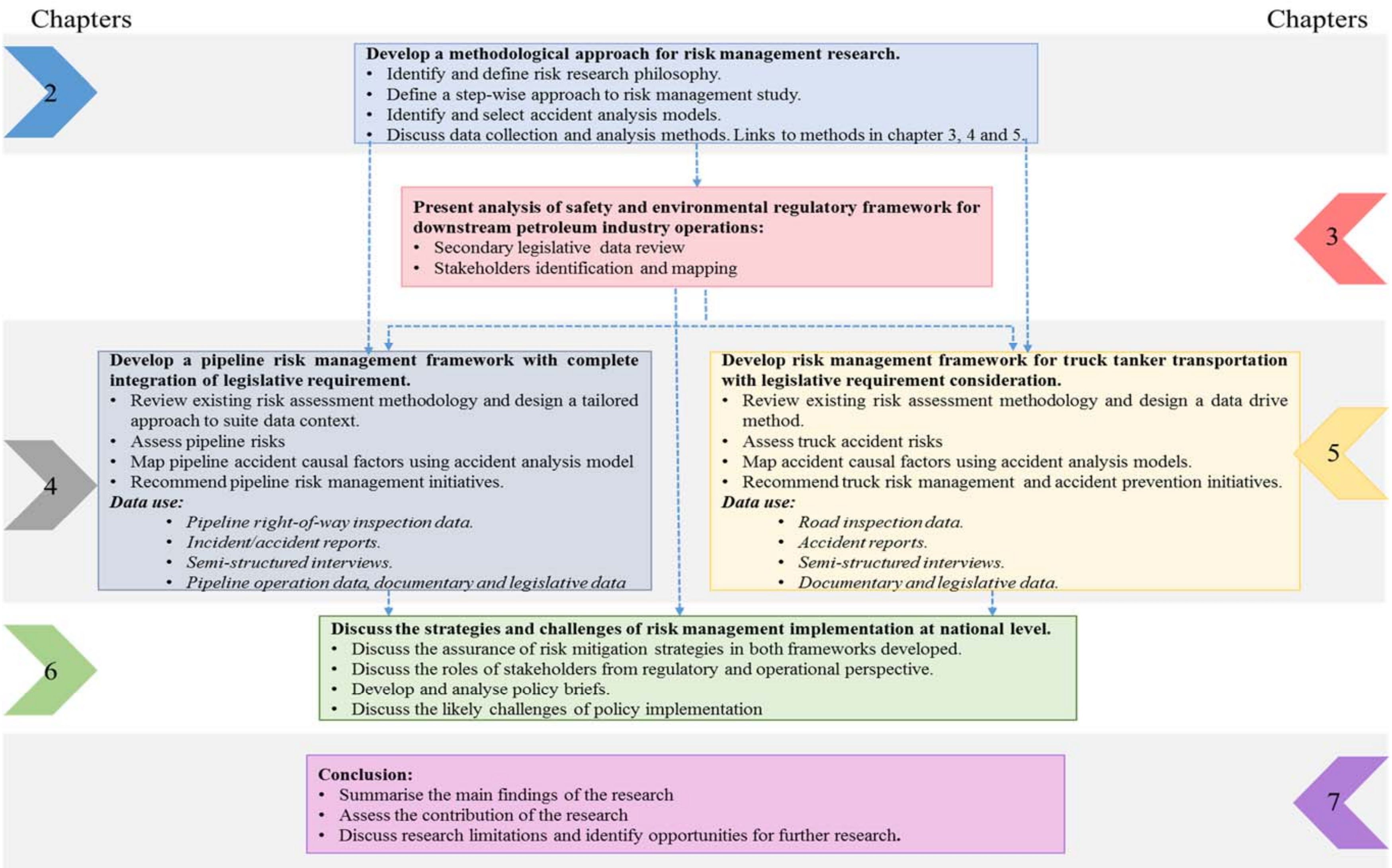

Figure 1-6. Thesis structure

2 CHAPTER TWO: APPROACH TO RISK MANAGEMENT RESEARCH

2.1 Chapter introduction

This chapter presents the general research approach used throughout the thesis. It presents the philosophy that governed the context of risk management research, the stepwise approach used for the risk research, accident causal factor analysis models used, and methods for data collection and analysis.

2.2 The philosophy of risk research

The concept of risk management is the systematic amalgamation of risk assessment together with judgment made during risk characterisation from the input material upon which risk management options are evaluated, assessed and selected (Aven and Renn, 2010). 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 and Renn, 2010).

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). On the other hand, a more extreme view suggests that risk is the same as perception, as has been asserted by cultural theory and constructivism (Jasanoff, 1999).

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.

Similarly, the risk property identified in Aven and Renn (2010) which is considered to address stakes should guide perception in risk management. This means that analysing and managing risk should seek to strike a balance between stakeholder perceptions (cultural theory and social constructivism) and scientific knowledge (ontological realism), e.g., via knowledge based probabilities and related risk assignment.

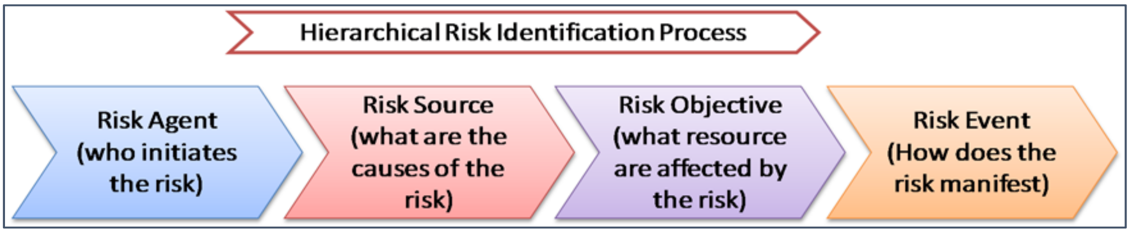

Figure 2-1. Hierarchical Risk Identification Process (information source: Fernandes et al. (2010))

For a risk event to appear risky there has to be a risk object or a receptor (risk has to be perceived). This has further been supported by the hierarchical risk identification framework in (Fernandes *et al.*, 2010) as show in Figure 2-1. Based on this framework, a complete understanding of risk requires the following question to be answered: what can go wrong? How can it happen? How likely is it to happen? And what are the consequences?

With this in mind, the assessment of risks from both pipeline and truck tanker petroleum product distribution was aimed at creatively collecting and analysing information obtained from the "real world" to provide structure and guidance on risk nature. Hence, the effective mitigation strategies were proposed with consideration of both the "physical" and "social" dimensions of risk.

Risk management involves applying management techniques to reduce and control (mitigate) risk identified during a risk analysis and assessment exercise. For this research, it will involve systematic application of policies and resources to the assessment and control of risk affecting human safety and the environment. Mitigation strategies are counter measures that could reduce the likelihood and/or the consequences of the risk events triggered by the risk sources.

Managing accident risk takes place at different system levels classified as “regulator” and “regulated”. The regulators are the authorities that make the regulatory frameworks, while the regulated are operators at the sharp end of the workplace (global, national and local industries). This two perspectives are often in conflict regarding risk management. While the “regulated” are particularly interested in profit, the regulatory agencies are interested in ensuring public and environmental safety. Hence, proper risk assessment principles among regulatory authorities and operating organisations involved in high-risk activities is required in order to understand and prevent the potential severe consequences posed by high risk activities. This should be aimed at striving towards the fullest possible integration of all relevant inputs so as to create capable political regimes and institutions (Zhang *et al.*, 2010).

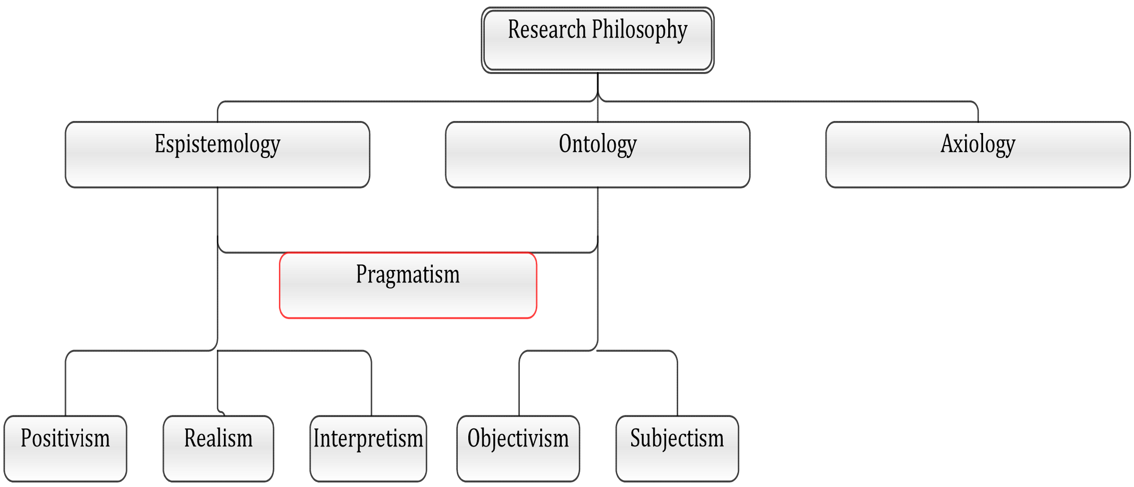

Figure 2-2. Research Philosophy Concept Structure (Adapted from: Saunders, et al. 2008)

It therefore goes to say that the questions raised by the philosophical arguments of ontological realism versus cultural theory/constructivism though important, should not mislead the focus and justification for risk assessment and management. This is because the most important element of risk management is integrating all contextual data, real-world elements and factors to provide information for achieving a reduction of either the likelihood of occurrence of harm or its corresponding magnitude. This suggest that the questions to be answered during the risk research should guide the research philosophical view. Hence for this study, the assessment of risk will be viewed from a pragmatic perspective as shown in Figure 2-2. This is because pragmatism argues that the most important quality of adopting a research philosophy is the research questions as one approach may be better than the other for answering a particular research question. This opens the door to multiple methods, different world view point and different assumptions as well as to different forms of data collection and analysis in mixed method study (Saunders *et al.*, 2012)

2.2.1 Relationship between safety and risk

Throughout this study, risks will be measured in terms of safety (human safety, environmental safety and asset safety). Therefore, it is important to establish a methodological link between the measures of safety in relation to risk.

Safety is defined as a condition where nothing goes wrong or more cautiously as a condition where the number of things that went wrong is acceptably small (Hollnagel, 2014). Such definition was identified as an indirect explanation of safety since safety is defined by what happen when it (safety) is absent. From a practical view point, therefore, this definition is the definition of lack of safety (unsafe). Moreover, with this definition, safety focuses on things that went wrong, hence there will be no means of measuring safety when safety is present (Hollnagel, 2014). This is not to say that this definition is wrong as it makes practical sense to focus on unexpected events that have consequential harmful implications and could lead to losses. Hence, perhaps, a more pragmatic way of defining safety is in terms of risks. This does not eliminate the argument as to whether safety should be define in relation to existence of unsafe or safe situations, but gives a means of measuring safety as safety itself cannot be measured.

The relationship between safety and risk is defined in Suddle (2009). Suddle explained safety in terms of two elements, i.e. objective and subjective elements. These two elements suggests that it is not automatic to assume that when a person experience s/he is safe from a psychological view point, means that he is safe from a mathematical point of view and vice versa.

Subjective safety is related to psychological aspects and thus can hardly be assessed objectively, while objective safety components can be assessed in objective terms if mathematical grounds are used (Suddle, 2009).

To define and to judge the objective elements of safety, Suddle linked safety with risk (the combination of probability and consequences), since safety cannot be quantified. This means that a maximum level of safety corresponds with zero risk, while a low safety level guaranteed corresponds with a risk of almost 100%. This gives room for risk to be quantified and judged based on its level of acceptability as safety itself cannot. Risk can thus be measured with loss per year, as a direct function of safety.

However, it is worth mentioning that the idea that safety can be linked to risk in this way – the lower the risk, the higher the safety, and vice versa – has been challenged by several researchers. For example, MÖLler *et al.* (2006) conclude that it is paramount to go beyond the view that safety is the antonym of risk. Uncertainty is considered of great importance when discussing safety and safety matters, but the uncertainty aspect is not reflected in many perspectives on risk, for example those based on probability and expected values. Aven (2009) provided a detailed analysis of this issue and argues that for some broad risk perspectives, which highlight uncertainties beyond probabilities and expected values, safety can in fact be considered the antonym of risk (Aven, 2014), and safety can be defined by reference to acceptable risk. An example of such a risk perspective is risk understood as uncertainty about and severity of the consequences of an activity.

With this in mind, risk in this study is defined as the combination of the probability that a hazard will occur and the corresponding consequences (usually negative) from that hazard associated with a given activity (pipeline and trucking operations).

Hence, if an activity with one event with potential consequences is considered, operational risk R is thus the probability that the event will occur (accident) P multiplied by the consequences given the event occurs Q.

$$\boldsymbol{R = P_i . Q_i} \tag{2.1}$$

If all hazards are taken into account, by summing up all possible hazards (scenarios) with their consequences for an activity, then as an obvious extension, multiple scenarios (*indexed i*) may be taken into account. This can be presented with the following formula:

$$\boldsymbol{R = \sum_i (P_i . Q_i)} \tag{2.2}$$

Where P_i and Q_i are the probabilities and consequence of scenario i. A coefficient of aversion can be factored in Q to emphasise the magnitude of Q.

In its classical definition probability is the number of favourable outcomes over the number of all possible outcomes (Armitage *et al.*, 2008). This definition arguably shows that probability is the "frequency of the occurrence of possible outcomes over the frequency of all possible outcomes". In fact probability is the "relative frequency" not the absolute frequency of outcomes. Hence, if probability is expressed for a parameter as frequency of occurrences per time lapse (e.g. number of failures of technical equipment per year), then risk can define as:

$$\boldsymbol{R} = \sum_i (\boldsymbol{F_i}\ \boldsymbol{Q_i}\ ) \tag{2.3}$$

Where F_i is the relative frequency of occurrence of event i expressed over a parameter e.g. time, km-year, etc., and Q_i is driven by factors such as: injury, or loss of life; property or asset damage costs; loss of economic activity; environmental losses; time loss; etc.

2.3 A stepwise approach to developing risk management initiatives

The stepwise processes used for developing risk mitigation strategies for the pipeline and truck tanker accident prevention and response are discussed in this section.

2.3.1 Risk assessment

A core objective of risk management is making informed decisions. Risk management decisions are informed by risk assessment – defined as the procedure in which the risks posed by hazards associated with processes or situations are estimated either quantitatively and/or qualitatively (Marcomini *et al.*, 2008). It involves using all available information to estimate the risk to individuals or populations, property or the environment, from identified hazards and comparing the risk limits with set targets (Suddle, 2009).

An integral part of risk assessment is risk analysis. These two (risk assessment and risk analysis) are often confused and used interchangeably in various literature without due consideration for their technical definition. For this study, risk analysis involves developing a scope, organising and analysing related data and information to evaluate the likelihood of occurrence of harm and its corresponding impact. Risk analysis process is shown in Figure 2-3.

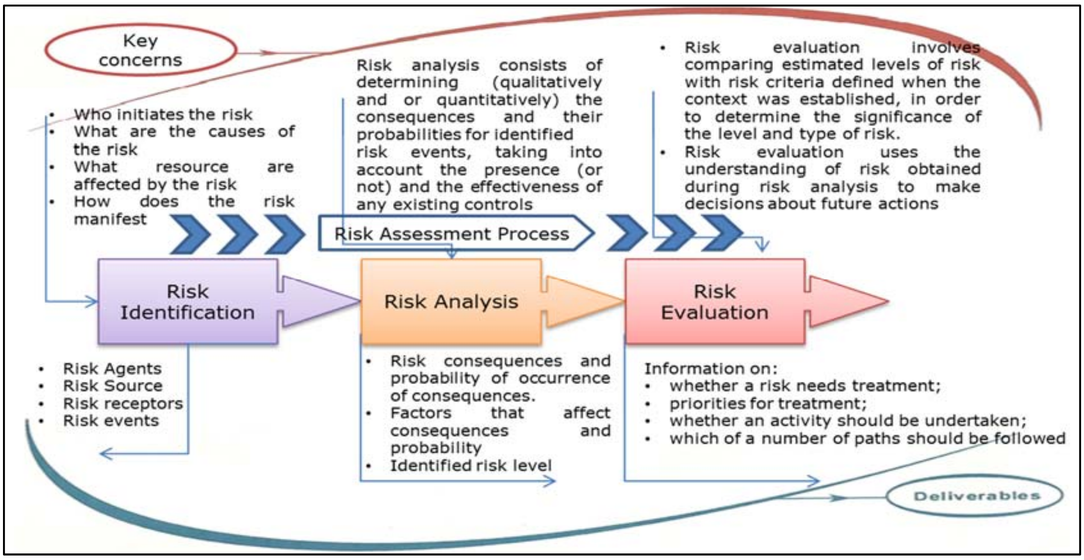

Figure 2-3. Risk assessment phases (Information source: BS EN 31010, 2010)

For this research, the entire process of risk identification, analysis and evaluation (comparing risk levels with legal or established levels) was therefore considered as risk assessment. Consequently, this meant that before identifying the best options to managing risks (be it risk avoidance, risk reduction and/or risk transfer) in decision making, the research viewed risk assessment as a critical part of a holistic risk management process.

Some schools thought (e.g. National Research Council, 1983), however, advocated for a separation between risk assessment and risk management. National Research Council (1983) justified this separation by asserting that while risk assessment involves activities conducted by application of technical scientific methodologies, risk management is seen as a political, social and economic assessment of information aimed at analysing and prioritising responds for effective decision making to be carried out. This approach is considered to be a fragmented way of understanding risk especially when considering the point of integration between risk assessment and risk management. For instance, stakeholder involvement is crucial to shape problem definition, scope, conduct and output of both risk assessment and risk management (Eduljee, 2000). Also, integrating risk perception from stakeholders and decision makers is a major determinant in establishing if risk is deemed to be acceptable and whether the risk management measures are seen to be effective and covers key risk perspectives as shown in Figure 2-4.

Hester and Harrison (1998) similarly supported the blend between risk assessment and risk management in the philosophy of scientific proceduralism. They recognised explicitly that science is not wholly objective and that subjective value judgement within technical risk assessment has to be acknowledged and dealt with in an appropriate manner. Their assertion does not argue for a wholesale rejection of risk assessment but focuses upon a blend of robust scientific and technical analysis, effective communication and stakeholder involvement.

Thus, both the analytical and characterisation phase of risk assessment in this research rely on scientific assessment methodologies which integrates both objective data from accident reports and subjective data from interviews. Similarly, the planning and communication phase of risk assessment was based on integration of scientific facts with socio-cultural beliefs, attitudes, judgments, and understanding of stakeholders. Therefore this study methodology integrated risk assessment as a key part of a holistic risk management process.

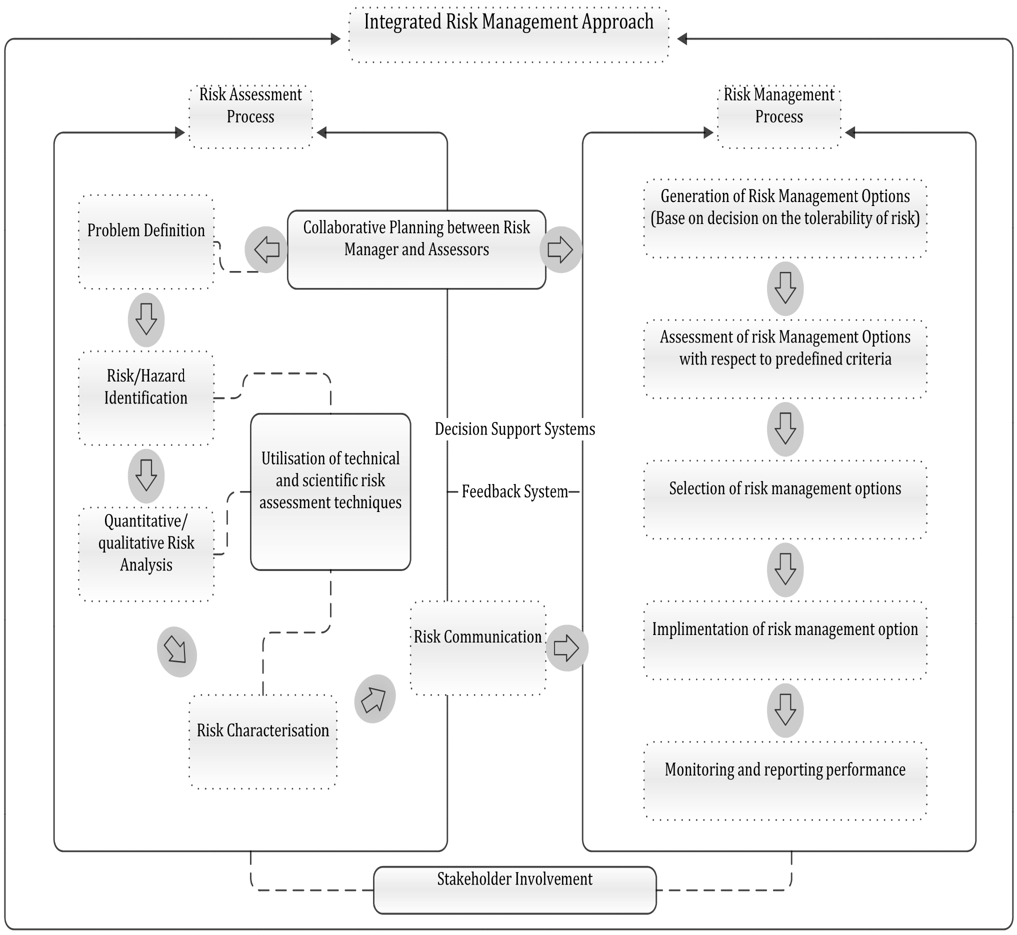

Figure 2-4. Integrated risk assessment and management approach (Adapted from: Eduljee, 2000)

With this approach proper dissemination of information on risk content across stakeholders was achieved even from the planning (scoping) phase of risk assessment and throughout the assessment/management processes rather than imposing risk management solutions based on scientific findings only. This approach has further been supported by BS EN 31010 (2010) which defines risk assessment as that part of risk management that provides a structured process that identifies how objectives may be affected in the analyses of risk in term of consequences and their probabilities before deciding on whether further treatment is required.

2.3.2 Risk evaluation

Having established the risk scope, analysed the risk values, the study then evaluated the risk limits from pipeline failure and truck accident risks by comparing with defined criteria (in the risk assessment stage).

The aim of risk evaluation, sometime called risk characterisation, was to guide the decision making process about risk acceptability. According to Aven and Renn (2010), risk evaluation serves two main purposes: First to grasp a balanced, value-based judgement on the tolerability/acceptability of risk or to perform a trade-off analysis of a set of functional equivalents (of the product, process, or practice under consideration). Second to initiate (if deemed necessary) a management process and make preliminary suggestions for the most suitable management approach. The main question to consider in the risk evaluation stage of the study is: *how safe is safe enough?*

Risk limits that are considered acceptable have either very low probability of occurrence and low consequences or both. Hence, developing further mitigation strategies are not necessary. Conversely intolerable risks are considered unacceptable. Amidst acceptable and intolerable risk is the term “tolerable”. This refers to an activity that is seen as warranted on the grounds of associated benefits, yet which requires additional measures in order to reduce the threat below as low as reasonable practicable (Aven and Renn, 2010).

The problem, however, is drawing the line between “intolerable risks” and “tolerable risks” as well as “tolerable risks” and “acceptable risks” as tolerability or acceptability judgement is informed by the results of risk analysis process but not determined by it. Moreover, the definition of acceptable risk varies on whether it is viewed from a personal perspective or societal perspective. Considerations from other wider social and economic factors may influence these characterisation. This meant that judgements on risk acceptability and tolerability in this study had to rely on two important inputs: values and evidence.

Two methods were, therefore, used in characterising risks, i.e. using individual risk limits and societal risk limits. For example, the Figures 2-5 and 2-6 were adopted from BS-PD8010 part 3 (2009) for application of pipeline risk assessment. Based on this, individual risk is a measure of the frequency at which an individual at a specific distance from a pipeline is expected to sustain a specific level of harm from the realised specific hazards. For pipeline risks, the United-Kingdom Health and Safety Executive (UK-HSE) defined a generic societal risk in which a constant distributed population in the vicinity of a pipeline is assumed, or site-specific, in which the details of particular developments, building layouts and population distributions are taken into account.

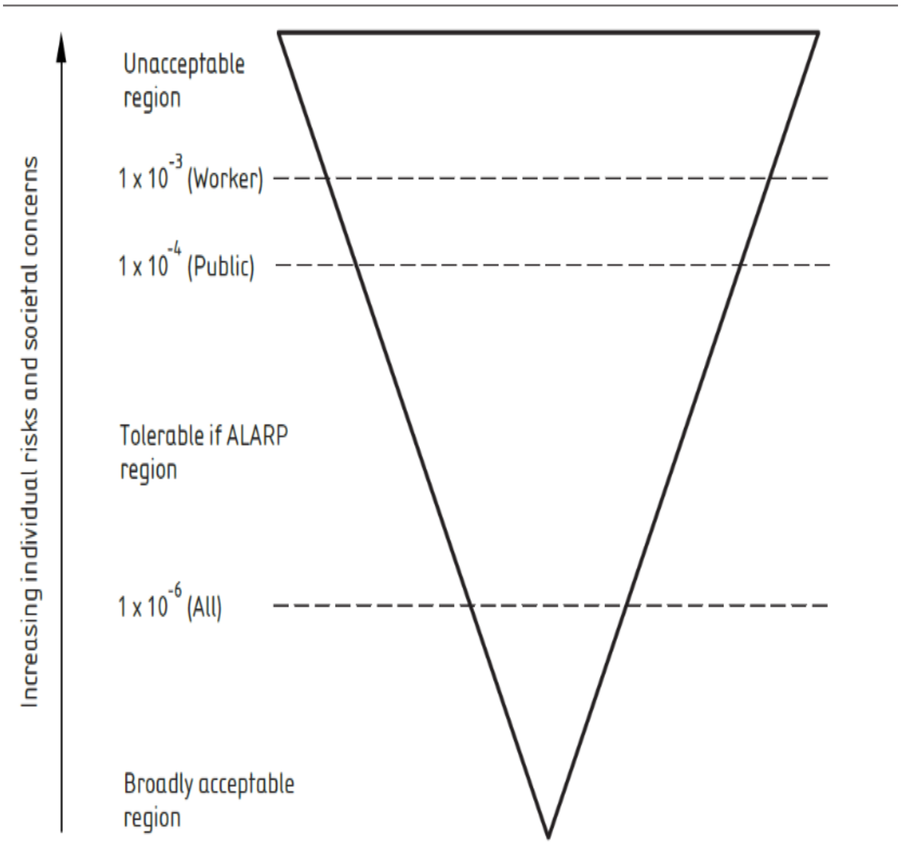

Figure 2-5. Framework for the tolerability of individual risk (BS PD8010-3, 2013)

The definition of acceptable risk is different for both individual and societal risk, since individual preferences may allow for additional risks, which may not be acceptable to the society.

For example, in the Netherlands, third party risk level must be less than $1E^{-5}$ per year to be adjudged acceptable for existing facilities, and $1E^{-6}$ for new facilities (Ale, 1991). The Western Australia's maximum acceptable risk level also stands at $1E^{-6}$ (Environmental Protection Agency, 2000). Hong Kong has acceptable risk of $1E^{-5}$ (Hong Kong Government Planning Department, 2008).

In the UK, an individual and societal risk limit has been established in BS PD8010-3 (2013). From Figure 2-6, the acceptable probability limit is $1E^{-6}$ for individual risk. This means for pipeline risk to be acceptable, the probability that a specific person shall be killed by a pipeline incident during 1 year should not exceed one in million.

Similarly, PD 8010-3 defined societal risk as the relationship between the frequency of the realisation of a hazard and the resultant number of casualties. From Figure 2-6 the limits for societal risk for pipeline accident occurring causing the death of 10 will be tolerated at a frequency of $1E^{-5}$ as far as it is as low as reasonably practicable (ALAP). For pipeline incidents, risk is often expressed by F–N-curves, showing the expected number (frequency) of accidents with at least N fatalities.

The idea of acceptable risk for different countries and installations may be influenced by historical catastrophic incidents (Dawotola *et al.*, 2012). Individuals and society alike often set-up the so called acceptable risk, with a view to mitigating the risk level to what can be termed 'bearable'. The decision process on the acceptability of risk is generally based on the development of risk acceptance criteria, with the view of using such criteria as a tool to facilitate decision making. This concept was adopted in the method used for risk assessment pipeline and truck tanker operations.

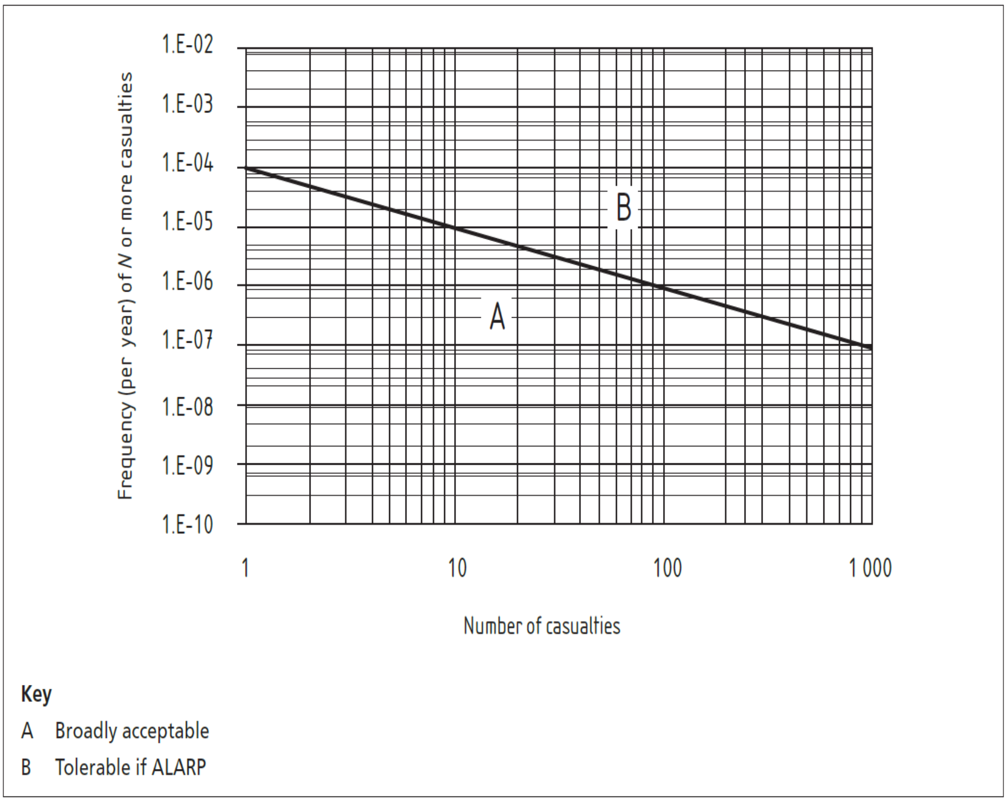

Figure 2-6. Societal risk FN criterion line applicable to 1 km of pipeline (BS PD8010-3, 2013)

2.3.3 Developing risk mitigation strategies

Recall that risk management starts with a review of all relevant information and establishing a scope, consisting of risk assessment. The assessments can be based on risk perception studies, historic data, economic impact assessments and/or the scientific characterization of social responses to the risk source. This information, together with the judgements made in the phase of risk evaluation and characterization, form the input material upon which risk mitigation options were developed, assessed, evaluated and selected. Naturally, the development of risk mitigation initiatives focused on tolerable and intolerable risks. However, this was not a clear cut process as the researcher also considered accident causal factors in proposing mitigation strategies.

2.4 Models for accident causation analysis

This section discusses the accident causation models used in this study. Their contextual concepts and their strengths and limitations were explored in order to justify their applicability to the context of risk management in the study. Since risk has been defined as the probability of occurrence of harm and its corresponding consequences and accident is mostly associated with sudden event(s) that leads to unwanted outcome, it means in safety terms, accident is the manifestation of a risk event. Therefore, accident prevention is an integral part of risk management.

2.4.1 Accident causation

Accident causation models were used as a way of representing beliefs about how accidents occur within pipeline and trucking operations. A model helps in determining what causes to look for, and brings order to the way that accidents are investigated.

The concept of accident and the perspective on accident causation have been a source of research interest for many years, e.g. Heinrich (1931). Heinrich presented a safety triangle which argued that major accidents can be prevented by preventing minor incidents. Since then, many researchers expanded on Heinrich’s model e.g. Bird and Germain (1966) and Salminen *et al.* (1992). Other research, however, suggested that while Heinrich’s triangle is still useful in some ways, if indiscriminately applied, the model can mislead safety experts and can give them unreasonable expectation about the control of risks (Hale, 2002) as major and minor accidents may not be of the same cause. Hale (2002) suggested a model with a more pragmatic view of accident prevention. Hale’s model suggests that understanding accident causal factors, accident scenarios and focusing on those incidents that could lead to a major accident is key to accident prevention rather than reluctantly drawing a cause-effect relationship between major and minor accidents. According to Hale (2002) the act of drawing a cause-effect relationship between minor and major accident have resulted in a surprisingly strong belief in identical causes of major and minor accidents which, subsequent to Heinrich’s original work, grew up among safety professionals and researchers. Consequently, researchers such as Saloniemi and Oksanen (1998) and Hale (2002) have tried to debunk the persistency of this belief as evident in the vigour with which they dissent this myth.

Maslow (King, 2009) created a theory of self-actualization. According to Maslow, self-actualization is a process by which individuals may ascend a hierarchy of needs that is linear as opposed to dialectical. The higher levels of this hierarchy are reached by psychologically robust and healthy self-actualizing individuals. This theory may also hold an explanation as to why people behave safely (or not) in work place. In addition, Maslow contends that these self-actualizing individuals are highly creative and demonstrate a capacity to resolve dichotomies inherent in ultimate contraries, such as life versus death and freedom versus determinism. The model (shown in figure 2-7 below) presented the idea that human actions are directed toward goal attainment. The four levels (lower-order needs) are considered physiological needs, while the top level of the pyramid is considered growth needs. The lower level needs must be satisfied before higher-order needs can influence behaviour (Maslow, 1943).

Figure 2-7. Maslow's theory of needs

The first four levels are considered deficiency or deprivation needs because their lack of satisfaction causes a deficiency that motivates people to meet these needs (Laboy-Nieves *et al.*, 2010). Also, the need to fulfil such needs will become stronger the longer the duration they are denied. Hence, where an individual or group of persons are denied these needs, they may behave in certain unsafe way in the quest to attain these needs. Maslow's theory has, however, been criticised by a considerable literature e.g. (Max-Neef *et al.*, 1991; Rutledege, 2011) for ignoring humans need for collaboration and the fact that it assumes human needs to be hierarchical. According to Rutledege (2011) needs are, like most other things in nature, an interactive, dynamic system, but they are anchored in people's ability to make social connections. Indeed, there are exceptional cases were reversal of the hierarchy can happen.

The intuitive nature of Maslow's has, however, been considered as a key strength. Intuitive nature is the awareness of emotions. It is this strength that supports using the theory despite the lack of supportive evidence (O'Connor and Yballe, 2007). Based on this characteristics, each person has an individual motivational framework which they work and behave. This framework differs from person to person and even for a single individual from day to day (Redmond, 2010). Hence, by understand this flexible, individualised theory as a dynamic solution to motivating people can be achieved. More on the impact of Maslow’s theory on safety is discussed as an integral part of the accident causation, stakeholder needs and behaviour in Chapters 4 and 5.

In order to select an accident analysis model that suite the context of this study, it was decided that a more basic way of understanding accident causation without engaging in the debate about the appropriateness of accident causation models is to first define the term accident.

Hence, based on the definition by Hollnagel (2004), accident is a ‘short sudden, and unexpected event or occurrence that results in an unwanted and undesirable outcome’. By this definition, an act of deliberate sabotage is not considered as an accident. This definition is, therefore, seen as limiting since it ignores the possibility of a significant overlap between safety and security, particularly when it comes to protecting the act of saboteurs from escalating into an unexpected even. For example, a pipeline vandal may illegally hot-tap into the line to syphon petroleum products for personal gains. This may not go as planned and an “unexpected” explosion may occur, thereby resulting in a consequential accident with negative implication for the pipeline operator. Therefore, in this study, the word “unexpected” in Hollnagel’s definition was interpreted from the view point of the person(s) or organisation that may incur losses from the undesirable outcome. By this composition, it is possible to protect third-parties and recipients against unwanted outcomes even if it was as a result of a preconceived act. This was considered an important and integral part of accident prevention.

By considering the above explanation as the basis for thinking about prevention, prevention was directed to either the event (causes) or its outcome. Since an accident is the event plus its outcome, it means that accidents and its corresponding outcome can be prevented. Based on this context, many accident prevention models were identified as suitable for understanding accident causation (Reason, 1990; Rasmussen, 1997; Leveson, 2004). Each of which has a different approach to accident analysis with increasing attention evolving from causation due to systems and equipment failure to a more detailed scrutiny on human factors at both individual and organisational levels.

By its definition, accident investigation is an attempt to find out both “how” and “why” an accident happen. The pursuit, therefore, was to find a model that integrates a systematic and rational approach to analysis so that the accident account is neither biased by premature assumption (as seen in the “human error” era) nor laden with preconceived hierarchical definition of causes within the organisational structure.

As observed in the review of literature, throughout the evolution of accident analysis (i.e. from the era of technological to human error to organisational casual analysis) the nub remain the same. The tendency is mainly to look for causes (why) and not explanation (how). The assumption is that if the cause of an accident is found and eliminated, then accident will not happen. The disadvantage of this kind of thinking as explained in Hollnagel (2004), is that accidents happen because a number of factors came together or aligned at a specific time contrary to the believe that accident happen because of a cause.

The researcher, therefore, believes that if the nub of cause-effect analysis was to prevail as the only way to investigate accidents, then eliminating accidents will only happen if the causes are identified and eliminated. The question, then, is what happens if the causes are not identified? However, if accident analysis stresses on both the “why” and the “how”, then the quest will be to account for the conditions and events that led to it as well as the causal factors. This way, causes will not only be identified but also the conditions (in case where it is impossible to identify the causes). Consequently, effective controls can be put in place. Two accident analysis models takes this approach: The Reason’s Swiss Cheese Model and Rasmussen’s Risk Management Framework. These models were, therefore, selected and used for accident analysis as they are relevant. Their concepts are discussed in 2.4.2 and 2.4.3 below.

2.4.2 Reason’s Swiss Cheese Model

The Reason’s Swiss Cheese Model (Reason, 1990) shows how accidents occurrence in complex sociotechnical systems are caused by a range of human and system factor interactions. High technology systems have many defensive layers: some are engineered (alarms, physical barriers, automatic shutdowns, etc), others rely on people (surgeons, anaesthetists, pilots, control room operators, etc), and others depend on procedures and administrative controls. Their function is to protect potential victims and assets from local hazards. Each defensive layer would interact and may have defects (like holes in a slices of Swiss cheese). The presence of these defects in any one "slice" does not normally cause a bad outcome. Usually, this can happen only when the holes in many layers momentarily line up to permit a trajectory of accident opportunity (Hopkins, 2012).

The holes in the defences arise for two reasons: active failures and latent conditions (see Figure 2-8). Nearly all adverse events involve a combination of these two sets of factors.

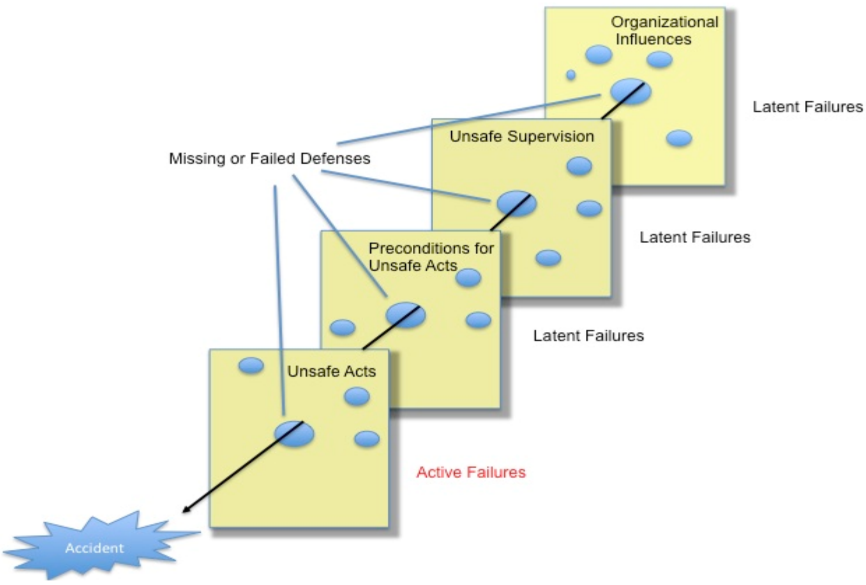

Figure 2-8. Reason's Swiss Cheese Model

Active failures are the unsafe acts committed by people who are in direct contact with the system. They take a variety of forms: slips, lapses, fumbles, mistakes, and procedural violations. Active failures have a direct and usually short-lived impact on the integrity of the defences (Reason, 2000).

Latent conditions on the other hand are the inevitable "resident pathogens" within the system. They arise from decisions made by designers, builders, procedure writers, and top level management. All such strategic decisions have the potential for introducing faults into the system. Latent conditions have two kinds of adverse effect: they can translate into error provoking conditions within the local workplace (for example, time pressure, understaffing, inadequate equipment, fatigue, and inexperience) and they can create long lasting weaknesses in the system.

Latent faults may lie dormant within the system for many years before they combine with active failures and local triggers to create an accident opportunity. Unlike active failures, whose specific forms are often hard to foresee, latent conditions can be identified and remedied before an adverse event occurs. Understanding this leads to proactive rather than reactive risk management (Reason, 2000).

Concepts from this model was used throughout this study. However, its application does not ignore the fact that the model has been criticised in various capacities.

Perhaps the main criticism was directed to its insufficiency, specifically regarding the nature of the “holes” in the “cheese” and their interrelationship (Luxhoj and Kauffeld, 2003; Dekker, 2013). This makes it difficult to apply the model in real accident investigation as it does not account for detail interaction amongst causal factors. The criticisms were also critical of analogy of faults in a systems as “holes” thereby prompting questions regarding the position of the “holes”, the composition of the “holes”, why there are “holes” in the first place, why the “holes” change in position and size and how the “holes” get to line-up. Shorrock *et al.* (2005) also raised several issues regarding the applicability of the model. They included:

1. Active errors may be the dominant factor: latent conditions are clearly important, but sometimes people really just slip up.
2. The causal link, or even the connection, between distant latent conditions and accidents are often tenuous, and only visible with the benefit of hindsight.
3. Latent conditions can always be identified, with or without an accident.
4. Some latent conditions may be very difficult to control, or take many years to address.
5. Highlighting management problems may hide very real human factors issues, like the impact of emotion on performance, and hamper the research needed to better understand human fallibility.

A few comments can be made on these critiques. The fact that front line operators’ slips sometimes fully accounts for the accident scenario does not mean that it explains the accident from a safety management perspective, and that ‘fixing’ the operator, therefore, is the right safety management strategy. Also, because deterministic causal connection between latent conditions and accidents cannot easily be identified (particularly before the event), does not rule out that efficient prevention policy can be based on addressing latent conditions. Although such connections may be long and difficult to control, they may also offer a real opportunity for effective accident prevention. From a safety management perspective, therefore, the key point is to identify, as well as possible, the potential contributors to multi-factorial defects within an entire system. Notwithstanding, some of the limitations of the Cheese Model have been acknowledged by this study and were complemented using the concepts discussed in Rasmussen's framework.

2.4.3 Rasmussen's Risk Management Framework

Rasmussen's Risk Management Framework (Rasmussen, 1997) also focused on mechanism that gives rise to behavioural patterns in organisational systems. Based on this model (see Figure 2-9), a hierarchy of factors, individual and organisation forms an integral part of complex system. Hence for a systems to function safely, decision about governmental, regulatory (top management) and information about the status of the system (individual level) need to be cascaded in downwards and upwards direction respectively without which failure can occur. Thus, accident under this model is treated as an emergent property of the overall sociotechnical system (Salmon *et al.*, 2011).

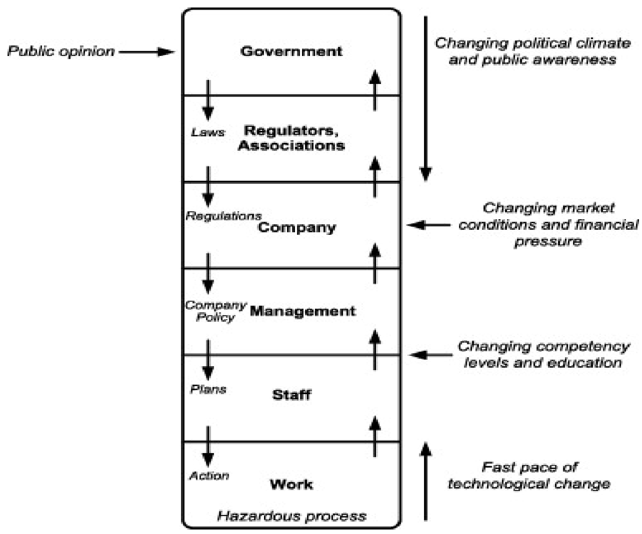

Figure 2-9. Rasmussen's risk management framework (Rasmussen, 1997)

Rasmussen's framework is underpinned by the idea that systems comprise various levels; actions and decisions across these levels interact with one another to shape behaviour, safety, and accidents. Typically the following system levels were described:

1. **Government level:** this is the level at which laws and regulations are developed;
2. **Regulatory level:** the level at which industry standards are developed based on laws and regulations;
3. **Company level:** the point where company policies and procedures based on industry standards govern work processes;
4. **Management level**: where company policies and procedures are implemented;
5. **Staff level**: the level representing the activities and characteristics of workers performing the processes; and
6. **Work level**: the level representing the equipment and environment within the work context.

In terms of accident causation, the framework argued that decisions and actions at all levels of the system interact with one another to shape system performance: safety and accidents are therefore shaped by the decisions of all actors, not just the front line workers in isolation, and accidents are caused by multiple contributing factors, not just one bad decision or action.

The model also argued that for safe and efficient performance, the decisions and actions made at higher governmental, regulatory, and managerial levels of the system should propagate down and be reflected in the decisions and actions occurring at the lower levels. Conversely, information at the lower levels regarding the system's status needs to transfer up the hierarchy to inform the decisions and actions occurring at the higher levels. This is known as 'vertical integration' and is a key component of safe system performance.

Trotter *et al.* (2014) used the Rasmussen's Risk Management Framework (RMF) (Svedung and Rasmussen, 2002) to test improvisation- defined as a spontaneous real-time concept and execution of a novel response to a situation that is beyond the preparedness of a system- and explain factors influencing improvisation in safety critical situation. Their research identified failures and limitation at various level, which explains the 'why' and 'how' of two accident causations.

This model for accident investigation eliminates the traditional approach which is used to investigate accidents at each level separately by a particular academic discipline, for example, risk management at the upper levels is studied without any detailed consideration of processes at the lower levels (Zahid, 2007). However, according to the lessons learnt from the application of Rasmussen's RMF and its derivative AcciMaps (Rasmussen *et al.*, 2000) by Waterson and Jenkins (2011), the model will be most effective if flexibility is considered by:

1. Establishing the purpose of the analysis,
2. Consideration of the role of causality, intentionality and the nature of system error in the analysis,
3. Domain specific considerations,
4. Data and information inputs to the analysis,
5. Constructing RMF and AcciMap representations (Branford *et al.*, 2011).

AcciMap is generic approach used to identify and link contributory failures across six sociotechnical systems levels defined in Rasmussen's risk management framework (Salmon *et al.*, 2012) (in Chapter 2). Rasmussen (1997) outlined the AcciMap method, which is used to graphically represent the system wide failures, decisions and actions involved in accidents. AcciMap analyses typically focus on failures across the following six organisational levels: government policy and budgeting; regulatory bodies and associations; local area government planning and budgeting including top management technical and operational management; physical processes and actor activities; and equipment and surroundings as shown in figure 5-10.

By using the AcciMap, a holistic view of the causation factors for both pipeline and truck tanker accidents/incidents was mapped. The map also incorporated factors that results in the consequential nature of the accidents. AcciMap allowed for the analysis of the entire system from the general context of the environment in which these accidents happened to the role of the government in shaping the system of work in petroleum product transportation and distribution. This made it possible to identify all the contributory factors involved in the events of the accidents and to describe (visually) the entire general trajectory of the failures across the systems and the interactions between them. Hence, by obtaining a structured holistic view of the causation factors, risk mitigation strategies were proposed. Also by linking causation factors within and between various levels allows faults to be considered in the context of factors influencing them in the risk management framework.

2.5 Research strategy

Figure 2-10 shows a pictorial representation of the approach in this study, starting from the philosophical stance for risk research discussed in section 2.2. In this section, the case study strategy was selected as a means of understanding and developing bounds in a research context.

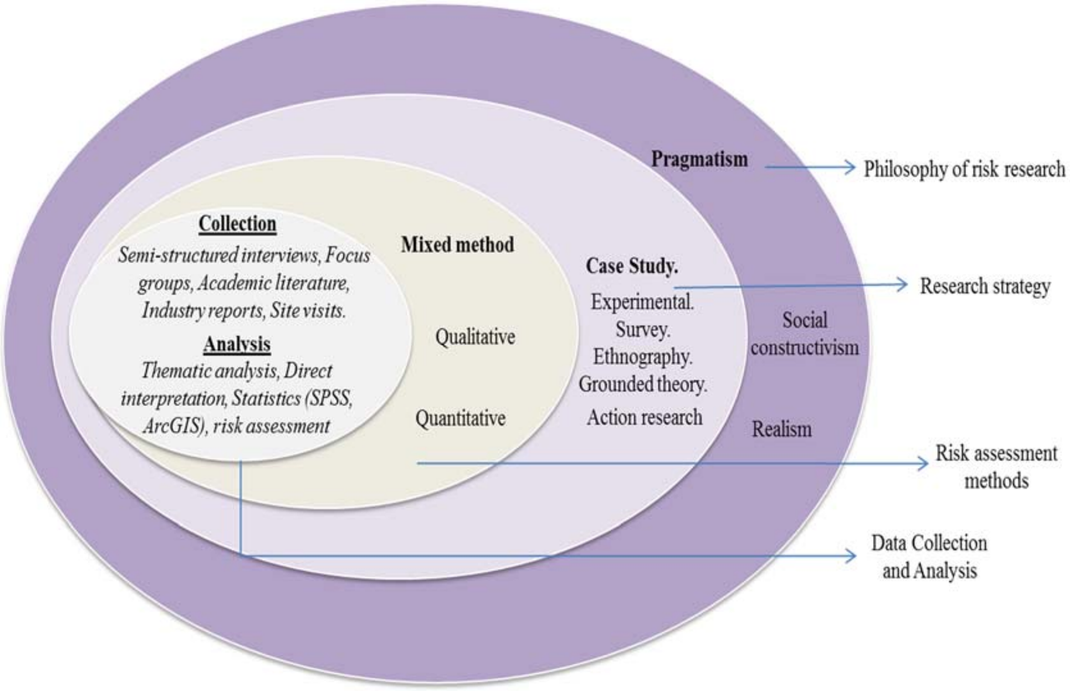

Figure 2-10. Research Onion (Adapted from: Saunders, et al. 2012)

2.5.1 Case study as a means of developing context for understanding research bounds

Case studies are often described as an exploration of a 'bounded system' (Bloor, 2006). The objective of using this research strategy can, therefore, be many. It can be used for studying a system, groups or organisations in their natural or 'real world' setting using a number of techniques over an extended period of time. Case study research and other forms of naturalistic research strategies are often not absolutely defined due to the shared preoccupations between them. The problem is made more critical by the fact that researchers have not used the term in a standardised way. For instance, there are debates about adopting case study as a methodological choice (Simons, 1996) or an object that is studied (Stake, 1995) or a method for practical problem solving (Murdaugh, 2001). However, the value of case study research strategy is optimal where the research context is too complex for experimental or survey research (Bloor, 2006).

Case study as a research strategy is aimed at obtaining detailed understanding of the processes involved within a setting. In this research, the setting includes the effect of accidents from petroleum transportation and distribution operations to human safety and the environment within the downstream structure of the Nigerian petroleum industry. This involves studying multiple high risk transport systems (pipeline and trucking) in a holistic perspective. It also involves integrating the contributions from relevant organisations and stakeholders, and studying organisational, technical and human culture within research domain using numerous levels of analysis.

By focusing in depth and from the holistic perspective on the downstream context, both unique and general understanding of risks and risk management strategies are obtained. The systems and organisations chosen for this study were carefully selected to enable the process of answering the research questions and achieving the research objectives. Additionally, the choice of the research strategy was guided by the issues to be addressed taking into consideration the extent of resource, availability of data as well as the philosophical underpinning of the research (Kumar, 2005).

The strategy adapted both primary and secondary sources of data and mixed method of data collection and analysis as shown in Table 2-1. However, while collecting and analysing the data, careful consideration was given to credibility and viability of the data source, the socioeconomic-demographic characteristics of the stakeholders and their specific interest.

Similarly, whilst extracting data from secondary sources, attention was given to the relevance of the data in establishing research elements such as the characteristics of pipeline and the nature of truck tanker transportation.

Table 2-1. Research phases and the used of data.

Lifecycle	Data type	Description
Research initiation	Primary and Secondary data	Initial review of relevant literature to establish research aim, objectives and questions and initial methodology. Conducting focus group discussion to establish scope.
Research planning	Secondary and primary data	Extensive review of literature to understand research context. Developing detail research methodology, understanding risk analysis methods via formal and informal meetings and interviews with Nigerian and UK petroleum industry experts
Collecting and extracting research data	Secondary and primary data	Conducting interviews with research stakeholders, extracting accidents and incident data from reports and pipeline data from various maintenance and operations documents.
Analysing research data	Secondary and primary data	Making sense of data to establish causal factors, risk probabilities and consequences
Reporting research finding and writing-up	Secondary and primary data	Validation of research findings and designing risk mitigation strategies and using existing theories to support findings

2.5.2 Justification for research location

This study is part of an ongoing process of developing and improving the Nigeria petroleum industry. The study is sponsored by the Nigerian government via the Petroleum Technology Development Fund (PTDF). As a critical part of the funding agreement, research conducted under PTDF funding must contribute to the development and advancement of the Nigeria petroleum industry in specific terms and the global petroleum industry in general. This shaped the reason for selecting Nigeria as a case study.

In chapter one, review of literature reveals the lack of application of risk management framework in the downstream operations of the Nigerian petroleum sector, particularly, the two main mutual medium of product transportation and distribution, i.e. pipelines and road truck tankers. It is for this reason that this research focussed on developing a safety risk and environmental management framework for transportation and distribution of petroleum products in Nigeria.

2.6 Qualitative and quantitative risk assessment in a mixed method research

Risk assessment is the estimate of risk from an activity. There are two main approach used: qualitatively (QaRA) – using subjective expert judgement to rank risk, and quantitatively (QRA) – using numerical estimate to develop an understanding of risk. These two main approaches were used throughout this study in a mixed research method.

By definition, the QRA method that was used generated numeric estimates of expected frequencies and/or consequences (Vose, 2008; Aven and Renn, 2010; Citro and Gagliardi, 2012) of accident events involving the distribution of petroleum products using the pipeline and truck tanker system. The results was generated and utilised in two forms: (1) In absolute form, and (2) in relative form. Absolute QRA results are specific "stand-alone" numeric estimates of risk of an accident obtained from models and historic data inputs. This was mostly applicable to the pipeline risk assessment results (in Chapter 4). The result were then used to evaluate whether the safety level of pipeline failure meets risk tolerance criteria. Thus, absolute risk results in this study generally deals with the questions regarding the acceptability of risk associated with the pipeline facility.

Relative QRA results on the other hand compares the difference between the level of risk of one or more cases of interest and a reference, or a baseline case (Arendt and Lorenzo, 2010). A typical example of risk assessment method with relative results output is the Kent's pipeline risk assessment method (Muhlbauer, 2004) which can be used to estimate the level of risks between two or more separate systems or between different sections of a pipeline. Example of its applicability can be found in Kalatpoor *et al.* (2011) where risk results shows a relative value between two pipeline sections. This method of risk quantification was used for the truck accident risk assessment model (in Chapter 5) were the risk of accident within various geographical locations were compared. The result was used in decision support about the best way to improve safety without having to define the absolute accuracy of the result. This method can also be seen in the pipeline risk assessment model in chapter 4.

Although QRA has many benefits, a number of disadvantages has been identified from its use. QRA is very data intensive, and in reality, sufficient data are generally not available to cover the entire analysis that may be required. This is particularly true with research conducted in developing countries whereby the availability of data limits the depth of analysis (Ambituuni *et al.*, 2015a). In addition, QRA can be very complicated, employing series of analyses and calculations in simulating the effects of different hazard scenarios. According to Landoll (2011) complex risk assessment calculations may be difficult to present to non-experts, and the outcome may become unclear and unacceptable.

Also, the considerable uncertainty associated with the assessments of both the frequency of failure and consequences may give misleading results.

The QaRA techniques used estimated the levels of risks in a comparative or relative way, but mainly from subjective expert opinion. The approach draws its results from methods such a brainstorming during focus group discussions and semi-structured interviews. This method has been proven effective as a screening tool to identify potentially high risk areas that may require a more detailed QRA (Arendt and Lorenzo, 2010; Aven and Renn, 2010). However, there are some limitations in the application of qualitative risk assessment. As observed in its application and supported by Khan and Haddara (2003), the outcome of a qualitative risk assessment is a relative value which may be meaningless outside the framework of the matrix. Another shortcoming of qualitative risk assessment is the level of subjectivity inherent in the decision making process. The presence of subjectivity means the outcome could be greatly influenced.

The choice between using both QRA and QaRA was motivated by the need to gain in-depth understanding of risk that will aid decision making, the availability of information and data and in accordance to regulatory requirement. It is, therefore, believed that the two methods should not be debated in the context of rivalry. Hence, contrary to the practice of comparing the reliability and credibility of the two methods, this study advocated and used QaRA to compliment QRA methods (Kajenthira *et al.*, 2012). This is because risk analysis needs to be scoped and systems characteristics specified (for cost-effective risk reduction), and no QRA can provide meaningful results if there is no fundamental knowledge of hazards involved (obtained qualitatively).

2.7 Methods of data collection

Throughout this research, a range of data collection methods were utilised to collect both primary and secondary data across Nigeria. The methods used for data collection are discussed in this section.

2.7.1 Sampling

Non-probability sampling was used as a means of linking the study population and its generalisation to the wider research domain (downstream petroleum industry in Nigeria). Non-probability sampling involved the selection of cases according to reason other than mathematical probability and includes techniques such as: quota, convenience, theoretical and snowball sampling (Bloor, 2006).

Throughout the study, theoretical (purposive) sampling technique was adopted. This involved the selection of cases and participants on the basis of the researchers own judgment about which will be the most useful. Furthermore, stakeholder organisations were selected based on their statutory interest and influence on both regulatory and operating activities within the downstream petroleum industry in Nigeria. Similarly, within these organisations, participants were drawn from relevant departments such as health safety and environment department. All participants were selected based on their industry experience, hierarchical position within their organisation, their roles and responsibilities and their willingness to represent the official views of their organisation. Locations selected for site visit and inspections were also selected based on prior knowledge.

2.7.2 Conducting fieldwork studies

Because of the multiple dimension of the research (various stakeholders, two different transport modes, and national case point), a large amount of data was envisaged and an effective process was developed in order to collect, organise and document the various data components. This section discusses the processes involved in the collection of the primary and secondary data.

2.7.2.1 Pre-fieldwork activities and pilot studies

Before undertaking the fieldwork, various meetings were held with experienced staff and research students from Newcastle University to obtain their views on the feasibility of methods to be used in the fieldwork.

Using the designed semi-structured interview questions guide, the researcher interviewed 3 selected staff of HSE department in Newcastle Council, and Tyne and Wear Fire and Rescue Service. The question guide was then refined based on observed limitations from the result of the pilot interviews.

Similarly, contacts were established with the sampled organisations via telephone calls and emails to understand the procedures for requesting data and interviews with their staff. Consequently, letters of introductions were then obtained for the head of supervisory team (as shown in Appendix 3) to introduce the researcher to the sampled organisations. Data collection objectives were set based on the developed knowledge of stakeholders and data requirements. The researcher and the head of the study supervisory team then concluded that two trips to Nigeria will be most appropriate to achieve the data collection objectives.

2.7.2.2 Fieldwork and collection of data

Focus group discussions

Upon arriving in Nigeria in the first trip (July 6th to September 11th, 2013), two focus group meetings were first conducted. The aim was to consult industry experts and have clarity on the scope of the research and the risk elements of pipeline and truck tanker operations.

Since the principle of brainstorming in qualitative risk analysis dwells on the perception and experience of experts which can be obtained via brainstorming sessions (Karwowski, 2001), focus group discussion was identified as a suitable means of conducting broad risk analysis (scoping). Its selection is motivated by the desire to explore risk context within the downstream structure at coarse level, but with credible inputs of experts. This method of exploring the initial phase of research using focus group has been endorsed by Wilkinson (1998).

At the basic level a focus group is an informal discussion among a group of selected individuals about a particular topic (Wilkinson, 1998). Puchta and Potter (2004) defined focus group as a research tool containing two of the following core elements: a trained moderator with focus on what to be discussed; and the goal of eliciting participant's perception about a selected topic. The group is focused because 'it involves some kind of collective activity' (Kitzinger, 1994). Group work allows the researchers to access different communication customs including recapturing past events.

In analysing safety and environmental risks within the downstream structure, the primary aim of using a focus group is to describe and understand meanings and interpretations of a select group of industry experts to gain an understanding of a specific risk issues of key operations from the perspective of the experts.

The composition of participants in focus group 1 (1FG) and focus group 2 (2FG) is shown in Appendix 1. During the meetings, the researcher adopted the role of facilitator, sharing information about the research aim, risk scoping exercise and safety, risk and environmental management with participants, while also engaging participants in meaningful discussion and guiding the discussion to yield data that will answer specific research questions.

Timeline of the research fieldwork

In the first trip to Nigeria (from July 6th to September 11th, 2013), accident and incident reports and regulatory documents were obtained from relevant stakeholder organisations in addition to the focus group meetings discussed above. Afterwards, semi-structured interviews were also conducted with the sampled stakeholders. The interview was structured based on the already designed interview guide developed from the pilot study and the new knowledge obtained from the accident reports and focus group discussions. The details of how the interviews were conducted is given in section 2.7.3.

In the second trip (from 23rd May, 2014 to 4th July, 2014), a follow-up data collection was done after evaluating the depth and quality of the data collected in the first trip. Data in the form of accident reports and semi-structured interviews, and site visit, road inspection and right of way inspection to two key transport corridors and pipeline right of way was conducted respectively to visually explore and collect data with regards to problems of petroleum transportation via truck and pipeline. Sections 2.7.4 and 2.7.5 further discuss the methods used for collecting documentary data and site inspections.

During both trips, both primary and secondary data were obtained and used for both qualitative and quantitative exploration of research questions which includes understanding the regulatory framework and risk context of truck and pipeline transportation within the study domain. Figure 2-11 shows the data collection techniques employed and the interactions with relevant stakeholders throughout the research while Table 2-2 shows summaries of data application across each chapter.

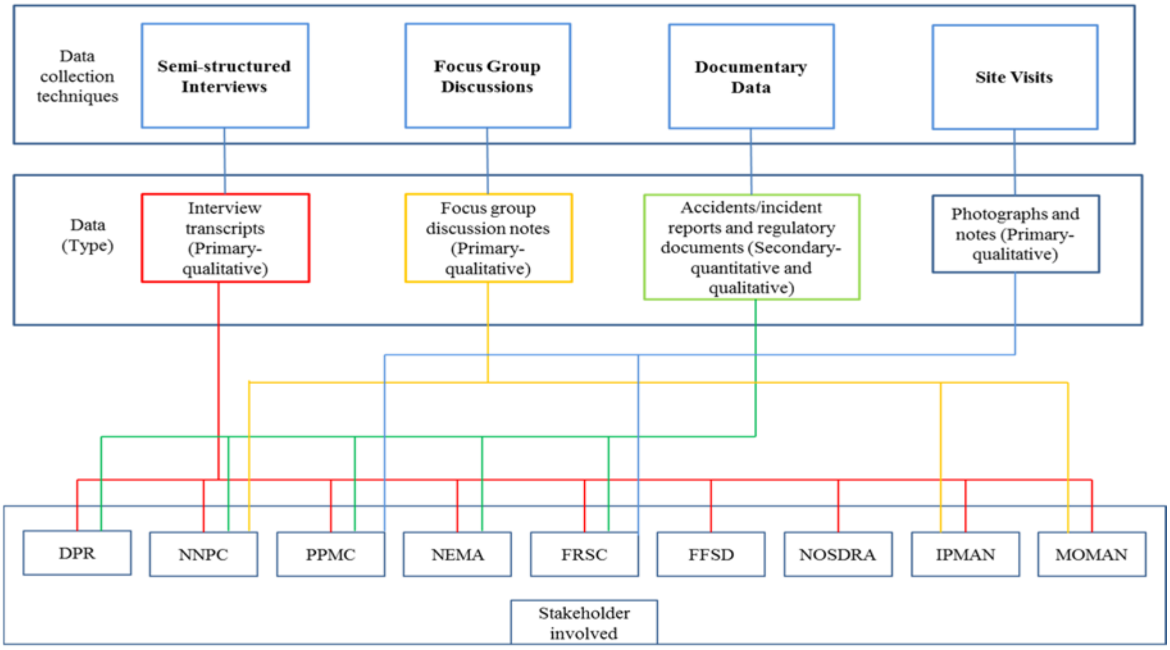

Figure 2-11. Research data collection techniques, data type and stakeholders involved. Note the following new abbreviations: Department of Petroleum Resources (DPR), National Emergency Agency (NEMA), Federal Road Safety Commission (FRSC), Federal Fire Service Department (FFSD), National Oil Spill Detection and Response Agency (NOSDRA), Independent Petroleum Marketers (IPMAN) and Major Petroleum Marketers (MOMAN) Association of Nigeria

Table 2-2. Chapters and Data use.

Chapters	Data used
Chapter 1 :Risk scoping	Data contained from focus group discussions notes and literature reviews on downstream operations.
Chapter 3: Regulatory review	Documentary data: Documents containing downstream safety and environmental related laws and regulations. Literature and research publications
Chapter 4: Pipeline risk assessment/ management	Interviews with relevant stakeholders. Documentary data including 13 years incident records. Notes and photos from observation and visual explorations and inspection of ROW via site visits
Chapter 5: Truck tanker transport risk assessment/management	Interviews with relevant stakeholders. Documentary data including 2318 accident reports covering 7 years. Notes and photos from observation, inspection and visual explorations via site visits and road inspection. Data from product sales and other relevant research

2.7.3 Collecting semi-structured interviews

Semi-structured interviews were conducted during the research for the purpose of integrating the socio-cultural, organisational and regulatory dimensions of risk factors into the study. The semi-structured interview technique was selected mainly because it provides the opportunity to modify predetermined questions based upon the researcher's perception of what seems most appropriate. This allows question wording to be changed and explanations given; particularly questions which seem inappropriate with a particular interviewee can be omitted, or additional ones included (Robson, 2002). This interview technique also provides opportunity to gain account of the values and experiences of the respondent in terms meaningful to them in a guided manner. The literature on the strengths and limitation of this interviewing style is extensive (Atkinson, 1990; Denzin and Lincoln, 1994; Coffey and Atkinson, 1996; Warren, 2012).

Some key limitations experienced throughout the interview process included: the time consuming nature of sourcing for participants, time consuming nature of conducting the interviews, translating and transcribing the recorded data, the resource committed to travelling to the case country, and the potential of data overload due to detailed data gathering. However, despite the availability of alternative data collection methods, semi-structured interview offered more individual and detailed accounts as respondents had the opportunity to clarify their thoughts on the issues being explored (King, 2004).

Based on the etiquette for designing interviews in King (2004), all interview questions were developed in:

1. Alignment with the research questions and the question to be answered throughout the interview,
2. Creation of interview guide in line with set research objectives,
3. Selection of participants based on stakeholder analysis and review of research domain and scope,
4. Interview schedule and implementation guide.

The guide spelled out interview questions which were followed by prompted questions based on the participant's responses and also included in the agenda which was developed in tune with research questions and key observations from detailed literature reviews. Interviews were conducted with stakeholders and shown in the guide (See appendix 1). The interviews conducted in Nigeria were all conducted in the respondent's office or work place except for one interview which was conducted in the respondent's car. The interviews spanned between 40 mins (minimum) to 70 minutes (maximum) and were all conducted in three interconnected sessions.

The aim of the first session was to discuss and understand contextual risk factors and underlying causes of accidents and to appraise the corresponding safety and environmental consequences and cost implications. In the second session, the discussion tilted towards understanding the missing regulatory links and operational limitations, while the last session saw an exploration of possible collaboration for maximum research impact. As the interviews were conducted for data collection for trucking and pipeline studies, stakeholders with both interests were simultaneously interviewed on both activities. Figure 2-12 shows the interview data collected within the pipeline and truck transport systems.

Most of the interviews were conduct in English language (with limited utilisation of local 'Pigeon' English and Hausa languages where needed). All interviews were done with complete integration of ethical considerations and interviewees were promised anonymity. The interviews were conducted face to face to enhance rapport, naturalness, comprehension, interest and attention (Irvine *et al.*, 2013). This allowed the researcher to pay special attention to questions phrasing and clarity in the presence of physical facial gestures (Stephens, 2007). The face to face approach was also used by the researcher to encouraged interviewees to talk more and explore issues by prompting them using unobstructed non-verbal gestures.

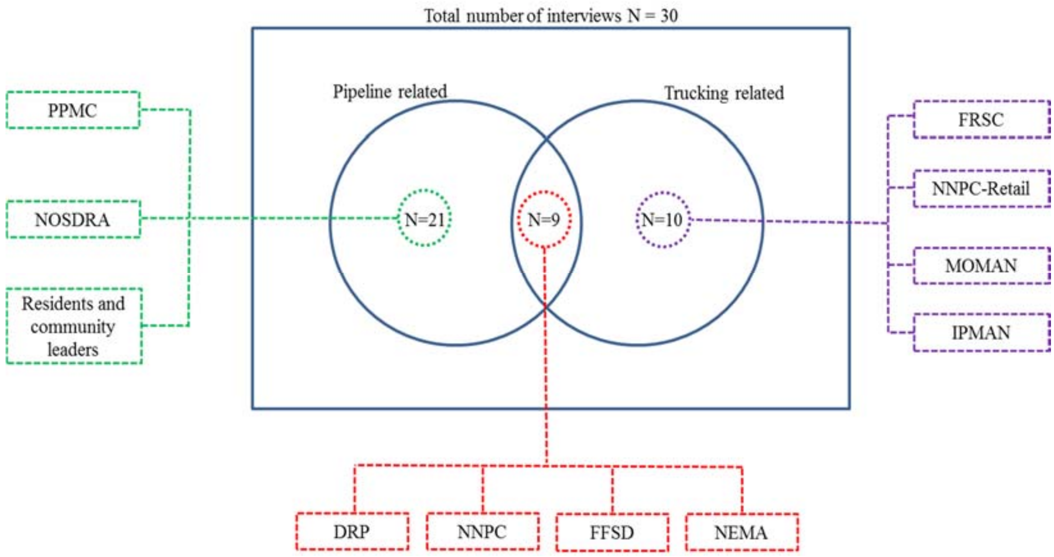

Figure 2-12. Showing the number of collected interviews from stakeholder within pipeline and truck transport systems

In the first trip to Nigeria, 22 audio recordings of semi structured interview and one written record (as the interviewer was uncomfortable with audio recording) was obtained.

While 17 audio recorded semi-structured interviews were obtained in the second trip, making a total of 40 interviews. Records of interviews were later transcribed (in few cases translated whilst transcribed) using MS Word. The participants were purposively sampled from relevant departments with the right affiliation and knowledge of the subject matter within the organisations. Being staff at managerial levels, the participants were informed that their views represent the views of the organisations they represent, except otherwise stated.

2.7.4 Collecting documentary data

Documentary data in the form of publish academic and industry literature were used throughout in research problem identification, literature review and also to set the research context. These data types were simply collected from online data bases. Essentially, documents related to Nigerian downstream petroleum industry regulation, regulatory reports and industry reports were collected and used for analysis of the regulatory frameworks which set the legislative backing for the proposed frameworks and also allowed structured identification and engagement with relevant stakeholders.

Moreover, documentary data in the form of accident/incident reports were collected and extensively used in conducting quantitative risk assessment for both truck and pipeline operations. These data types were collected from identified stakeholder organisations after writing for permission and signing confidentiality agreements and also obtaining management approval to use the data for research purposes only.

2.7.5 Observation, inspections and site visits

Although mainly qualitative and subjective, the application of observation, inspection and site visits have been recognised as appropriate means of data collection (Robson, 2002). During both trips to Nigeria, these techniques were employed to obtain data related to the study. These techniques allowed the researcher to obtain risk perception and understanding in the context of petroleum product transportation and distribution and also visibly explore how the stakeholder incorporate safety measures in their activities. Road and Pipeline Right of Way (ROW) inspection also allowed the researcher to collect relevant data about the infrastructure and their existing operating environment so as to analyse how the environment contributes to accident. Data in the form of inspection notes and photos were collected. In many instances, the researcher undertook informal discussion with road users (particularly truck drivers) and people living in close proximity to the pipeline ROW to obtain information about the operational risk posed by the physical environment. Table 2-3 shows how these techniques were applied and the data type collected.

Table 2-3. The use of observation, inspection and site visits in data collection

Technique	Context	Output
Observation/site visit	The process of loading and off-loading truck tankers in refineries and retail stations respectively.	General understanding of the activities, safety critical processes and responsibilities.
Observation/site visit	Demonstration of firefighting process and facilities in refinery.	General understanding of emergency response process.
Inspection/site visit	Analysis of road condition and road use.	Data on the condition of sampled roads. Data on general road user behaviour
Inspection/site visit	ROW condition	Data on the general condition of the sample ROW Data on the contextual pipeline failure factors

A structured data base of all the collected data was created and backed up appropriately. Using organised indexing, the data based provided quick reference to any data when required, at any moment. The data were saved in the form of excel documents, MS-word, audio recordings, field notes, memos, and pdf.

2.8 Data analysis

Analysis of data provides means of making sense of the collected data. This involves arranging and preparing data for analysis, exploring the data to achieve familiarity, conducting different types of analysis and generating meaning from the data. Data analysis also involves presenting the data in understandable format and making interpretation of results within its wider context (Creswell and Clark, 2011). Based on the recommendations in Robson (2002), initial thought was given on how data are to be analysed at the designed stage of the research. This is important not only because it ensured collection of analysable data, but also simplified the process of analysis. Importantly, as data was collected by the researcher both primarily and secondarily, it was vital to begin the analysis with some prior knowledge of the data (Braun and Clarke, 2006) and possibly some initial analytic interests. This was achieved via repeated active reading of the data and initial exploration, to search for meanings and patterns which shaped the analysis techniques adopted (Stake, 1995).

Analysis techniques can adopt qualitative, quantitative or mixed methods. Selection and use of the techniques in this research was directly related to the nature of the research questions. It was also motivated by the objectives of the study, the type of data collected and the ‘analysis template’ that were designed to identify patterns. Throughout this study, 4 method of data analysis were utilised. They included: cross content thematic analysis, direct interpretation, document content analysis and exploratory and descriptive statistics. Table 2-4 and Figure 2-13 show their application to research data and how these methods helped the process of achieving the research objectives. The combination of these methods in research ensured that regularities and patterns are discovered in the collected data sets, while also comprehending the meaning of text, variables or action and offering critical reflection.

Table 2-4. Data analysis methods and application to research questions

Stages of developing the risk management framework	**Data analysis techniques**				
	Thematic analysis	Document content analysis	Direct interpretation	Descriptive statistics	Stakeholder analysis
Problem identification and scoping	□	□			□
Analysis of regulatory framework		□	□		□
Designing pipeline risk management framework	□	□	□	□	□
Designing trucking risk management framework	□	□	□	□	□
Developing implementation plan		□	□		

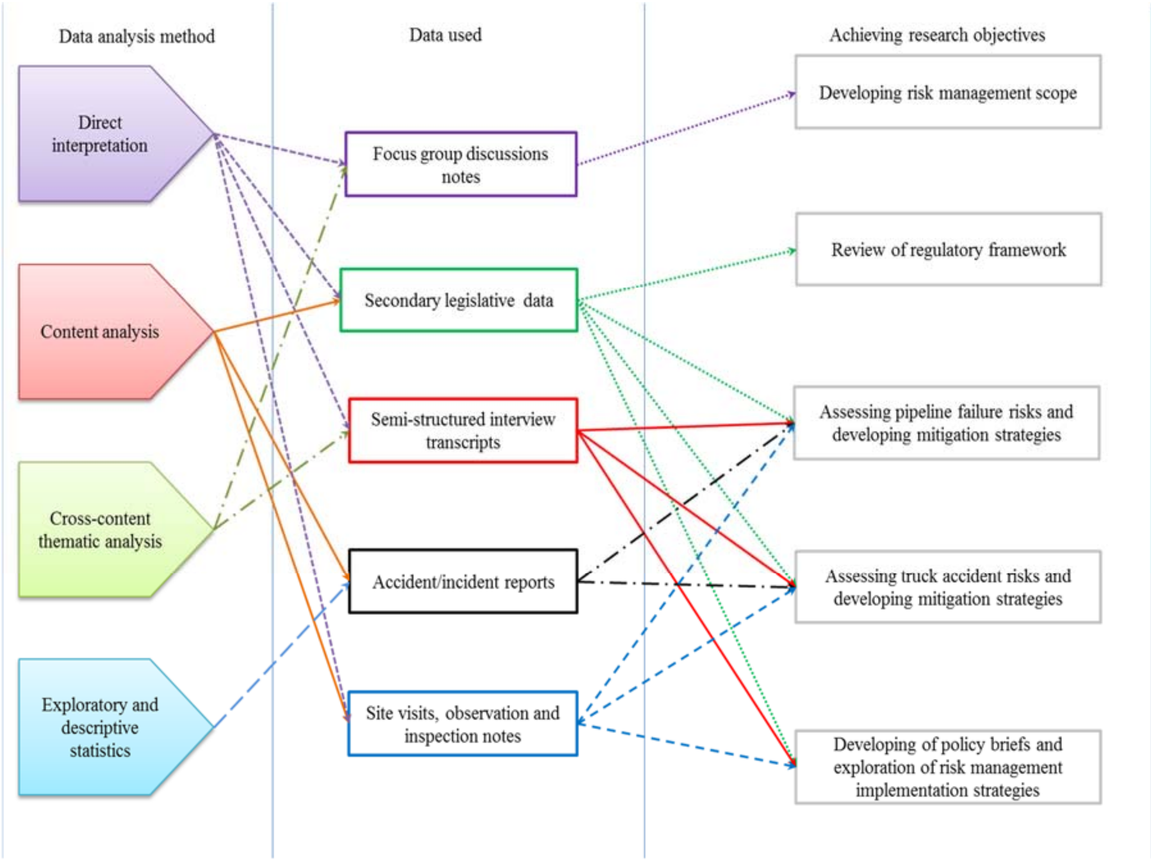

Figure 2-13. Data analysis methods, their application to research data and how the methods aimed the process of achieving the research objectives.

2.8.1 Direct interpretation

Direct interpretation was used in analysing both primary data (interview transcripts, focus group discussion notes, fieldwork inspection notes and pictures) and secondary data (legal documents, accident and relevant publications). This method of analysis simply involved interpreting or citing the information within various data sources to establish discussion themes that are aimed at answering the research questions. The technique was applied in this study due to the high quality of data which could be directly used as evidence in developing a platform for constructive arguments.

From the perspective of its application to secondary data, direct interpretation was used within the literature related to investigating the extent of application of a risk management concept to petroleum product transportation. The method was also used in the analysis of legal documents for the review of the regulatory framework for downstream petroleum industry operations, especially transportation and distribution of petroleum products.

Direct quotes from interviews, observations, and fieldwork inspection notes and pictures were also used as evidence to support analysis of risk assessment and risk management elements which provided information used to propose the mitigation strategies.

2.8.2 Content analysis

Content analysis is a common approach to documentary data analysis. It involves the quantitative and/or qualitative analysis of what is in a document using a codified "common sense" (Robson, 2002). In this study, documents in the form of legislative documents, accident/incident reports, industry reports and relevant academic literatures, site visit notes and pictures were also analysed using content analysis; starting with the research question in mind to develop a recoding unit or themes.

For instance, content analysis was used to analyse legislative documents in the process of analysing the regulatory framework for downstream petroleum industry operations and stakeholder mapping (in Chapter 3). Themes were coded with the guide from research questions 2.1 – 2.3 such that the documents were subjected to a "common sense" codification to identify the relevant laws whilst also identifying the limitations of the laws, the prospects and the factors affecting its implementation. The same method was used to identify and map stakeholders based on the regulatory and operational interests.

2.8.3 Cross-content thematic analysis

Thematic analysis was used as an analysis method of qualitative data (semi-structured interview transcripts) analysis. This was mainly due to its ability to identify, analyse and report patterns (themes) within data (Braun and Clarke, 2006).

Although thematic analysis offered means for interpreting various aspects of the research questions, the researcher noted the poor branding of the method in various literature source (Braun and Clarke, 2006). For instance, in Holloway and Todres (2003) the method was identified as means of 'thematising meanings' as one of a few shared generic skills across qualitative analysis. Boyatzis (1998) on the other hand characterises it, not as a specific method, but as a tool used across different methods. Similarly, Ryan and Bernard (2000) locate thematic coding as a process performed within 'major' analytic traditions (such as grounded theory), rather than a specific approach in its own right. For this research, thematic analysis was adopted as an analysis method in line with the step by step guide highlighted in Braun and Clarke (2006).

First, data familiarisation was obtained by repeated reading of the entire data set for ideas and identification of possible patterns. As all but 1 of the interviews were recorded in audio format, transcription provided a good opportunity for familiarisation. Meanings were created and notes taken during this period.

Second, initial codes were produced from the data. The codes identified are features of the data that appears interesting to the study and refer to 'the most basic segment, or element, of the raw data that can be assessed in line with research questions. This involved manually working systematically through the entire data set, giving full and equal attention to each data item and identifying interesting aspects in the data items that may form the basis of repeated patterns (themes) across the data set.

Table 2-5. Thematic analysis phases: adopted from Braun and Clarke (2006)

Phases	Description of the process
Data familiarisation	Transcribing data, reading and re-reading the data, noting down initial ideas.
Generating initial codes	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code
Searching for themes	Collating codes into potential themes, gathering all data relevant to each potential theme.
Reviewing themes	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
Defining and naming themes	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
Producing the report:	Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

The next phase involved sorting the different codes into potential themes, and collating all the relevant coded data extracts within the identified themes. At this point, data analysis begins as consideration was given to codes and how different codes are combined to form an overarching theme using tables. Subsequently, relationships were established between themes and codes and between themes from participating stakeholders. The fourth phase involved revising sets of theme candidates and refining the themes. Here, some irrelevant themes were excluded while similar or different themes were either collapsed to form a clearer cohesive theme or separated to form different themes. Table 2-5 shows the application of this method in data analysis.

2.8.4 The use of quantitative analysis – exploratory and descriptive statistics

Various descriptive and explorative statistical techniques were used as an integral part of the risk assessment framework developed for both pipeline and truck transport systems. Their specific application can be seen in Chapters 4 and 5. Their use is justified by the need to quantitatively explore various risk elements from the accident reports obtained.

2.8.5 Developing risk assessment models

The method sections in Chapter 4 and 5 discusses the specifics of how the risk assessment models for both pipeline and truck transport systems were developed. This section gives a general illustration of the processes used (in Figure 2-14) and highlights the factors that influenced the selection of methods.

A range of risk assessment tools and techniques were evaluated for consideration for both qualitative and quantitative risk assessment. A list of some of the risk assessment tools and techniques that were reviewed can be found in BS EN 31010 (2010). The following factors influenced the selection of techniques used. They include:

1. The complexity of the problem and the methods needed to analyse it.
2. The nature and degree of uncertainty of the risk assessment based on the amount of information and data available and what is required to satisfy objectives.
3. The extent and availability of resources required in terms of time and level of expertise, and cost.
4. Requirement for either qualitative or quantitative output.

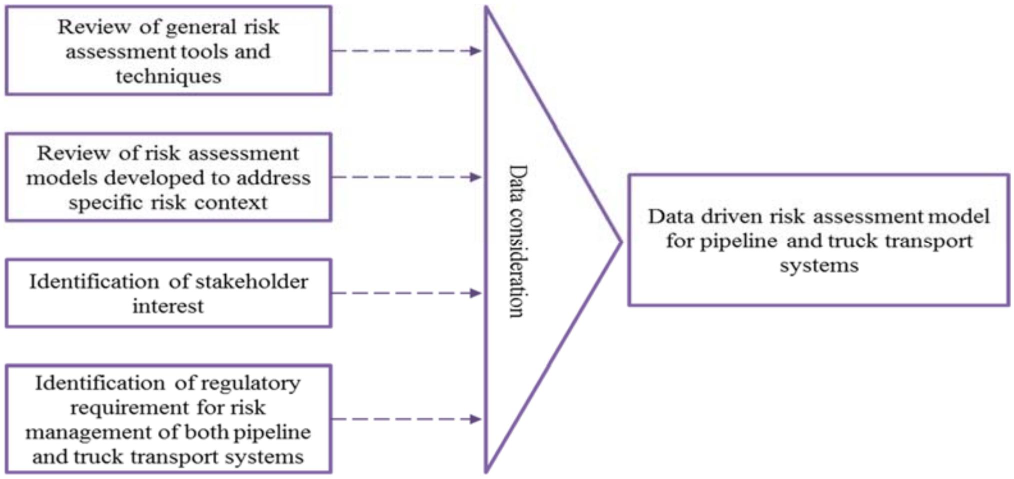

Figure 2-14. Developing the risk assessment models for pipeline and truck transport systems

2.9 Ethical considerations

Ethics refers to rules of conduct (Robson, 2002); typically in conformity to a code or sets of principles. From the initial stage of this study, serious thoughts was given about ethical consideration in line with the requirements for conducting a PhD research in Newcastle University. This was needed for obtaining ethical approval from the University. After designing the research objectives and proposing data collection and analysis methods, the supervisory team concluded that no ethical approval was needed as the research has no serious ethical issues. However, this does not mean that no ethical consideration was given. For instance as organisational data in the form of accident reports were used, it became important to establish that the use of such data will not compromise confidentiality.

Moreover, throughout the study, the student made known of his position as a researcher to all organisations and participants. Hence, during all the interviews and meetings, the researcher was introduced as a PhD research student from Newcastle University. It was also made known that the information generated from such meetings is to be used for research purposes only. The researcher also promised secrecy to all participants and where participants represented their organisation, their role as representatives was reinforced, and their views were taken as the view of the organisation except otherwise stated. All stakeholder organisations agreed to the request in a written letter of introduction which stated the research requests and purpose of the research.

3 CHAPTER THREE: ANALYSIS OF SAFETY AND ENVIRONMENTAL REGULATIONS FOR DOWNSTREAM PETROLEUM INDUSTRY OPERATIONS IN NIGERIA, PROBLEMS AND PROSPECTS

3.1 Chapter overview

As this research considers transportation and distribution of petroleum products from the perspective of downstream petroleum industry operations, it became important to analyse the entire downstream regulatory framework so as to see how the laws, regulations and institutions interact with the specifics of petroleum product transportation. Therefore, this chapter sets out to:

- *Identify and analyse the laws governing the entire downstream petroleum industry operations in Nigeria.*
- *Identify the stakeholders involved in transportation and distribution operations both from operational and regulatory perspective, and identify their interests.*
- *Identify and discuss the problems and prospects, if any, within the regulatory framework.*

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The chapter is made of five sections. As part of this introduction, the next subsections provide a brief overview, highlighting broadly the justification for the analysis and key developments in safety and environmental regulations. Section 3.2 analyses provisions in various safety, environmental and petroleum laws to evaluate their adequacy for ensuring safety and proper environmental management in the downstream sector and specific to petroleum product transportation. Section 3.3 explores the institutional arrangements and stakeholder organisations for monitoring and enforcement of the laws, identifying key enforcement challenges. Following on from this, Section 3.4 illustrates the main findings within the analysed regulatory framework. The section also looked beyond the regulatory framework to factors within the wider socio-political and governance framework that contributes to the effectiveness or otherwise of the regulatory framework. Section 3.5 is the chapter conclusion.

3.1.1 Introduction

As stated in chapter 1, energy generation is largely dependent on petroleum products in Nigeria (Iwayemi, 2008), although there is some contribution from hydropower, biomass and coal. According to AGUSTO (2008), petroleum consumption has been on the increase in Nigeria since the early 1980s. This upward trend is evidenced in the energy consumption data of 2006, 2007 and 2011 where petroleum products represents 53, 67.3, and 68.5 percent respectively of the total energy consumed in the country (Energy Information Administration, 2012).

This increase in consumption of petroleum products has obvious implications for the operations of the petroleum industry in the country (both upstream and downstream), including the risks posed to human safety and the natural environment. Potentially, any of the activities in either the upstream or downstream sectors pose human health, safety, and environmental risks; and the challenge for any government is balancing these concerns with national economic development and energy security goals. This is done through the establishment of an adequate regulatory framework consisting of laws and regulations setting out rights, obligations, procedures and standards, and regulatory institutions charged with responsibility for monitoring compliance (Principle 11, 1992).

It is against this back-drop that this chapter analyses the safety and environmental regulatory frameworks applicable to the downstream sector of the Nigerian petroleum industry. The aim is to evaluate their adequacy in addressing the particular risks or concerns from this sector, specifically pipeline and trucking activities.

The motivation for this analysis is that, first, as seen in Chapter 1, accidents and disasters (especially in transportation activities) within the downstream petroleum sector have been identified as a major source of safety and environmental problems in Nigeria. (Dare *et al.*, 2009; Bala-Gbogbo, 2010; Fadeyibi *et al.*, 2011; Anifowose *et al.*, 2012). Indeed, environmental pollution, deaths and other human disasters from the transportation and distribution sub-sectors within the downstream Nigeria petroleum industry have been highly visible. (Ogri, 2001; Emeseh, 2006; Onuoha, 2007; Zabbey, 2009; UNEP, 2011).

There is, therefore, a need to evaluate the adequacy and comprehensiveness of regulations and also to identify the elements that can be used to ground the risk management framework in this study.

Second, with the combination of 4 refineries, 21 product depots (with a total capacity of 3.7 billion litres), approximately 5001km of pipeline network (NNPC, 2005), over 5000 truck tankers involved in daily product transportation (FRSC, 2011) and over 26,000 retail stations (PPPRA, 2006), it is important to evaluate the synergy between the various pieces of legislation and institutional framework governing downstream facilities, activities and stakeholders within them, with regard to human safety and the environment.

Third, it appears that there is already some awareness of the need for a more focussed regulation of the downstream sector and health and safety in Nigeria. In the new Petroleum Industry Bill (PIB-Draft, 2012) and the National Oil Spill Detection and Response Agency (NOSDRA) Amendment Bill (2012) currently before the National Assembly on restructuring of the Nigerian petroleum industry and introduction of specific regulatory bodies to deal with safety and risks issues. It is important to evaluate whether this new framework offers any real advantage in managing safety and environmental issues by assessing in light of the issues present in the existing framework and the extent to which these are addressed in the new proposals.

3.1.2 Safety and environmental regulations in Nigeria

Although open to a variety of definitions, regulation generally involves a sustained and focused control exercised by a public agency over activities that are valued by a community (Selznick, 1985). In this context, safety and environmental regulation involves the establishment of laws and regulations governing the interaction of man with the natural environment, in order to restrict or minimize the negative impacts on safety, human health and the quality of natural environment. Prevention underlies modern safety and environmental regulation, and various mechanisms are adopted to achieve the objectives of the regulation (Testa *et al*., 2011).

Effective monitoring and enforcement by a regulator is crucial to the effectiveness of any regulatory regime, and this is facilitated by the laws being sufficiently robust, comprehensive and consistent; provision for a range of sanctions, including but not limited to criminal sanctions, to help compel compliance; appropriate institutional capacity and necessary resources to undertake enforcement action; and a conducive wider socio-political and governance environment for effective enforcement (Ogbodo, 2009). It is within this context that the safety and environmental regulation of the downstream sector is analysed. However, it is impossible to fully engage with all of the variables outlined above in this chapter. So while some mention will be made of various factors, the focus is on the adequacy of the rules and the institutional arrangements which are a necessary foundation for any enforcement action. This is, however, not to detract from the understanding that various other factors may undermine effective regulation and lead to enforcement deficits.

As with most developing countries, coherent safety and environmental regulation generally, and specifically of the petroleum industry, is a relatively new phenomenon in Nigeria. Although, there are some provisions relevant to environmental protection dating back to the colonial period, these were essentially public health related (e.g. various provisions in the Criminal Code Act of 1916 and Public Health Act 1917). Following independence in 1960, there was some ad hoc enactment of certain laws such as the Oil in Navigable Waters Act 1968 relating to the discharge of oil in navigable waters in furtherance of treaty obligations under international law (Ladan, 2009).

Focussed safety and environmental regulation of the industry followed much later. This has been associated with the increases in incidents of sabotage and awareness of environmental quality both on a global and local scale (Agha *et al.*, 2004). Notably, the key driver for enactment of safety, health and environmental laws in Nigeria was the 1988 toxic waste dumping incident in Koko (Emeseh, 2006). The incident prompted the enactment in 1988 of the Harmful Wastes (Special Criminal Provisions) Decree; and the Federal Environmental Protection Decree, a framework environmental legislation which among other things established the Federal Environmental Protection Agency (whose functions are now largely taken over by the Federal Ministry of Environment created in 1999). These set the first coherent framework for human safety and proper environmental management in the country, although the extent to which this was achieved is debatable (Ogri, 2001).

As will be gleaned from the discussions above, it took decades to enact petroleum industry specific environmental law. Nevertheless, these two laws in 1988 had implications for the petroleum sector and also invigorated discourse and analysis of environmental provisions in extant sectoral laws, including those governing the entire petroleum industry.

3.2 Nigerian downstream related safety and environmental laws

This section analyses safety and environmental downstream related provisions in relevant laws in Nigeria. The aim is to determine their applicability and adequacy/effectiveness in addressing the safety and environmental issues relating to downstream activities (specifically, petroleum product distribution). The laws are discussed under the following headings:

1. Constitution
2. Environmental laws.
3. Petroleum industry safety related laws.
4. Safety, security and environmental laws specific to petroleum product distribution.

The broad range of laws analysed reflects a need to provide a holistic appreciation of the policy as well as legal environment, the interconnectedness of safety and environmental concerns, and the piecemeal approach to regulating the sector in the country. The analysis takes into consideration subsidiary legislation and guidelines developed by key regulatory bodies. The review focuses on federal laws owing to the fact that except for minor variations, most of the relevant state and local laws essentially replicate federal laws. Thus, for purposes of uniformity, the review relies on federal laws in its analysis. A similar approach was adopted by Emeseh (2006). Potential prospects and solutions from the PIB and NOSDRA Amendment Bill which was at the floor of the National Assembly as at May, 2015 were also analysed.

3.2.1 The Nigerian Constitution (Act No. 24, 1999 as Amended)

Generally, the Nigerian Constitution recognises the importance of improving and protecting human safety and the environment. Under section 20, one of the objectives of the Nigerian State is protecting and improving the environment and safeguarding the air, land, water, forest and wildlife of Nigeria. Similarly, section 33 and 34 which guarantee fundamental human rights to life and human dignity respectively, can also arguably be linked to the need for a healthy and safe environment to give these rights effect. By virtue of these provisions, the ultimate responsibility for managing risks to safety and the environment (especially from petroleum product operations) is that of the Nigerian government.

Paradoxically, the active involvement of the federal government in petroleum industry operations either through equity participation or as outright ownership, including pipeline operations, means that the federal government is also potentially a polluter. Indeed all the refineries and downstream pipeline owned by the federal government, through the State owned NNPC, have been implicated in some of the major pollution incidents. For example, Vivan *et al.* (2012) examined the effect of Kaduna refinery on its host environment and asserted that in addition to gaseous pollutants that are released during oil refining, solid and liquid waste emanating from the refinery pollute the study area. The evidence is seen in pollution of the River Romi and the high number of adverse health issues within the community.

Thus, while the constitution of Nigeria vests the responsibility of protecting human health and safety, and improving the quality of the environment on the government, the same government through its corporation is in this case clearly polluting the environment and endangering the safety of its citizens. Similarly, Adewuyi and Olowu (2012) asserted the existence of notable threats to human and ecological wellbeing from oil related pollution in their research which revealed concentration of contaminants within and around the NNPC Apata product depot to be higher than allowable limits by the World Health Organisation (WHO) and the European Union (EU).

3.2.2 Environmental laws

The environmental laws this section will look at are: The Harmful Waste (Special Criminal Provisions) Act (Cap H1, LFN 2004); Environmental Impact Assessment (EIA) Act of 1999 (CAP E12, LFN 2004); National Environmental Standards and Regulations Enforcement Agency (NESREA) Act of 2007; and the National Emergency Management Agency NEMA (Establishment) Act 1999. These are the main laws relevant to the protection of the Nigerian environment within the context of downstream activities.

3.2.2.1 Harmful Waste (Special Criminal Provisions) Act Cap H1, LFN 2004

The Harmful Waste (Special Criminal Provisions) Act was enacted solely for the purpose of regulation of disposal of toxic waste. This was motivated by the 1988 Koko incident, when an Italian company dumped toxic wastes in the remote port of Koko (Ogbodo, 2009). The Act prohibits the carrying, dumping or depositing of harmful waste without lawful authority in the air, land or waters of Nigeria. According to the Act, a harmful waste means 'any injurious, poisonous, toxic or noxious substance…that can subject any person to the risk of death, fatal injury or incurable impairment of physical and mental health' (see section 15). Although the law did not make specific reference to the petroleum sector, this definition is evidently broad enough to include harmful wastes generated from crude oil refining (a critical downstream operation) and product transportation.

Section 6 and 7 of the Act prescribes a stiff penalty of life sentence and that officers of a body or corporate entity may be held liable under this Act. This means that NNPC and perhaps even its top executive could potentially be liable within the context of the findings by Vivan *et al.* (2012) and Adewuyi and Olowu (2012). It must, however, be noted that by virtue of section 12(1) of the NNPC Act, any suit against NNPC or its officers or employees must be instituted within 12 months. This is an extremely short time frame considering the peculiar nature of environmental harms and the challenges of instituting such suits.

Moreover, there is scant evidence that the Act discourages corporate environmental pollution. Perhaps, because the origin of the law is the Koko incident, the focus has been outwards looking on foreign dumping of hazardous wastes rather than issues of disposal of harmful waste such as those generated in the process refining petroleum products, pipeline pigging or cleaning truck tankers. There is also the question of the suitability of the limited sanctions within this regime in providing for only criminal liability. Although liability is strict, and somewhat reduces the challenge of a criminal prosecution, there is ample research evidence indicating regulators use criminal sanctions as a last resort and that therefore a variety of civil and/or administrative sanctions could potentially be more effective. Civil sanctions also provide a better chance to civil society groups or private individuals to institute action rather than relying almost completely on the regulator, whom as indicated in Section 3.3 and 3.4 below already suffers from issues of conflicts of interests.

3.2.2.2 Environmental Impact Assessment (EIA) Act of 1992 CAP E12, LFN 2004

Environmental impact assessment is a preventative regulatory tool which systematically investigates the long and short term impacts (both positive and negative) of proposed development projects on the natural and human environment (Eneh, 2011). An EIA ensures that potential impacts are assessed, identified and mitigation measures implemented where possible (see Section 1-2 of EIA Act 1992). In appropriate cases, the regulator may refuse permission for the project on environmental and safety grounds. Nigeria introduced this tool through enactment of the EIA Act in 1992. Responsibilities under the Act were originally vested in the now moribund Federal Environmental Protection Agency (FEPA) and some of its function (including responsibilities for EIA decisions) now subsumed under the Federal Ministry of Environment (FME).

Under the EIA Guidelines, downstream projects fall within categories of projects that require an EIA either under class 1 or 2. It can therefore be said that the Act provides a framework to ensure prevention of negative safety and environmental consequences from downstream project development such as pipeline construction. However, in practice it is questionable whether or not this Act has indeed provided effective protection for the environment. For instance, large projects like the Bonny liquefied natural gas plant commenced without an EIA being undertaken and without legal consequences (Eneh, 2011). Hence, while it is true that an EIA Act exists, implementation and enforcement deficits limit its potential for safety and environmental protection. Moreover, an EIA is forward looking and can only apply to new projects and not existing installations such as all the refineries and pipelines in Nigeria which were built prior to its enactment.

3.2.2.3 National Environmental Standards and Regulations Enforcement Agency (NESREA) Act of 2007

The Act establishes NESREA as the main environmental regulatory body, (Section 2, NESREA Act, 2007). In general, it is a successor to the now repealed FEPA Decree of 1988 which established the then FEPA as the main environmental regulator. Although there are some variations, on the whole, the two laws are substantially quite similar.

One interesting area of similarity is the exemption of environmental concerns arising from oil and gas related activities from the remit of NESREA (see Section 7 (g), (h), (j), (k), and (l) of NESREA Act 2007); as indeed section 23 of the now repealed FEPA Act did in relation to FEPA. However, this exemption appears to contradict other provisions of the NESREA Act such as section 7(c) which gives the agency the power to enforce compliance with the provisions of international agreements, protocols, conventions and treaties on the environment, including climate change, biodiversity, conservation, desertification, forestry, **oil and gas**, chemicals, hazardous wastes, ozone depletion, marine and wild life, pollution, and sanitation. Clearly, oil and gas is included in these broader functions under section 7 (c). Furthermore, the inclusion of a Director represented by the Oil Exploratory and Production Companies in Nigeria as one of the representatives on the Governing Council (see section 3) raises a rather controversial question on the limitation provided in section 7 (g, h, j, k and l).

The provision also appears to be in conflict with the role ascribed to NESREA as the main environmental regulator under the National Policy on Environment (NPE). Under section 4.14 of the National Policy on Environment (NPE), the oil and gas sector is recognised as the backbone of national development.

Consequently NESREA is charged with upholding and ensuring sustainable development of the sector. It is difficult to see how they can do this without being involved in the environmental aspect of oil and gas since virtually all of the activities in both the upstream and downstream sectors are not only pollution prone but can also lead to social discord. Similar conflicts arising from the then FEPA provisions were roundly criticised (Adegoroye, 1994; Okonmah, 1997) and it is therefore difficult to justify why similar "mistakes" have been made in this new law. It is therefore not farfetched to surmise that perhaps the intention is not to have independent regulation of the petroleum industry because of its economic significance to the country.

3.2.2.4 National Emergency Management Agency NEMA (Establishment) Act 1999

The NEMA Act establishes a National Emergency Management Agency charged with responsibility for Disaster Management in Nigeria. Section 6 of the Act defines disaster as natural or other disaster which includes any disaster arising from any crisis, epidemic, drought, flood earthquake, storm, train, road, aircraft, oil spillage or other accidents and mass deportation or repatriation of Nigeria from any other country.

The inclusion of disaster from road and train transport gives NEMA jurisdiction in an accident scene that is or could lead to potential disaster. This may include accidents involving hazardous material such as petroleum products. Importantly, the Act recognises the need for integration of national policies via collaboration with state governments. Thus, section 8 establishes a State Emergency Management Committee (SEMC) in each of the 36 states of the federation. The state SEMCs are to respond to any disaster within the State and may seek assistance from the Agency if it deems fit in any circumstance.

Pursuant to the provisions of section 6 of the Act, NEMA has been actively involved in responding to various forms of emergencies including accidents from downstream activities such as those involving product transportation via pipeline and road truck tankers, spillage and fire disasters (BBC, 2012). In order to perform their statutory obligation, the agency developed a National Contingency Plan which integrates hazard risk scenario and planning assumptions; objective strategies and guiding principles (see section 6 of NEMA Act). This legislation is seen as establishing a potentially effective structure for disaster management. However, again it suffers from implementation deficits largely due to lack of adequate funding. This issue is further discussed in section 3.4.

3.2.3 Petroleum industry laws

The petroleum industry laws applicable to safety and environmental protection within the context of product distribution operations are:

- Petroleum Act 1969 (Cap.P.10 Laws of the Federation of Nigeria, 2004);
- The Oil in Navigable Waters Act 1968 (Cap 06, LFN 2004);
- Oil Pipelines Act Chapter 338 (Laws of the Federation of Nigeria 1990);
- The National Oil Spill Detection and Response Agency (NOSDRA) Act 15 of 2006; and
- Environmental Guidelines and Standards in the Petroleum Industry in Nigeria (EGASPIN) 2002.

The Petroleum Act is the main legislation on the exploration, production, refining and distribution of petroleum resources in Nigeria and contains provisions with respect to safety and environmental protection. Section 9(b)(iii) of the Act charges the Minister for Petroleum Resources with the power to make regulations providing generally for matters relating to licences and the prevention of pollution of water courses and the atmosphere throughout the processes of refining, importing, testing, transportation and distribution of petroleum and petroleum products. Surprisingly, “land” is omitted from these provisions (see section 9b, iii Petroleum Act 1969). This perhaps reflects the underlying rationale for, and an undue emulation of the international law in relation to petroleum pollution issues in light of some major petroleum pollution disasters. However, the omission of “land” greatly limits the scope of environmental protection under the Act. This is especially true when considering the interdependent relationship between water course, atmosphere and land.

Notwithstanding, Section 8(1) (f), (g) and (h) also confers on the minister the power to suspend any operations which in his opinion are not being conducted in accordance with “good oil field practice”. This wider provision can arguably be applied more broadly to all aspects of pollution, including “land”.

Although this regulation does not define “good oil field practice” the phrase is defined in the Mineral Oils (safety) Regulations (2004) as that which is in accordance with the appropriate Institute of Petroleum Safety Code, the American Petroleum Institute Codes, or the American Society of Mechanical Engineering’s Codes and the British Standards (Emeseh, 2006). These are believed to adopt practices or engineering techniques recognised as being the most effective and practical means to develop the resource, while minimizing adverse safety, environmental and other negative effects (AECOM, 2009). It is therefore clear that the aim of the Act is to maintain best international standards of operations in terms of health, safety and good environmental practice in Nigeria. However, in light of the evidence of pollution and lack of safety in the industry, it is highly debateable that best industry practices are being adopted even with provisions of serious sanctions in case of breach of these provisions in section 6 of the Act.

Another relevant legislation is the National Oil Spill Detection and Response Agency (NOSDRA) which was established in 2006 as part of the FME in pursuance of the country’s obligations as a party to the International Convention on Oil Pollution Preparedness, Response and Cooperation (1990), which requires states parties to prepare a National Oil Spill Contingency Plans.

The Agency is primarily responsible for coordination and implementation of the blueprint/manual for checking oil spill through, containment, recovery, and remediation/restoration (NOSDRA, 2012) as provided in the National Oil Spill Contingency Plan. However, although spills from distribution activities can be included in the interpretation of oil spills, the agency appears to focus only on spills from the upstream sector. Possibly, this could be because the NOSDRA Act did not specifically state that the agency should also be involved in downstream oil spill clean-up. Perhaps this is one of the reasons why there is a draft amendment bill on the floor of the National Assembly that seeks to dissolve NOSDRA and establish in its place an Agency to be known as the National Oil Pollution Management Agency that will be responsible for preventing, detecting, minimizing and responding to all oil spillages (downstream included) and other forms of pollution such as gas flaring, leakages and other hazardous and obnoxious substances in the petroleum sector.

In line with various statutory provisions (e.g. Petroleum Act, 2004; Oil Pipelines Act, 1990; Oil in Navigable Waters Act, 1968; FEPA Act, 1992; etc.), The Department of Petroleum Resources (DPR) has responsibility for enforcing safety and environmental regulations and ensuring that distribution operations conform to national and international best industry practices and standards (Agha *et al.*, 2004). Against this backdrop, DPR has developed various Safety and Environmental Guidelines and Standards in the Petroleum Industry in Nigeria (EGASPIN) covering all aspects of oil and gas operations since 1981, with the current one being in 2002.

According to Agha *et al.* (2004)the Guidelines were developed to enhance control of the petroleum industry taking into consideration existing local conditions, international practice, available technology, and monitoring programmes. Arguably, the Guidelines can be said to have covered most of the regulatory aspects of the downstream industry safety and environmental management operations including; product transportation and distribution, management of hazardous waste disposal operations, EIA procedure, and hazard, safety/risk assessment integration. However, even with the inclusion of monitoring programmes, implementation has proven to be ineffectual considering evidence of magnitude of downstream safety and environmental issues in the country (Fadeyibi *et al.*, 2011; BBC, 2012).

3.2.4 Safety, security and environmental laws specific to petroleum product distribution.

In addition to generic environmental and petroleum laws discussed above, there are a few regulatory frameworks that are specific to the context of transportation and distribution operations. These include the Hydrocarbon Oil Refineries Act, (Cap H5, LFN 2004); the

Nigeria Security and Civil Defence Corps Act (2003); and Petroleum Products and Distribution (Anti-Sabotage) Act, Cap P12, LFN 2004. Hydrocarbon Oil Refineries Act (2004) is concerned with the licensing and control of refining and downstream supply chain activities. For example, section 1 prohibits any unlicensed refining of hydrocarbon oils in places other than a refinery, and section 9 requires refineries to maintain safe and pollution prevention facilities including in line product piping. The provision also mandates that construction, testing and operation of refineries, distribution depots and in-line pipeline shall be in accordance with "good refining practices", acceptable to and approved by the Director of Petroleum Resources.

One of the key regulations of the industry (The Petroleum Products and Distribution (Anti-Sabotage) Act, 2004) on the other hand prohibits illegal dealings with petroleum products or installations largely in response to the increased spate of pipeline vandalism and prescribes a maximum penalty of the death.

From security perspective, the Nigeria Security and Civil Defence Corps Act (2003) provided the NSCDC with the powers to arrest with or without a warrant, detain, investigate and institute legal proceedings by or in the name of the Attorney-General of the Federation in accordance with the provisions of the constitution of the Federal Republic of Nigeria against any person who is reasonably suspected to have committed an offence under this Act or is involved in pipeline related crime including interdiction.

From the above discussions, there is an apparent (in paper) regulatory framework, which provides some protection for safety and environmental issues arising from downstream activities and, in specific, to petroleum product distribution as well as security. The question however, is whether these provisions are sufficiently comprehensive, adequate and effective. The analysis so far indicates very limited range of sanctions, clear areas of oversight, lack of specificity in references to international codes, and institutional overlaps and duplication of responsibilities.

While acknowledging wider enforcement challenges (Emeseh (2012); and discussed further in 3.4 below), there are obviously gaps in the laws which need to be addressed in order to ensure better protection for the environment and citizens. In this regard, a number of more recent laws such as the NOSDRA and NEMA Acts (1999) have addressed some long standing gaps in the regulation of the sector. However, even these are riddled with various shortcomings. A comprehensive and holistic revision of the regulation of the sector is therefore necessary.

To this end, some of the Bills mentioned earlier such as the amendment to the NOSDRA Act (2012 as amended), and the Petroleum Industry Bill (2012 as amended) (discussed in 3.4 below) promises to address some areas of concern. These are, however, still not far reaching enough and the substantive industry laws and those specific to the downstream sector need to be reviewed. One key area is the range of sanctions available. The overreliance on criminal sanctions ignores the rather extensive literature on enforcement mechanisms, and the broader criminology literature criminal sanctions and their effectiveness. Yet, it is incontrovertible that there is little or no enforcement by regulators (Emeseh, 2006; Onuoha, 2008) and that this is not only a result of the weaknesses in the laws, but wider enforcement challenges some of which are explored below.

3.3 Institutional framework for enforcing downstream related regulations: stakeholder mapping

There is a complex and often overlapping institutional framework for monitoring and enforcement of the substantive provisions of the laws reviewed above. These include ministries, parastatals, agencies, and departments (see figure 3). This section evaluates various institutional frameworks for enforcing downstream related environmental and safety regulations in Nigeria. The aim is to identify all relevant institutions, and critically evaluate their role in enforcing environmental regulations and also to identify stakeholder within the two distribution activities so as to engage them in the study.

Figure 3-1 shows a pictorial representation of key downstream actors, their interests, interactions and structures of accountability. It can be seen from the figure how government actively dominates the downstream sector both in terms of operations and regulatory functions.

It also demonstrates the complex regulatory framework resulting in overlaps of functions and potential conflicts of interests. One of the glaring examples of this is the anomalous position of the NNPC as both regulator and operator in the industry and its relationship with DPR which for practical purposes acts as a department under the Ministry of Petroleum Resources (the owner of NNPC) but has regulatory oversight over operations of the NNPC. For instance, while NNPC remains the dominant downstream operator, the relationship between NNPC and DPR (the main petroleum industry regulator, downstream included) are not at arms-length. Indeed, the relationship between NNPC and DPR may be characterised as one which advocates regulatory seizure. Organisationally, NNPC and DPR share facilities and the employees of both institutions are often seconded to each other.

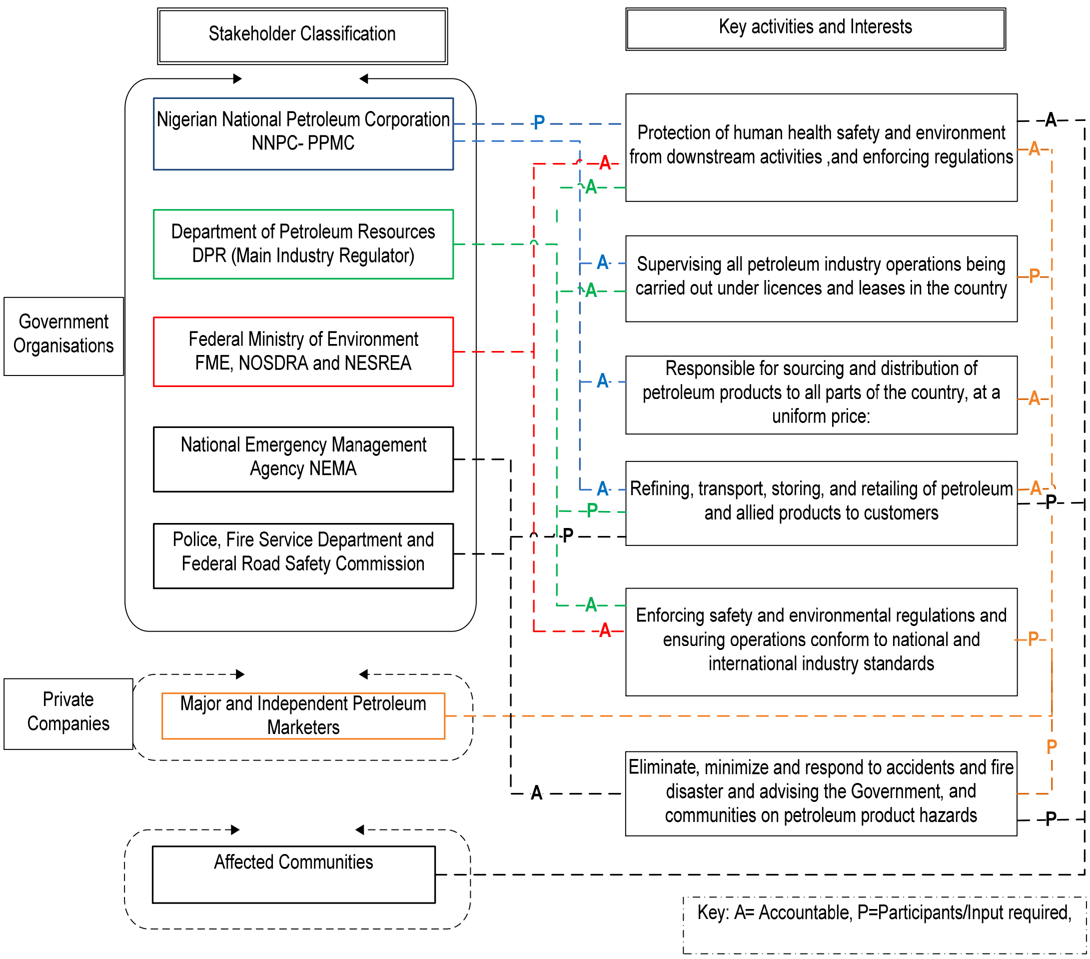


Figure 3-1. Downstream stakeholder structure

Also, NNPC directly funds the operations of DPR, including the payment of staff salaries and funding of some DPR's monitoring functions (Amundsen, 2010). The closeness between the entities compromises the ability of DPR to effectively and independently police NNPC activities.

There is also an argument on the legality of DPR when it was created in the 80s to carry out the regulatory/inspectorate functions previously carried out by NNPC. Adefulu (2008) asserted that the responsibilities conveyed upon NNPC, which were now transferred to

DPR were not legally transferred because the legislation which granted those powers and functions were not amended to reflect this functional transfer.

Aside from the NNPC and DPR, Overlaps and duplication of functions occurs elsewhere in the institutions on two levels: federal and state levels. The problems at each of these levels and their implication for enforcement are discussed in section 3.4.3.2

3.4 Chapter findings

The analysis of regulatory frameworks in this chapter reveals significant findings and answers the research questions set out in the introductory part of this chapter. The answers are highlighted in the following sections:

3.4.1 Laws governing downstream petroleum industry operations in Nigeria.

There is an apparent framework for regulating safety and environmental issues within the downstream sector of petroleum activities, including product distribution operations in Nigeria. The Petroleum Act (2004), Harmful Waste Act (2004), Petroleum Product Distribution Act (2004), Oil Pipelines Act (1990); and the NESREA Act (2007) 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 environmental friendly synergy within downstream facilities.

Additionally, within the examined framework, there are both preventive (EIA Act (1996), Petroleum Act (2004) and DPR Guideline (2002) and remedial (the NOSDRA Act (2006) and NEMA Act (1999)) regulations. This covers regulations for safety and environmental risk management from potentially degrading operations. It also covers issues of remediation in events where unforeseen accidents occur and the subsequent compensation of affected victims.

Also, in addition to the provisions for creating public awareness and providing safety and environmental education on sustainable development, the NESREA Act (2007) is commendable in taking cognisance of the fact that hazardous materials need to be strictly monitored at every stage especially with respect to oil refining and product transportation and distribution. With these legislations, it is possible to develop a risk management framework grounded by regulatory requirements.

However, despite these laws, the current regulatory framework remains largely ad-hoc, patchy and non-comprehensive. This contributes in part to duplications, overlaps and conflicts of interests amongst regulators. These results in lengthy bureaucratic processes, waste of resources, and ultimately ineffective enforcement. It was recognised that there were some promising proposals in two Bills (the PIB and NOSDRA Amendment Bill) currently before the National Assembly which would help address some of the gaps or deficiencies of the current laws.

More attention needs to be given to safety concerns in the laws. Although the definition of environment can be said to include human health and safety, to avoid ambiguity, it is important to clearly provide for this in the laws. Attention also needs to be paid to diversifying enforcement options in place of the current over reliance on criminal sanctions. At the institutional level, there needs to be more coherence and clarity of regulatory functions.

3.4.2 Stakeholder interests and areas of participation

The analysis (see figure 3-1) did find that the main industry regulator is the Department of Petroleum Resources (DPR). DPR is mainly responsible for the supervision and regulation of all petroleum operations, Consequently, DPR is responsible for ensuring that pipelines, depots, refineries and retails stations are operated safely. However, DPR is not responsible for ensuring the safe operation of truck tankers on road. Their area of jurisdiction for tanker operations is only applicable if the truck tanker is within a depot, refinery or retails station to load or off-load products.

Road safety regulation is mainly the responsibility the Federal Road Safety Commission (FRSC). FRSC issues drivers licence and carries out its regulation on truck tankers via its Guideline for Articulate Lorries and Truck Tankers (2012).

From this, it obvious that the two regulators (DPR and FRSC) have areas of mutual interest and therefore need to collaborate to ensure a holistic regulation of safe product transportation and distribution. The Federal Fire Service Department and NEMA also need to form part of this collaboration as these two agencies are responsible for responding to accidents which includes pipeline and road truck accidents.

NOSDRA, FME and NESREA on the other hand are involved in regulating activities with potential adverse effect on the environment. Typically, NOSDRA ensures that oil spills are cleaned and adequate compensation issued to affected persons.

The Nigeria National Petroleum Corporation (NNPC) is the biggest industry operator (and arguably, a regulator). NNPC via is subsidiary PPMC own and operate the 5001 km distribution pipeline in Nigeria and is largely involved in trucking operations via its affiliates, as well as depot and retail operations.

From the marketing perspective (including trucking operations), there are 6 major marketers: Oando Nig. Plc; Mobil Oil Nig. Plc; Total Nig. Plc; Forte Oil Nig. Plc; MRS Nig. Plc, and Conoil Plc. The 6 major marketers control 25.47% share of the fuels retail market and are working under an umbrella associate known as: Major Marketers Association of Nigeria (MOMAN).

There are over 3800 Independent Marketers controlling 51% of the fuels retail market and operating under a union known as: Independent Petroleum Marketers Association of Nigeria (IPMAN).

These stakeholders (shown in figure 3-1) were engaged throughout the process of developing the risk management framework.

3.4.3 Problems and prospects of the regulatory framework

The analysis did find a number of problems within the regulatory framework in Nigeria. This includes, the lack of specific approach to regulations, conflict and overlaps within institutions, and wider socio-economic issues such as: lack of good governance and inadequate funding of regulatory bodies. These issues and some prospects for improvement are also discussed below.

3.4.3.1 Lack of specific regulatory approach

The analysis reveals that there is no specific regulatory approach in the regulatory framework. Defining a regulatory specific approach should therefore be an important point of action for any reform within the safety and environmental legislation in Nigeria.

In the global best practise context, two regulatory approaches exist, i.e. prescriptive and goal setting. In-service inspection of pressure systems, pipeline, storage tanks and containers of hazardous materials has traditionally been driven by prescriptive industry practices.

Prescriptive practices fixed the locations, frequency and methods of inspection mainly on the basis of general industrial experience for the type of equipment. These practices, although inflexible, have, on the whole, provided adequate safety and reliability. Prescriptive inspection has a number of short-comings. In particular, it does not encourage the analysis of the specific threats to integrity, the consequences of failure and the risks created by each item of a system. It similarly lacks the freedom to benefit from good operating experience and focussing finite inspection resources to the areas of greatest concern.

Goal setting legislation on the other hand has enable a move towards inspection strategies based on the risk of failure. The legislation leaves the user or owner, in conjunction with the Competent Person, with the flexibility to decide a 'suitable' written scheme for examination to prevent danger on the basis of the available information about the system and best engineering practice.

Notably, throughout the review of the regulatory system in Nigeria, it is unclear which of the recognised system is in practise. This has obvious implication on clear lines of responsibilities within the regulator and the regulated.

The goal-setting approach is guided by the principle of As Low As Reasonably Practicable (ALARP). Meaning that employer (operator) does not have to take measure to avoid or reduce the risk if they are technically impossible or the cost of measure would be grossly disproportionate to the risk.

In the context of petroleum distribution operations, this means that operators have to adopt good management practices and common sense to ensure that risk are identified and sensible measure are tackled via risk management initiatives. This gives the operators freedom to decide how to manage the risk they identified.

This system of regulation may suite the Nigerian context as operators are allowed to develop methods based on peer reviews and the regulator will then concentrate on implementation. Notwithstanding, legislation can also be prescriptive and prescriptive regulatory compliance can also be used as requirement for licensing. For instance development of safety case can be used as prescription for trucking or pipeline operation licensing. The safety case can then be used to scrutinise safety procedures and risk management claims by an operator. The onus is therefore on the identified stakeholder to develop or adopt a system which will be suite the Nigeria case.

3.4.3.2 Conflicts and overlaps of institutions and laws

A critical evaluation of the pictorial representation of the stakeholder analysis in figure 3-1 reveals some key responsibility issues that contribute to regulatory enforcement problems in Nigeria. It is factual that there exist multiple involvements of various agencies all established by various provisions of the legislations reviewed, with the same and duplicating functions. This perhaps is a typical example of the saying "too many cooks spoil the broth".

Overlaps and duplication of functions can occur at two levels (Federal and State level). At the federal level, the conflict between DPR and FME (NOSDRA and NESREA inclusive) is mainly motivated by overlapping functions. While FME is statutorily required to collaborate with various agencies (including DPR) on matters and facilities relating to the protection of the environment and the conservation of natural resources (see FME Mandate 2013), the extent or form of collaboration remains largely unclear. Furthermore, as noted in the provisions of NESREA Act, despite being the main regulatory environmental agency, conscious attempt is made to relegate the role of NESREA (a parastatal under FME) in the regulatory context of oil and gas activities (Ladan, 2012). Potentially, conflicts can also occur between NEMA responsible for disaster management and other agencies or services such as the Federal Road Safety Commission, the Police and the Fire Departments

Conflict also exist between the Federal and State agencies over competency with regard to environmental damage arising from petroleum operations (Emeseh, 2012) due to unclear definition of regulatory jurisdiction. This leads to rivalries and jealousies (Eneh, 2011) resulting in top-down legislation having limited applicability and effect within the downstream context.

Again, this is a further illustration of the way in which lack of comprehensiveness of the regulatory framework affects enforcement. The implication of such overlapping regulatory functions is explained by Eneh (2011) as too expensive, very bureaucratic and time wasting. Consequently, this results in conflicting responsibilities for monitoring and enforcement, and discordant, inconsistent inter-intra organisational relationship (UNEP, 2011). For example, UNEP (2011) found DPR and NOSDRA have differing interpretations of EGASPIN. This has enabled oil industry actors to discontinue remediation processes in oil spill contaminated sites before they have been fully restored to an adequate environmental status.

Arguably, the new Petroleum Industry Bill (PIB) offers some solutions to the inherent conflicting regulatory responsibilities. The PIB was developed in light of government's effort to restructure and reorganise the decaying structure of the Nigerian petroleum industry. The Bill which has received contested acceptance by many industry players is been commended for its effort to codify all the several legislations applicable to the petroleum industry in Nigeria into one legislation with: fundamental objective; institutions; upstream operation; downstream operations; local content; health, safety and environment; fiscal provision; repeals; transitional provisions; and interpretations (see PIB, 2012). In addition, a structured proposition for an integrated downstream regulatory framework that assimilates concerns for licensing, construction and operation of downstream facilities, national logistical operations, and management of health, safety and environment from downstream activities was included. The objective of the Bill also gives a focussed approach to management and allocation of petroleum resources in accordance with the principle of good governance, transparency and sustainable development in Nigeria (see PIB, Section 1-8), an issue that is of great importance to attaining success in regulatory enforcement.

An examination of the PIB Bill reveals a strategic approach that decouples the regulatory arm of NNPC from its investment division and suggests a complete deregulation of the downstream sector. This will promote regulatory transparency as government will not be involved in downstream competition and NNPC will no longer be a competitor and a regulator. Also, if successfully enacted, the PIB-Bill will establish a separate government agency to deal strictly with downstream (including distribution of petroleum products) regulations. This could prove effective as the proposed agency will not face the upstream distractions being faced by NNPC and DPR.

Furthermore, since the proposed regulatory Agency will integrate both NNPC and DPR's downstream regulatory responsibilities (PIB, 2012) and will be responsible for promoting healthy, safe, environmentally friendly and efficient operation of product distribution systems (PIB, 2012), the issues of conflicting and duplicating responsibilities will be reduced. The challenge, however, will be in the actual implementation of its function as it may still inherit the earlier discussed conflicting responsibilities with FME and State agencies.

Nevertheless, since the provisions of the PIB are such that the government will no longer be involved in downstream competition, it provides fewer opportunities for conflicts of interest between the regulator and the regulated under the current framework. Perhaps also better consultation and coordination of policies and programmes could help reduce conflicts even within the current framework. For instance some of the conflicts with the FME could possibly be resolved if the current, or proposed new agency develops its industry Guidelines with the inputs of all stakeholders especially including the FME. By doing so, the proposed agency will align its interest with that of the FME, and use the advantage of FME’s collaborative partnership with states and local environmental agencies across Nigeria to enhance regulation and enforcement on a wider scale .

3.4.3.3 Lack of good governance

The relationship between national governance and the petroleum industry in Nigeria cannot be over emphasised (Ogri, 2001; Nwafor, 2006). Petroleum accounts for about 65 percent of government revenues (Amundsen, 2010).

However, this huge source of revenue (which is estimated to be about USD 400 billion since independence) has led to a system that has lent itself to ‘rent-seeking’ and ‘elite capture’, and has developed a ruling elite in control of the state apparatus, thereby fuelling poor governance and lack of political will to effectively regulate the industry (Mehlum *et al.*, 2006; Humphreys *et al.*, 2007). This affects enforcement of laws in various sectors of the economy (downstream included) owing to obstruction and manipulation of the system by actors who are beneficiaries of the dysfunctional system which enables the perpetuation of rent seeking and other underhand practices (Amundsen, 2010). This system is perpetuated through corruption and weakening of the very institutions and structures tasked with ensuring the justice, accountability and the rule of law (Obia, 2013; Usman and Okolie, 2013).

Successive governments have failed to curb rent-seeking and ultimately appear to succumb to its pressure. In 2012, the NNPC awarded a pipeline protection contract worth N5.6 billion (about $43.7 million) to bodies headed by what some have argued are well-known criminal cabals, militants and armed militias (Legist-Admin., 2013). Whether or not this will lead to fewer incidents of pipeline vandalism remains debatable. While there are legitimate public policy goals in the government's goal of rehabilitating the militants as part of a strategy to de-militarize the Niger-Delta following decades of socio-political crises, it is debatable whether the approach adopted was the most appropriate and efficient in the circumstances. Arguably, such actions potentially undermines the authority of law enforcement agencies such as the Nigeria Police, Armed Forces, Nigerian Security and Civil Defence Corps, statutorily charged with security functions on behalf of the State and could encourage others to adopt similar measures for personal gains.

Furthermore, the wider governance deficits prevent individuals and civil society groups from effectively holding public officers accountable for dereliction of their regulatory functions owing to authoritarian governments, poverty and other capacity deficits, and lack of effective frameworks or forums for accessing justice (Emeseh, 2012). Similarly, it has been suggested that a "rentier mentality" dis-incentivises the citizenry from seeking longer term political solutions compared to immediate economic advantages offered as pacification (Aigbedion and Iyayi, 2007; Amundsen, 2010; Bazilian and Onyeji, 2012).

It is important to assert that various attempts have been made by previous governments to reform the petroleum industry (see Amundsen, 2010; and PPPRA, 2012). However, confusion still persists regarding the specific approach to be adopted for managing safety and environmental issues from the downstream sectors of the Nigerian petroleum industry. This should not be the case because the regulation of downstream environmental and safety concerns (especially product distribution) does not appear to be complicated by broader political concerns such as ownership of oil resources which besets the regulations of the upstream sector (Ejobowah, 2000; Omeje, 2006). Arguably, certain aspects of downstream safety and environmental problems are attributable more to issues of operations and safe handling of petroleum products (Dare *et al.*, 2009) and can be easier to enforce in light of existing provisions in the laws.

The PIB also recognises that downstream issues should be treated separately from upstream issues as both are unique from a managerial and technical perspective. The approach under the PIB portends well for providing solutions to some of the inherent problems of safety and poor environmental management within the sector. However, perhaps, indicative of the powerful interests and the scale of challenge involved in bringing about change and accountability within the industry, the Bill remains stalled on the floor of the Senate for over 8 years because of the opposition from a small but powerful minority. The implication of this to the downstream sector is continuous incremental decay of the system resulting in more loss of lives and properties, high levels of environmental pollution and the consequently health problems.

3.4.3.4 Inadequate funding

Poor enforcement can also be attributed to inadequate funding of the regulatory agencies by depriving them of the resources required (such as adequate numbers of appropriately trained staff, necessary facilities and equipment, and national coverage of offices) to effectively discharge their regulatory function (Aprioku, 2003; Ebigo, 2008). For instance, most issues relating to pollution and poor safety distribution operations are particularly visible at state and local level. However, the main enforcement agencies do not have a sufficiently wide national coverage and concentrate mainly in the capital cities of the main oil producing states in the Niger Delta region where they also have responsibilities for the activities at the upstream sector. This limits the agencies' ability to monitor and respond to downstream related accidents in 30 of the 36 states in the country.

This is not to imply that these agencies are necessarily efficient in the areas where they have a presence. They are unduly dependent on industry players to provide facilities, resources and equipment for monitoring activities. This result in a situation where the opinion of industry players influences the regulator's application of policy and reporting of data (Eneh, 2011). This is further complicated in light of the relationship between the regulators on the one hand and their relations with the government. For example Amundsen (2010) reports a situation where DPR (the main industry regulator) was treated like another arm of the NNPC subject to directives and pressure from the NNPC and the presidency. As a result, DPR often fails to discharge its functions effectively (Osayande, 2008).

3.5 Chapter summary

An analysis of the regulatory framework for safety and environmental protection was carried out in the context of downstream petroleum operation, focussing more on product transportation and distribution operations, i.e., pipeline and truck tanker operations. The pieces of legislation applicable to the development of risk management framework in the context of the two operations under consideration were identified. The review revealed the limitations of the framework such as incoherent laws, overlaps, duplications and conflicting regulatory functions. In addition, the chapter looked beyond the regulatory framework to factors within wider socio-political and governance context that contribute to the lack of effectiveness of the regulatory framework. Poor governance, rent seeking culture and inadequate funding were also identified as the key contributing factors to implementation deficit. However, the chapter did find that provisions in laws such as the Petroleum Act, Harmful Waste Act, Petroleum Product Distribution Act, Oil Pipelines Act; and the NESREA Act can be considered key regulations relating to "good oil practices". There are also prospects identified in the Petroleum Industry Bill (PIB) (Draft) and National Oil Spill Detection and Response Agency (NOSDRA) Amendment Bill which addresses some of the limitations within the reviewed framework.

Also, the stakeholder involved in the operations from both the perspectives of regulator and the regulated were identified. Their interest and areas of participation were also identified. This forms an important part of the process of stakeholder engagement throughout the process of developing the risk management framework.

The next two chapters, therefore, present the risk assessment and management framework for pipeline and trucking operation in Nigeria respectively. The frameworks are grounded by the elements of legislation discussed in this chapter.

4 CHAPTER FOUR: PIPELINE RISK MANAGEMENT FRAMEWORK

4.1 Chapter introduction

Having established the identified the pieces of legislations that govern downstream petroleum industry operations in Nigeria, this chapter presents a risk management framework for the pipelines described in chapter 1. The aim of the chapter is to *assess the risk associated with the pipeline and developing risk mitigation strategies for pipeline operations.* Consequently, the following research questions will also be addressed:

- *What model can be use of the pipeline risk assessment?*
- *What are the risks associated with the pipeline systems?*
- *What factors contribute to the frequencies of pipeline failure and the consequences of such failure?*
- *How best can stakeholder interests be integrated for the deployment of the designed risk mitigation strategies?*

Parts of this chapter is based on a published work under the following title:

Ambituuni, A., Hopkins, P., Amezaga, J.M., Werner, D. and Wood, J.M. (2015) 'Risk Assessment Of A Petroleum Product Pipeline In Nigeria: The Realities Of Managing Problems Of Theft/sabotage', in Brebbia, C.A., Garzia, F. and Poljak, D. (eds.) *Safety and Security Engineering VI. Volume 151 of WIT Transactions on The Built Environment.* WIT Press.

As noted in chapter 1, this study is perhaps the first time the concept of risk management is being applied to develop a structured management initiative aimed at improving the poor safety and environmental performance of the petroleum distribution pipelines in Nigeria.

Notably, some elements of existing research have pointed out the safe and environmental problems associated to operation of pipelines and the activities of saboteurs in Nigeria e.g. Anifowose *et al.* (2012) Anifowose *et al.* (2014); Omodanisi *et al.* (2014); and Aprioku (2003). However, none of these research approached pipeline operations from a risk management perspective even with the opportunities (discussed in Chapter 1) that risk management concepts offers in developing effective risk mitigation options.

In Anifowose *et al.* (2012) a quantitative analysis of the spatiotemporal pattern of pipeline interdiction – defined as the deliberate or intentional act of destruction on a system such as transport pipeline (Church *et al.*, 2004; Anifowose *et al.*, 2011) was performed to understand the stakeholders, claims and actions within the complex web of causes of interdiction of pipeline in Nigeria. The research illustrated geographical patterns of pipeline interdiction via choroplethic and bivariate GIS maps. The statistical analysis explored patterns and discussed correlations with socio-economic and socio-political factors such as poverty. Similar exploration was done in Anifowose *et al.* (2014). The research reported a positive increase in reported vandalism on pipeline observed right after the execution of some environmental activist in the Niger-Delta by the military junta of the Late General Sani Abacha in 1995 (Anifowose *et al.*, 2012). Perhaps, also, a surprising element of the research was the reported negative correlation between interdiction and poverty incidence. This critiqued the assertions in Onuoha (2008) and (Onuoha, 2007) which linked poverty to pipeline interdiction incidents. The research, however, suggested poor data quality as a possible reason for this finding.

From an environmental management perspective, Omodanisi *et al.* (2014) combined data from digital and social surveys, laboratory readings and spatial information in a geographical information system to investigate the effect of a pipeline explosion which happened in December 2006 at a rural community in Lagos Nigeria. The research identified faulty and exposed pipeline, inadequate security or poor monitoring of the pipeline, and sabotage from certain 'greedy' people as the causes of pipeline explosion. Using satellite imagery, the study spotted and reported the likely involvement of the Nigerian police in product theft. This raises significant questions about the efficiency of the current pipeline protection system, and law enforcement in Nigeria. The research also raised questions regarding the lack of a framework for risk reduction and disaster management.

While these research are instrumental in shaping the contextual understanding of risk factors that may be encountered while assessing the pipeline risks, the likely contribution that risk management offers in managing these issues has not been explored by any know research. This can also be seen from the methods applied by the reviewed research. None of the reviewed research made use of the technical capabilities that pipeline risk assessment models such as De Stefani *et al.* (2009) and Muhlbauer (2004) to generate risk mitigation options. Hence, the concluded recommendations in the research were neither pragmatic, within the purview of regulatory requirements for pipeline risk management, nor a holistic approach to pipeline risk management.

This chapter, therefore, sets out to develop a risk management framework for the downstream product distribution pipelines, with complete integration of regulatory requirements and stakeholder interests. The end product will form part of a policy proposition for the pipeline operator (in Chapter 6).

The method chapter illustrated how it is important for risk assessment to form an integral part of risk management, hence, section 4.2 explored existing models in order to develop a model suitable the risk assessment of the case pipeline.

4.2 Existing pipeline risk assessment methods and approaches.

Pipeline accident is defined by Roed-Larsen, *el al*, (2004) as an unplanned pipeline failure event which occur suddenly and causes injury, fatality or loss leading to decrease in material value and environmental quality, and increase in liability (Citro and Gagliardi, 2012; Hopkins, 2012). Hazards from pipeline operations are due to the possibility of loss of containment (LOC) (Dziubiński *et al.*, 2006) with risks of fire and/or explosions in addition to environmental damage. The risk of pipeline should therefore be fully assessed in order to develop appropriate mitigation measures. Developing mitigation measures entails understanding two elements of safe operation of pipelines i.e. the risk posed by the pipelines and the pipeline failure or accident/incident causal factors.

For the first element, risk assessment involves: analysing failure likelihood or frequencies and failure consequences quantitatively and/or qualitatively, and charactering risk values by comparing with established limits to define the acceptability of risk poses by the pipelines. The second element entails understanding pipeline failure or accident/incident causal factors as suggested in the accident causation models (Heinrich, 1931; Reason, 1990; Rasmussen, 1997; Hale, 2002; Leveson, 2004) discussed earlier in chapter 2.

There are a variety of different systems in used for conducting pipeline risk assessment**.** These systems sometimes combines either qualitative or quantitative approach to develop a suitable methodology. Palmer-Jones *et al.* (2009) placed them into three generic methodologies:

- Point-scoring (uses qualitative approaches)
- Ranking and (uses qualitative approaches)
- Quantified.

This chapter explores these methodologies in order to develop a method which utilises analytical techniques that best suit the set of data collected for the purpose of conducting risk assessment of the petroleum product pipeline distribution network in Nigeria. The results informed the mitigations strategies and risk management recommendations proposed.

4.2.1 Point-scoring system

One of the most common point scoring methods in pipeline risk assessment is the Kent's method (Kalatpoor *et al.*, 2011). In this method, Relative Risk Rating (RRR) is used as the final measure for estimating the risk level of the selected pipelines. This can be between two separate lines or within various sections in a line.

Unlike many other methods that are deterministic; i.e. based on the judgement of a competent engineering personnel, Kent's method is a probabilistic method, i.e. based on quantitative computation of probability density distribution (Lawson, 2005). This feature is important, especially in management of corrosion risks (Kalatpoor *et al.*, 2011). However, Lawson (2005) asserted the need to be cautious in utilising probabilistic methods due to claims that rigorous application of probability theory will yield a superior conceptual framework for understanding and managing risk. Palmer-Jones *et al.* (2009) also asserted that point based risk assessment method cannot replace expert knowledge and always need to be modified to suit a particular system whilst also requiring updates as pipeline characteristics changes. Hence, the application of either probabilistic or deterministic or both risk assessment methods should factor in the contextual characteristics of the system to be assesses as well as the regulatory requirements in place.

Kent Muhlbauer (2004) defined Relative Risk Rating (RRR) as:

$$\boldsymbol{RRR = (Index\ Sum) \div (Leak\ Impact\ Factor)} \quad \textbf{(4.1)}$$

$$\boldsymbol{Index\ Sum = Third\ Party + Corrossion + Design + Incorrect\ Operation} \quad \textbf{(4.2)}$$

$$\boldsymbol{Leak\ Impact\ Factor = Product\ Hazard(PH) \times Leak\ volume\ (LV) \times Dispersion\ (D) \times Receptos(R)} \quad \textbf{(4.3)}$$

A strength of Kent's method is the consideration given to the impact of leaks on the environment. Although the third party index factored in consideration for; pipeline public education, right of way condition inspection, depth of cover, frequency of patrol, etc. which when factored into risk management strategies can mitigate interdiction on pipelines, the method and the modification by Kalatpoor *et al.* (2011) ignored activities of vandals and saboteurs as a risk factor in pipeline risk assessment.

4.2.2 Ranking system

The ranking or deterministic system is quite a simple and flexible approach and mostly qualitative in nature. It relies on expert or team of experts to credibly identify hazards for a pipeline and also rank the probability of failure for each hazard typically as high, medium or low. The consequence of failure from each hazard for the pipeline are also qualitatively ranked. This system has the advantage of being applied even where there is limited data (Palmer-Jones *et al.*, 2009). However, the system is difficult to get consistent risk levels for different hazards, consequence and pipeline section.

4.2.3 Quantified risk assessment

This system uses the process of calculating absolute risk levels based on computation of failure frequency and failure consequence. Failure consequence are predicted using fire models, oil-dispersion models, loss models, etc. this method offers consistent risk level comparison for different failure modes and the benefits of risk mitigation via which failure reduction can be quantified. It, however, requires good quality data and specialist software which can be quite expensive. Examples of quantified approaches can be found in Jo and Bum (2005) and Ma *et al.* (2013).

Jo and Bum developed a method of quantitative risk assessment for transmission pipeline carrying natural gas which introduces parameters of fatal length and cumulative fatal length. They estimated these parameters by using the information of pipeline geometry and population density of Geographic Information Systems (GIS). The method was then tested using historical data from European Gas Pipeline Incident Data and BG Transco to estimate the value of individual and societal risk. Their research found that based on the regulatory acceptable criteria for pipeline risk, individual risk at the minimum proximity of the pipeline to occupied buildings is approximately proportional to the square root of the operating pressure of the pipeline. Notably, quantified risk assessment are mostly modelled to suit certain pipeline context.

4.2.4 Hybrid pipeline risk assessment

Various frameworks for pipeline risk assessment have been developed using a combination of the three systems in a rational manner to suit the problem instance of specific pipeline operation and regulatory context. PD8010-part 3 (and IGEM TD/2) is an example of a risk assessment code of practice (CP) developed with an integration of quantified risk assessment system and regulatory requirements. Figure 4-1 shows an overview of the code. The document covers risk assessment of buried pipelines and the safety risk caused by flammable substance.

Pipeline consequence prediction such as computation of ignition probability, thermal radiation and safety effects were adequately covered in the code. The use of event tree for illustration of failure effect was similarly encouraged based on two failure modes, i.e. puncture and rapture. In modelling failure consequence from the two failure modes, the document recommended considerations for outflow as a function of time; ignition (immediate or delayed) probability (Rew *et al.*, 2000); thermal radiation from jet and carter fires; degree of wind tilt; spillage rate and duration of release; immediate and delay pool fires; etc.

Haswell *et al.* (2009), asserted that the primary purpose of developing PD 8010 PART 3 (and IGEM TD/2) was to provide authoritative and accepted guidance on the risk analysis of site specific pipeline details and additional risk mitigation measures, which could be applied as part of development. The codified advice aims to ensure a standard and consistent approach, and reduce the potential for technical disagreement between stakeholders regarding the methods used to assess pipeline risk acceptability.

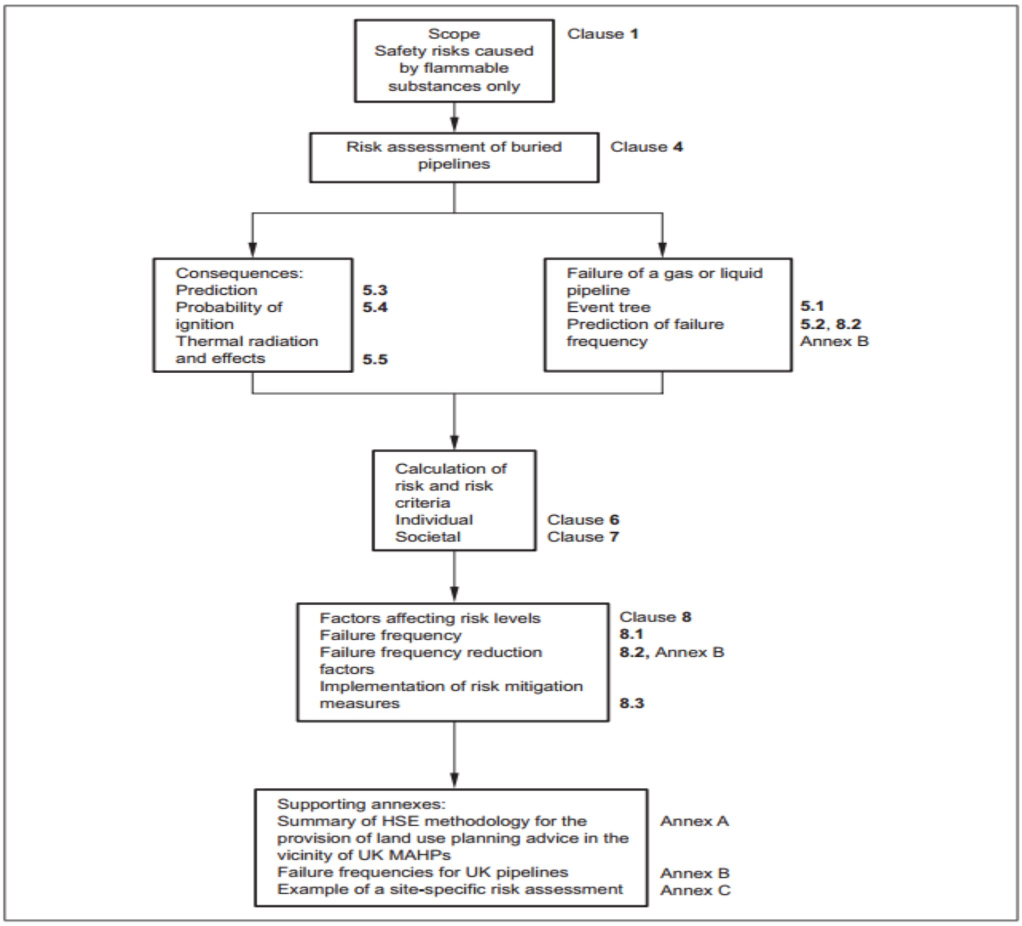


Figure 4-1. Overview of PD8010-Part 3 (source: PD8010-Part 3)

Attention was given to failure causes such as; corrosion (internal and external), material or construction defects, ground movement, fatigue and operational errors, however, there was no mention of failure cause from pipeline interdiction or sabotage. Even where external interference was mentioned, this was done in the context of accidental damage. This perhaps could be due to the fact that interdiction and sabotage of pipelines in the UK has not been an acute problem.

Notably, however, in the risk assessment models presented by De Stefani *et al.* (2009), sabotage and pilferage (interdiction) was considered as part of failure frequency influencing parameters that are highly specific to particular pipeline or locations.

4.3 Developing a pipeline risk assessment model and the use of data

The method used for analysis of pipeline risk in this study draws relevant techniques from the above reviewed risk assessment models. It combined both quantitative and qualitative approaches to obtain results that overcome limitations in the data required for risk assessment of long pipelines.

This section illustrates the model developed and the data set used to established the characteristics of risks from the pipelines.

4.3.1 Establishing pipeline characteristics

At this stage, data was collected to establish the general context of the pipelines. This included documented data related to the construction, operation, and maintenance of the pipeline from operator (PPMC). Using this data, it was possible to establish the characteristics of the pipelines and the operating parameters: including pipeline diameter, wall thickness, steel grade, length, fluid type, line capacity, design flow rate (min/max), design pressure, cathodic corrosion protection, depth of cover, etc. The details (shown in Appendix 2) were used for various calculations.

4.3.2 Historic data

Historic accident and incident data was obtained from the pipeline operator (PPMC). The historic data used comprised data for 13 years reports (from 2000-2012) containing information on accidents and failures in the entire 5001 km pipeline system across the 5 operations and distribution zones. This also includes details of fatalities, quantity and financial value of product loss, failure causal factors, etc.

4.3.3 Condition of Right of Way – site survey

To improve the contextual understanding of the pipeline, a site inspection was conducted on a sampled section of the pipeline (system 2B- alone the Atlas-Cove to Mosimi section) to obtained site specific data on the condition of right of way. The section of the pipeline inspected was purposively selected due to its activeness. 2B accounts for 70% of the service gateway for product importation. The area inspected is classified under the Mosimi Region as shown in figure 4-2.

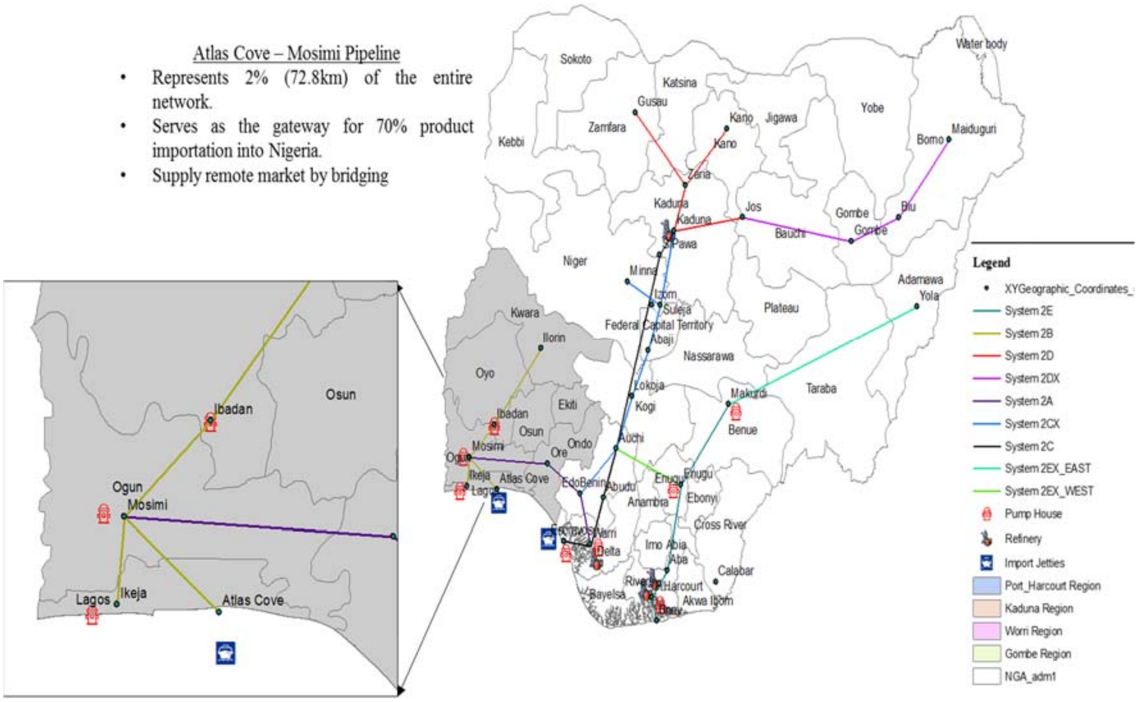


Fig. 4-2. ROW inspected area

Table 4-1. Coordinates of section of pipeline ROW inspected

Start point Coordinate:	6°35'00.4"N	3°16'15.2"E
End point Coordinate:	6°27'55.14"N	3°15'14.91"E
Distance:	13.26 km	
Initial bearing:	008°01′00″	
Final bearing:	008°01′07	
Midpoint:	06°31′28″N,	003°15′45″E

In total, about 13km of that section was inspected over a period of four days (from 17th to 20th June, 2014). Details of inspected coordinates are given in table 4-1. The inspected area cuts across towns and countryside. To conduct the inspection, the researcher joined a team of right of way patrol staff after getting the highest approval from the operator. As there are no standardised or legal right of way visual inspection processes in Nigeria, the recommended process by The Association of Oil Pipeline was adopted. This method simply involves:

- Determining section of the pipeline ROW to be inspected,
- Determining the method to transverse ROW (in this case, foot patrol and patrol vehicle were used to transverse the sampled area)

- Ensuring the researcher has a clear understanding of which pipeline need to be inspected; the location of the pipeline; and the beginning and ending points of the pipeline, and documenting all notable observations on the ROW.

4.3.4 Interview with stakeholders

As shown in Section 2.7.3, a total of 30 semi-structured interviews were collected from stakeholders with interests and some level of participation in operations of the pipeline.

The interviews were analysed using the cross content thematic analysis method described in Section 2.8.3 to establish pipeline accident/incident causal factors as well as factors that lead to the consequential nature of such accidents/incidents. Using the selected accident analysis models in section 2.4, the interview result was combined with the results from pipeline risk assessment and ROW inspection to establish a structured hierarchical understanding of pipeline risks, technical, human and organisational failure causes, stakeholder interests, and the existing emergency systems. This understanding shaped the risk mitigation strategies proposed.

4.3.5 Failure frequency (F) analysis

Equation 2.3 defined risk as the expected consequences associated with a given activity. For a pipeline with *n* possible accident events the risk is defined by:

$$\boldsymbol{R = \sum_i (F_i \; Q_i \;)} \qquad \textbf{(from Eqn. 2.3)}$$

Where F_i and Q_i are the frequency and consequence of event *i*. Pipeline failure frequency is expressed in 1000 kilometre-years.

Failure in pipeline can occur due to a range of potential threats. These threats can be time dependent, e.g. internal/external corrosion and material fatigue or time independent, e.g. ground movement, third party interference and incorrect operations. Failure of a high pressure pipeline can occur as a leak or rupture. Leaks are defined as fluid loss through a stable defect while ruptures are fluid loss through an unstable defect which extends during failure, such that the release area is normally equivalent to two open ends (BS PD8010-3, 2013). Failure frequency can be computed based on classification of causal factors (e.g. Muhlbauer (2004)) or based on accident scenario using empirical formulas to calculate frequencies from historic data and illustrate the result on event tree. (e.g. BS PD8010-3

(2013)). For this study, the model for computing failure frequency present in De Stefani *et al.* (2009) was adopted and modified as its parameters closely suit the context of pipeline risk assessment in Nigeria. Failure frequency is therefore given as:

$$\boldsymbol{F = F_{TPD} + F_{MF} + F_{CO} + F_{NH} + F_{IN}} \quad \textbf{(4.4)}$$

$$\boldsymbol{F_{TPD} = F_{ffreq} \times P_{hit} \times P_{pm}} \quad \textbf{(4.5)}$$

$$\boldsymbol{F_{MF} = F_{yr} \times P_{age}} \quad \textbf{(4.6)}$$

$$\boldsymbol{F_{co} = F_{Bc} \times P_{fl} \times P_{wt} \times P_{pig} \times (P_{IC} + P_{EC} \times P_{CP} \times P_{CT})}$$
(4.7)

Table 4-2. Failure frequency parameters

Parameter	Description
F	Calculated failure frequency – from all causes
F_{TPD}	Calculated third party damage failure frequency
F_{MF}	Modified Mechanical Failure frequency
F_{CO}	Modified Corrosion failure frequency
F_{NH}	Modified Natural Hazards failure frequency
F_{IN}	Interdiction (Sabotage and Pilferage) failure frequency
F_{ffreq}	External Interference failure frequency generated using FFREQ – incorporates effects of pipeline-specific parameters, depth of cover, and location
P_{hit}	Hit rate modification factor – e.g. country
P_{PM}	Protective measures modification factor – e.g. physical protection, surveillance
F_{yr}	Mechanical failure frequency – dependent on year of construction
P_{age}	Pipeline age modification factor
F_{BC}	Corrosion failure frequency
P_{fl}	Fluid type modification factor
P_{wt}	Wall thickness modification factor
P_{pig}	In-line inspection modification
P_{IC} –	Proportion of internal corrosion events – dependent on fluid type
P_{EC}	Proportion of external corrosion events – dependent on fluid type
P_{CT}	Coating type modification factor – applicable only to external corrosion
P_{CP}	Cathodic Protection modification factor
F_{SCC}	Stress Corrosion Cracking frequency – added if pipeline is vulnerable to such events

4.3.6 Consequence analysis

Consequence analysis involved assessing the effects of accidents in order to determine the severity of pipeline failure. Using historic data, the consequence of LOC was assessed at this stage. This included: ignition frequencies; fatality; volume loses; financial loses; and environmental damage.

4.3.7 Risk estimation.

Generally, individual risk (*IR*) and societal risk (*SR*) are used to describe risk (Ma *et al.*, 2013). Ma *et al.* (2013) defined IR at a specified location of individual risk value (x, y) as:

$$\boldsymbol{IR(x,y) = \sum_i \quad \sum_Q \int_{1-}^{1+} F_i \, . \, p_{ci}\,(x,y)dL} \tag{4.8}$$

where the subscript *i* denotes the accident event, F_i is the failure frequency per unit length of the pipeline associated with the accident event *i*, *L* the pipeline length, P_{ci} the probability of casualty associated with the accident event *i* and l± represents the ends of the interacting section of the pipeline in which an accident pose hazard to the specified location (x, y) as shown in figure 4-3.

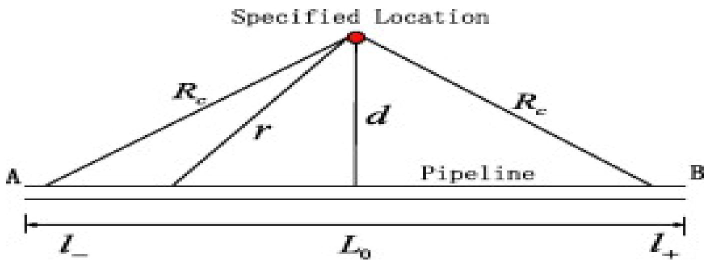


Fig. 4-3. Individual risk geometric model. Source, Jo and Bum (2005).

Calculating the individual risk value along a pipeline length at a particular location is important in assessing the consequence of an accident event involving interdictors. This is because interdiction or sabotage of pipeline will usually occur at a point within the interactive risk geometry of the pipeline. Consequently, based on either delay ignition (within 30 sec) or immediate ignition period, the resultant consequence will vary. The interaction distance can be multiplied by the pipeline failure frequency (*F*), the probability of ignition (P_{ign}) and the consequences (lethality P_c) to obtain the risk at any distance from the various points of release (steps on interactive length) *j* (BS PD8010-3, 2013).This means that individual risk can also be given as:

$$\boldsymbol{IR(x,y) = \sum_{j=1}^{n} \left(F \, . \, dL \, . \, p_{ign} \cdot p_c\right)_j} \tag{4.9}$$

4.4 Pipeline risk assessment result and discussion

4.4.1 Failure frequency and causal factors

Table 4-3 shows the pipelines within each distribution region, the length of the lines, number of reported failures from year 2000 to 2012 and the computed failure frequency per Km year.

Gombe region recorded the highest value of 3.17 failure per km year in 2011. This means in that year, NNPC reported an approximately 3 incidents of pipeline failure per km within that region. In absolute term, the pipeline systems within Port-Harcourt region recorded the highest number of failure (2091) in 2006 but with a relatively lower failure per km year.

The 13 years mean value of failure per km-year across the entire NNPC-PPMC pipeline network stance at 0.351 per km-year. This rate is very high compared to failure rate from other data base such as: the Oil Company European Organisation for Environment Health and Safety (CONCAWE) with a computed failure rate of 0.54×10^{-3} and 0.24×10^{-3} per km-yr from 1971 to 2011 and 2007 to 2011 respectively; UKOPA with failure rate of 0.23×10^{-3} per km-yr from 1962 to 2012; and US with failure rate of 0.135×10^{-3} per km year from 1994 to 2012 (see Table 4-4).

These exponential differences may be as a result of the problems of vandals and interdictors within the pipeline systems in Nigeria. Notably, pipeline systems in the UK and US have also reported incidents of interdiction and sabotage (Anifowose *et al.*, 2012; Ambituuni *et al.*, 2015b), however, failure frequencies in these countries remain relatively low. Moreover, even when the data from interdiction was excluded from the analysis, failure frequency of the Nigerian pipelines is higher (7.57×10^{-3}) than what is obtainable in UK (0.23×10^{-3}) and the US (0.135×10^{-3}). Perhaps, the integrity of the pipeline materials (e.g. steel grade, cathodic protection) may have deteriorated by the high number of hits on the pipelines especially if the repairs afterwards is not done to good standards, thereby exposing the pipelines to threats such as corrosion and fatigue.

As the failure frequency analysis revealed interdiction and sabotage as the major failure incident causal factor, there is a need to explore and understand the reason interdiction is recorded as the major causal factor.

Table 4-3. Number of reported failure incidents (F) per year (2000 to 2012) and failure rate per km-year (F/L)

Regions	L (KM)	F 00	F/L	F 01	F/L	F 02	F/L	F 03	F/L	F 04	F/L	F 05	F/L	F 06	F/L	F 07	F/L	F 08	F/L	F 09	F/L	F 10	F/L	F 11	F/L	F 12	F/L
PH	1526.6	823	0.54	382	0.25	445	0.29	624	0.41	429	0.28	1017	0.67	2091	1.37	1631	1.07	551	0.36	382	0.25	142	0.09	336	0.22	393	0.26
WR	1561.2	242	0.16	51	0.03	30	0.02	104	0.07	266	0.17	769	0.49	662	0.42	306	0.20	745	0.48	280	0.18	161	0.10	548	0.35	495	0.32
MS	512.6	53	0.10	46	0.09	56	0.11	78	0.15	152	0.30	209	0.41	486	0.95	479	0.93	530	1.03	609	1.19	191	0.37	49	0.10	481	0.94
KD	1132.8	3	0.00	8	0.01	7	0.01	20	0.02	122	0.11	243	0.21	176	0.16	126	0.11	129	0.11	123	0.11	255	0.23	585	0.52	646	0.57
GB	267.8	0	0.00	0	0.00	4	0.01	1	0.00	2	0.01	20	0.07	268	1.00	702	2.62	357	1.33	86	0.32	111	0.41	850	3.17	241	0.90

Table 4-4. Comparison of failure data

Source	Period	Failure Frequency (per km-years)
US	1994 – 2012	0.135×10^{-3}
	1970 – 2010	0.351×10^{-3}
EGIG	1970 – 2010	0.162×10^{-3}
	2006 – 2012	0.227×10^{-3}
UKOPA	1962 – 2012	0.227×10^{-3}
	2008 – 2012	0.122×10^{-3}
CONCAWE	1971 – 2011	0.52×10^{-3}
	2007 – 2011	0.24×10^{-3}
NNPC-PPMC	2000 – 2012	0.351

4.4.2 Failure causal factors

Equation. 4-4 gives the formula for computing failure frequency classification based on causal factors. National failure data from 2000 to 2012 is represented in table 4-5. Based on the data analysis, F_{NH} = 0. The data limited failure causal classification to two types. i.e:

1. Failure due to interdiction F_{IN} – defined as the deliberate or intentional act of destruction on a system such as transport pipeline (Church *et al.*, 2004; Anifowose *et al.*, 2011). This failure classification is believed to be a combination of failure from third party damage (F_{TPD}) and F_{IN}, and,
2. Failure due to rupture which is believed to be a combination of F_{MF} and F_{CO}.

As expected F_{IN} is the largest contributory factor. This failure causal factor has a mean contributory value of 96.49% of the pipeline failure while failure from rupture (i.e. F_{MF} and F_{CO}) accounts for 3.51%.

Care needs to be taken in interpreting this result as it does not give in-depth details of causal factors. For instance the term 'rupture' was given as a failure cause in the obtained reports without regards to its actual technical definition.

Table 4-5. Yearly % failure contributory factors

Year	Absolute F(Interdiction)	F(in)% Contribution	Absolute F(Rup)	F(Rup) % contribution
2000	984	87.78	137	12.22
2001	461	94.66	26	5.34
2002	516	95.20	26	4.80
2003	779	94.20	48	5.80
2004	895	92.17	76	7.83
2005	2237	99.07	21	0.93
2006	3674	99.76	9	0.24
2007	3224	99.38	20	0.62
2008	2285	98.58	33	1.42
2009	1453	98.18	27	1.82
2010	836	97.21	24	2.79
2011	2768	99.32	19	0.68
2012	2230	98.85	26	1.15

F_{IN} has assumed various dimensions within the Nigerian oil and gas industry. Consequently, various terms such as oil bunkering, oil theft, pipeline vandalism, fuel scooping (see figure 4-4), pipeline sabotage and oil terrorism has been used to describe the act of illegal break into pipelines (Onuoha, 2007; Onuoha, 2008; Anifowose *et al.*, 2012). Onuoha (2008) asserted the roles of actors such as cult leaders, politicians, corrupt government officials, serving and retired security agents, shipping lines, international oil dealers and youths to include the act of puncturing pipelines, as well as providing security during theft, transport and distribution of petroleum products to black market.

As stated earlier, the problem of interdiction is not only unique to Nigeria as pipeline interdictions have been reported in many countries, including Indonesia, US, UK, Canada, Iran and Iraq (John *et al.*, 2001; Davies *et al.*, 2009); Russia and Former Soviet Union (ESMAP, 2003); Columbia and Saudi Arabia (Lia and Kjok, 2004). These countries treat interdiction and sabotage in in the context of crime. In many cases, these attacks resulted in substantial spills in sensitive locations hard to reach for facility operators to repair. Also, response efforts may be prevented by communities or militants according to (Fabiyi, 2008).

Figure 4-4: Petroleum scooping from a vandalised product pipeline in Nigeria (source: Bala-Gbogbo, 2010)

The trend of product pipeline interdiction has evolved in the recent years in three dimensions. This includes:

i. Increase in the frequency of attack on pipelines across all the distribution regions.

ii. Increase in sophistication in the technology used including the use of funnels, drilling tools and plastic hoses (Onuha, 2007). This is further discussed in Section 4.5.

iii. Links to various national socio-political events.

For instance, table 4-6 and figure 4-5 illustrates 13 years record of percentage change in number of pipeline interdiction per year across the NNPC-PPMC product distribution regions. From these illustrations, records of interdiction revealed some exponential increase in number of interdiction within certain socio-political period. The likely reason for increase between 2004 to 2005 – the largest in absolute terms (across all the regions) have been explained by Anifowose *et al.* (2012).

Table 4-6. % change in interdiction across distribution zones

System/yr	00	01	02	03	04	05	06	07	08	09	10	11	12
PH% Change	0	-48	17	37	-35	157	106	-22	-66	-31	-63	137	17
WR% Change	0	-80	-40	246	168	219	-14	-54	143	-62	-43	240	-10
MS% Change	0	-19	38	75	110	32	147	-4	12	17	-70	-75	941
KD% Change	0	-167	75	-450	-900	-115	26	28	13	9	-140	-138	-9
GB% Change	0	0		-100		1900	1225	165	-49	-76	27	680	-72
Total % Change	0	-53	12	51	15	150	64	-12	-29	-36	-42	231	-19

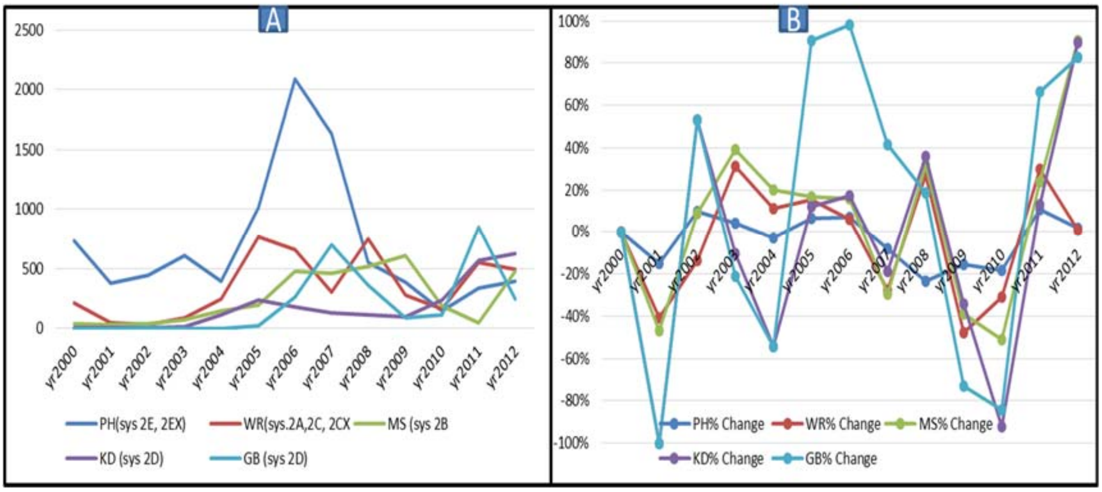


Figure. 4-5. Figure A represents the absolute number of reported interdiction across NNPC distribution zones while figure B represent the % change in interdiction pattern across the region.

The increase was possibly linked to the reported failure to fulfil promises made by politicians to the populace before the 2003 general elections, especially in the Niger Delta. The increase is mostly influenced by the upsurge in interdiction within the Port-Harcourt region (the region recorded a percentage change from -35% in 2004 to 157 % in 2005) which forms part of the Niger-Delta (as seen in Figure 4-5A). The Niger-Delta is replete with historical antecedents of socio-political injustice and failed promises e.g. lack of developmental projects like roads, potable water and health facilities inter.

The drop in national number of reported interdiction within 2006 to 2010 as shown in figure 4-6 may be attributed to the amnesty granted to ex-militants by the Federal Government. The programme appears to have substantially reduced interdiction until 2010. From 2010 to 2011, interdiction increased nationally by 231.10%, making it the highest national percentage increase on record.

2010/11 was the period of the Nigerian general election. Notably, also, interdiction figures appears to rise (in absolute terms) within other periods of general elections in 2003 and 2007. This suggests that, perhaps, politicians are actively using this illegal medium to fund their expensive campaigns, or on the other hand, perhaps, locals use pipeline sabotage as a means of registering their grievance during the election period. Notwithstanding, from these trends, it can be asserted that interdiction and sabotage on pipeline in Nigeria is influenced by socio-political events, hence with this knowledge, security can be enhanced along the pipelines as periods of general elections approach.

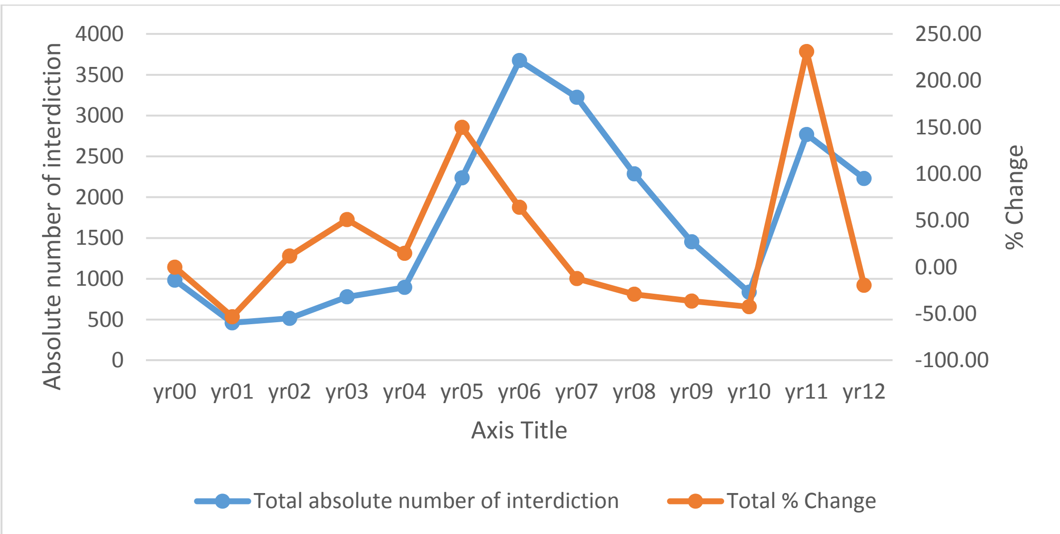


Fig. 4-6. Total National absolute number of interdiction and % change

4.4.3 Assessment of the techniques used by pipeline interdictors

As seen from the discussion in section 4.4.2, interdiction takes different form with involvement of different actors. Interdiction can be an act of sabotage on the pipeline using explosives or other inferno starting techniques. This is mostly used as a means of protest or registering dissatisfaction with the operator or the government. Another form of interdiction involves illegal hot tapping into the pipelines to steal products for personal gains. This section looks at the techniques used by interdictors for hot tapping. Using data from photographs obtain from the operator and interviews, this section explains the techniques used by the interdictors.

Hot tapping technically refers to authorised installation of connections to pipelines while they remain in service. Hot tapping is frequently used in pipeline engineering to repair area(s) that have undergone mechanical damage or corrosion or to add branches for system modifications. Hot tapping is also referred to as line tapping, pressure tapping, pressure cutting, and side cutting (Muhlbauer, 2004).

The level of sophistication used by interdictors can range from simple to very complex techniques. In simple terms, one of the most common techniques used is the use of hacksaw or manual drill or a sharp ended metal bar to cut or drill or puncture the line. This method (shown in figure 4-7 A and B) is mostly used by interdictor who will dig the 0.9m ground cover of the pipelines and a large hole used in containing LOC. They will then puncture, cut or drill into the line and allow the product to leak-out. Afterwards, a mechanical pump is used (see figure 4-7 B) to pump the product into trucks or other means of transportation.

Figure 4-7. Showing the process of product theft by interdictors (Photo credit: NOSDRA)

A more sophisticated technique used by organised criminals is a combination of difference mechanical hot tapping systems. The most popular equipment (shown in figure 4-8) used by this class of interdictors includes a tapping drilling machine, boring bar, branch fittings, and valves.

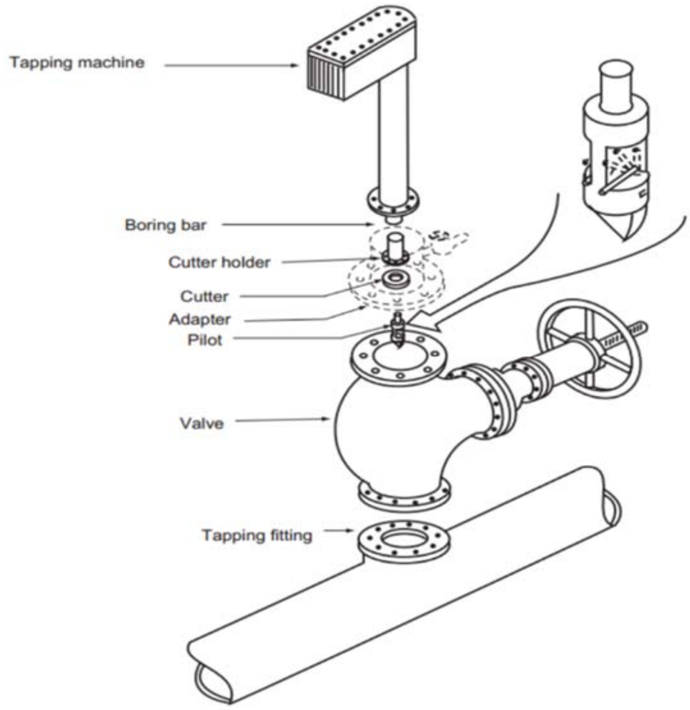


Figure 4-8. A commonly used hot tapping technique

Figure 4-9 shows some illegally hot tapped pipelines. The drilling machine used typically consists of a mechanically driven telescoping boring bar that controls a cutting tool. The cutting tool is used to bore a hole into the pipeline wall in order to centre a hole saw that cuts out a section of pipeline wall. Connection to the pipe is then made within a fitting, which can be a simple welded nipple for small connection to a larger pipeline. Suitable valves such as ball or gate valve is then used to control the flow of products into trucks or other means of transportation. This type of interdiction is usually not a one-off attempt to syphoned products. Based on the operator's assertion, the interdictors will steal from the system, close the valves and cover their tracks, and come back to the spot to steal again.

The hazards and risks associated with illegal hot tapping are enormous. For instance where welds are used for drilling, burn-through can occur when the un-melted area beneath the weld pool is not strong enough to contain the internal pressure of the pipe. Similarly, there exist the risk of ignition from heat (during drilling or cutting) or naked flame in hydrocarbon charged atmosphere. Illegal hot tapping also have vast environmental impacts as interdictor care less about spills and clean-up.

Figure 4-9. Showing unauthorised inserted valves into pipeline (Photo credit A-NOSDRA; B, C and D-PPMC)

4.4.4 Relationship between pipeline failure and quantity of product loss

Pearson correlation of number of reported pipeline failure and quantity of product loss shows a negligible strength of 0.155 (P-value = 0.613). The scatterplot in figure 4-10 also shows no observed pattern between the two variables. Therefore, it appears that there is no relationship between the numbers of reported failure incidents with product loss. This is further illustrated in figure 4-11. As can be seen, in 2005, over 650×10^3 metric tons of petroleum products was reported loss and more than 2200 incidents of pipeline failure was also reported in that year. The number of failure increased to over 3500 (representing over 64% increase) in 2006, however, product loss reduced to over 5300×10^3. Similarly, from 2010 to 2011, failure rate increased by over 230% but product loss reduced from 194.42×10^3 to 157.81×10^3 metric ton representing about -18% decrease.

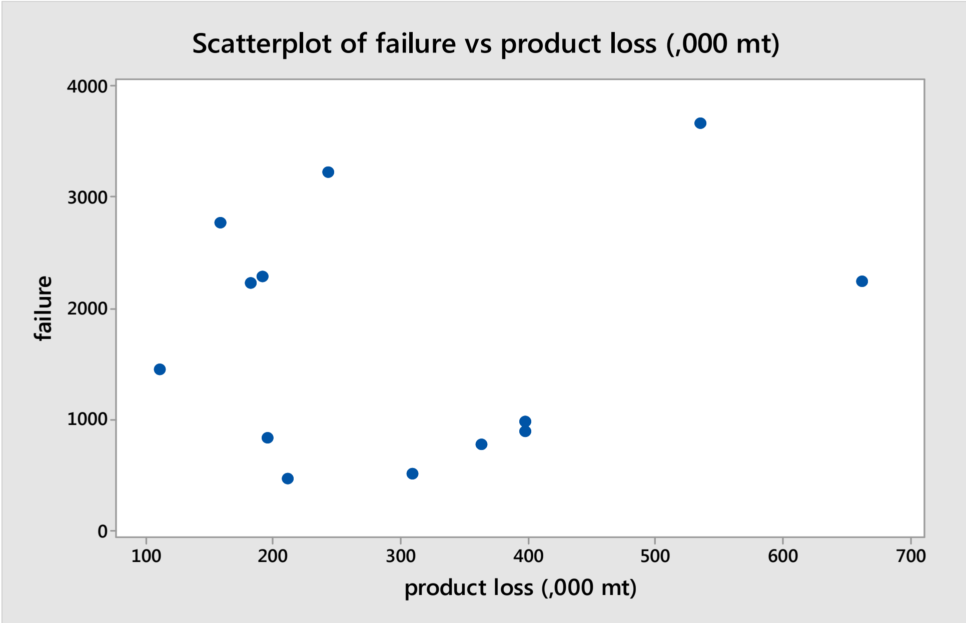
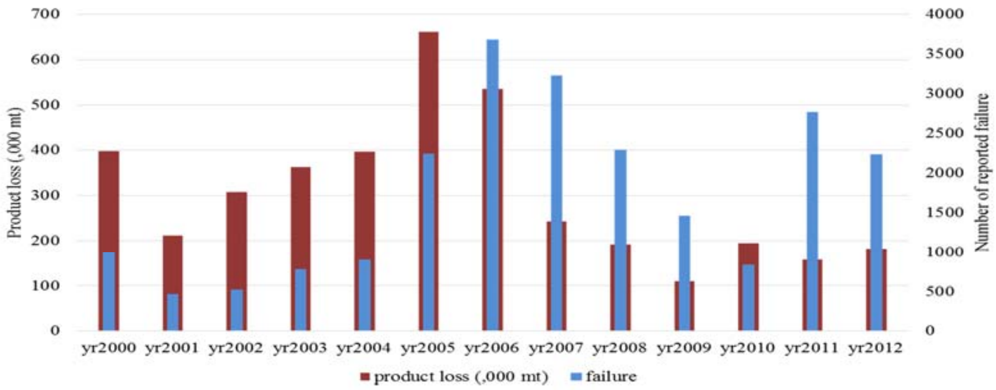


Figure 4-10. Scatterplot showing no observed pattern of relationship between pipeline failure and quantity of product loss



Years	yr2000	yr2001	yr2002	yr2003	yr2004	yr2005	yr2006	yr2007	yr2008	yr2009	yr2010	yr2011	yr2012
failure	984	461	516	779	895	2237	3674	3224	2285	1453	836	2768	2230
product loss (,000 mt)	397.6	211.08	308.24	363.13	396.88	661.81	535.62	242.23	191.62	110.38	194.42	157.81	181.67
Total % Change	0	-53.1504	11.93059	50.96899	14.89089	149.9441	64.23782	-12.2482	-29.1253	-36.4114	-42.4639	231.1005	-19.4364

Figure 4-11. Showing the relationship between numbers of reported pipeline failure incidents and quantity of loss products

4.4.5 Effect of age of pipeline on failure frequency

The pipeline systems are classified into two according to the year of installation i.e. 1978/80 and 1995 categories (see Appendix 2). To determine the effect of aging on failure frequency, relevant failure frequencies associated with their age classification was extracted. System 2DX was used to represent pipelines under the 1995 while the system 2B was used to represent pipelines under the 1978/80 category as all pipelines within the system were installed in 1978/80.

Table 4-7. Pipeline age and mean failure frequency. Note that F(IN) is failure due to interdiction and F(Rup) is failure due to rupture.

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Maximum
F(IN)-2B per km-yr	13	0	0.493	0.119	0.428	0.057	1.180
F(IN)-2DX per km-yr	13	0	0.765	0.296	1.065	0.000	3.208
F(Rup)-2B per km-yr	13	0	0.02011	0.00341	0.01230	0.00390	0.03902
F(Rup)-2DX per km-yr	13	0	0.00203	0.00101	0.00365	0.00000	0.01132

For table 4-7, it can be seen that there is a noticeable difference between failures from interdiction and sabotage across the two age categories. Surprisingly, the newer line (2DX) have a higher hit rate. This reveals that interdictors attack lines irrespective of the age of the pipeline. It is worth mentioning, however, that the high value of interdiction frequency on system 2DX is influenced by an outlier (3.208 per km-year) in 2011. The reason for this high hit rate may be due to the explanation offered in section 4.4.2

As expected, failure due to rupture increased with pipeline age. As can be seen, the failure rate due to rupture for the 1978/80 pipeline category is about 0.02 per km-year, while 0.002 per km-year was computed as the mean failure rate of the 1995 pipeline. Unfortunately, the available data did not permit further analysis to ascertain the precise relationships, i.e. whether the failure is related to time dependent threats, e.g. internal/external corrosion and material fatigue or time independent, e.g. ground movement and incorrect operations. Notwithstanding, this result suggests that stringent integrity based inspection and maintenance schedule needs to be put in place if the 1978/80 pipeline category is to continue running as it has outlived its designed lifespan of 25 years.

4.4.6 Consequence analysis

The consequence of pipeline failure were examined in this section. This consists of determination of the consequences of particular physical effects in hazard zones and the impact on receptors (man and the environment). A hazard zone is the region in which physical effects of the hazard exceeds critical threshold values and induces negative effects (Dziubiński *et al.*, 2006). Consequence intensity depend on many factors including:

ignition frequency, the proximity of receptors (human and environmental elements); the properties and volume of released substance, process conditions and the way of release.

4.4.6.1 Ignition frequencies

Only records from 2007 had causes of ignition. Prior to that, only the number of ignition recorded per year was recorded in the obtained reports. Of the 106 ignition recorded from 2007 to 2012, about three-fourth (see figure 4-12) was as a result of deliberate arson after scooping fuel, unintentional fire as a result of illegal hot tapping or bomb attack. Most of the sources of fire from mechanical faults are not clearly reported. However, one incident was attributed to sudden rupture. Also, sparks from electric overhead cables, bush burning for hunting purposes and construction activities were mostly the source of fire from third part damage. The type of fire caused by these ignitions and the area of impact was not reported.

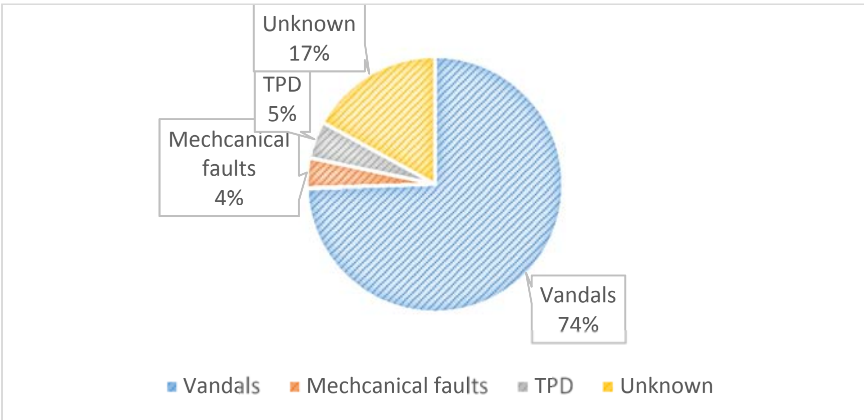


Fig. 4-12. Showing % contribution of ignition causal factors

By dividing the number of ignition cases within each region with the total number of pipeline failure reported in that region, it is possible to compute the ignition frequencies within each distribution region. From table 4-8 it can be seen that Port-Harcourt region (PH), Warri (WR), Mosimi (MS) and Kaduna regions all have ignition per failure incidents within the same range (i.e., about 1 in 50), while Gombe (GB) region recorded the lowest ignition frequency of approximately 1 in 100 per reported failures. There are questions as to the reason why ignition rate is high in PH, WR and MS regions. Perhaps this could be associated to the techniques used for illegal hot tapping, or the flash point of the product involved. However, with this information, emergency response capabilities can be enhanced across the regions. Leak detection and incident response technologies should focus on the high risk regions. This was further discussed in section 4.6

Table 4-8. Ignition frequencies within NNPC-PPMC distribution regions

Regions	Pipeline failure (2000 to 2012)	Fire incidents (2000 to 2012)	Ignition frequency
PH	9246	206	2.23E-02
WR	4659	122	2.62E-02
MS	3419	76	2.22E-02
KD	2443	50	2.05E-02
GB	2642	27	1.02E-02

4.4.6.2 Lethality

The lethality of pipeline failure within each distribution region is illustrated in figure 4-13. No fatality was recorded from pipeline failures in GB and KD regions, while on average, the pipeline systems in PH, WR and MS regions recorded lethality rates of 0.044, 0.071 and 0.38 per km-yr. This lethality rates could be a direct function of the high ignition rate within these regions. Other influencing factors include the proximity of buildings due to high population density in the regions, the flash point of the product involved as well as the incident response time and access. However, surprisingly, KD region recorded no fatality even though the ignition frequency in that region is similar to ignition frequencies in PH, WR and MS. This suggests that other influencing factors (as discovered during the pipeline right of way inspection) may include the proximity of buildings to the pipelines, incident response time, ease of access to incident sites, as well as the flash point of the product involved.

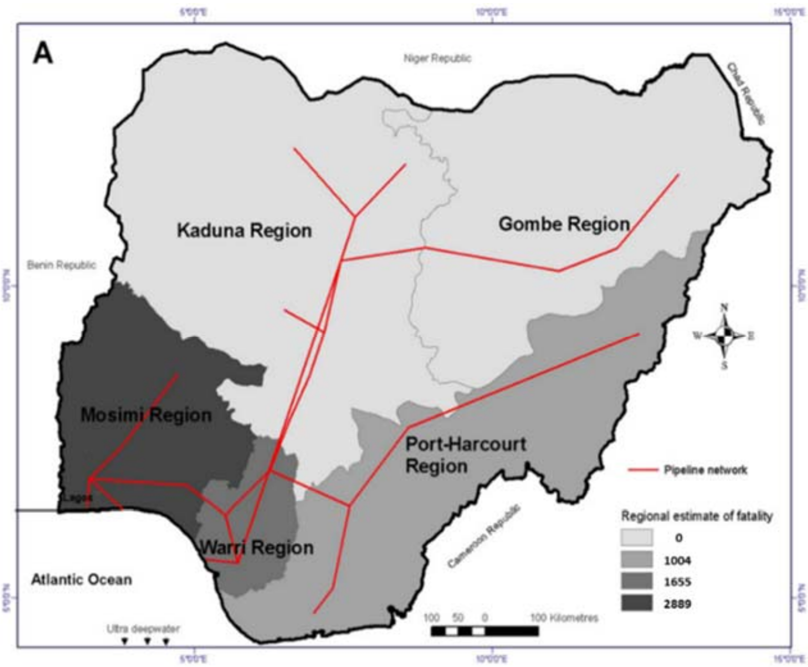


Fig. 4-13. Fatality from 1998 to 2012 within regions. Updating from Anifowose et al. (2012)

4.4.6.3 Quantity of product loss and financial value

The data representing the quantity of product loss was extracted from the NNPC-PPMC reports and illustrated in table 4-9. It is not clear whether the missing data from the table means that no product was loss or reported loss in that year, or whether it is the case of missing information as failure incidents were reported in those years. Notwithstanding, the scale of problem can be seen in financial terms in figure 4-14. From the figure, the spike in 2003/04, 2005/06, 2007/08 and 2011-2012 may be related to the political issues discussed in section 4.4.2. On average the operator loses about 100 million USD per year. This value does not even considers cost associated to payment of compensation, fines, environmental clean ups, litigation, etc.

Table 4-9. Quantity of product loss

Region/	Product loss (10^3mt)												
yr	00	01	02	03	04	05	06	07	08	09	10	11	12
PH	320	133	222	226	150	337	336	96	151	-	-	-	5
WR	17	31	12	28	73	145	16	-	22	-	46	14	0
MS	55	45	71	109	157	146	183	142	13	111	145	127	163
KD	4.30	2.20	2.63	0.02	3.16	16.6	-	5.10	5.13	-	3.99	16.06	13.06
GB	1.50	0.78	0.62	0.14	13.1	16.6	-	-	-	-	-	-	-

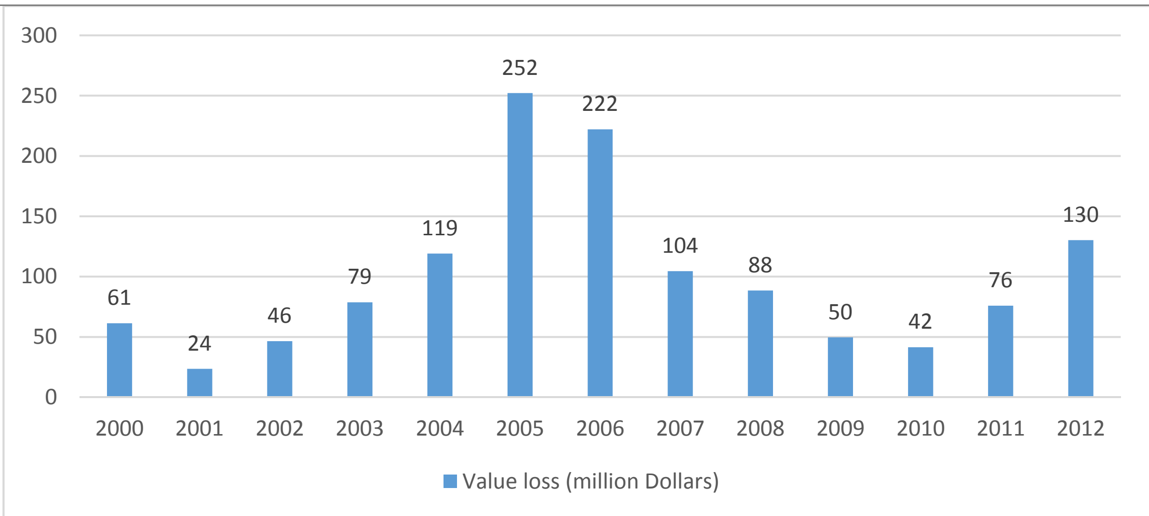


Fig. 4-14. Dollar value of product loss: Note, Mean value of value loss per year =100 million Dollars.

4.4.7 Individual risk based on historic data

Figure 4-15 illustrates the computed IR associated with the section of the pipeline inspected. The figure also illustrates the IR limits established by BSI BS PD8010-3 (2013). As there is no defined acceptable risk limits in Nigeria, the BSI limits was used because of its general appropriateness within the global pipeline industry best practices.

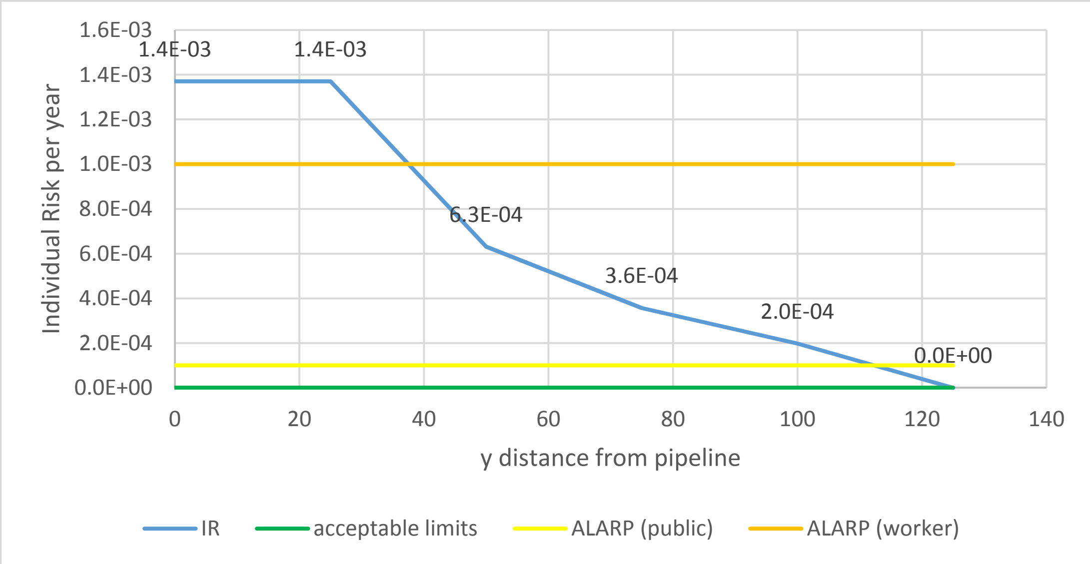


Fig. 4-15. Pipeline IR values

At about 40 m from the pipeline, the IR value is not within the BSI PD tolerable limits. Above 40 m the IR value is tolerable if the risk is ALARP (see Appendix 2 for detail IR calculations). The ROW inspection conducted revealed that in many cases buildings and other public infrastructures are located less than a meter from the pipeline and there are visible traces of activities of vandals. This may be the reason for the high fatality rates recorded. This affects the IR values along the pipeline. IR information was later used in developing the risk mitigation strategies in section 4.6.

Large scale accident such as pipeline failure raises questions of responsibility for safety and public accountability in a way that accidents to individuals do not. This requires consideration for societal risk (SR) calculations. Whilst IR gives the probability of dying on a certain location, IR is insensitive to the number of individuals present. SR gives a risk value for a whole area, no matter precisely where the harm occurs within that area. SR value will be important in demonstrating how the framework integrates consideration for social protection to include prevention, mitigation, and coping strategies to protect basic livelihoods and promote risk taking.

As shown in figure 4-16 below while the values of individual risk remains the same in scenarios A and B, the values to societal risk will not be the same due to the fact that the number of lives involved has increase in scenario B. For this reason, SR_A is less than SR_B. An individual is obviously not exposed to the threat from the entire length of a multiple-km pipeline simultaneously. Individual maximum exposure occurs if s/he is exposed to the pipeline 24 hours of every day. The farther s/he moves from the pipeline, the lower the IR due to deceased exposure. At a point IR will be zero or tolerable for that person. However, the societal risk within that persons point of origin remains and may even be intolerable especially if there are other individual present within the pipeline risk exposure contour (as SR increases with exposure time and proximity). And except every person moves out of the contour, there will be an associated SR value.

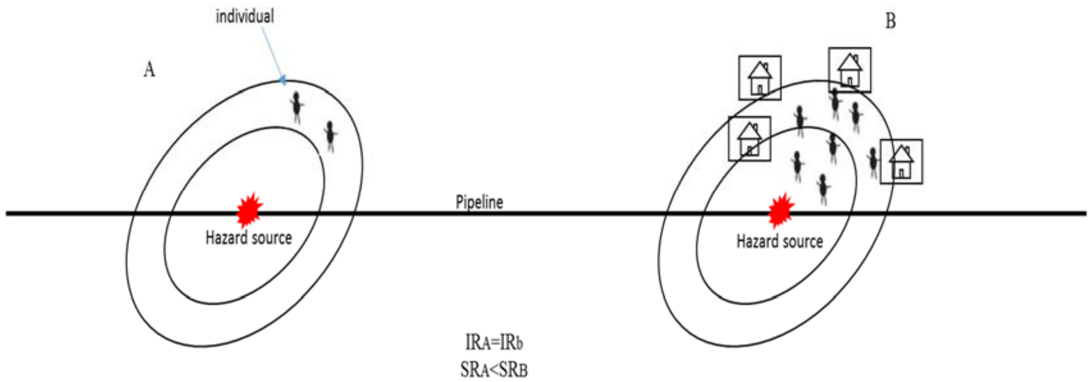


Figure 4-16. Implication of SR compared to IR

From figure 2-6 it can be seen that SR is represented as an F-N curve. The graph plots the expected annual frequency (F) of the number (N or more) of casualties in the whole surrounding area arising from all possible dangerous incidents at a hypothetical hazardous location. SR can be given as F x N^a. where *a* is the aversion factor.

The slope of the SR criterion (when plotted on a log-log basis) can also be used to represent the degree of aversion to multi-fatality events embodied in the criterion. Based on the requirement of PD8010-3, when the F-N curve slope is equal to -1, the risk criterion is termed 'risk neutral.' A risk criterion for which the curve slope is more negative than -1 is said to be more risk averse; in other words, the risk criterion reflects a greater concern for scenarios causing larger numbers of fatalities.

For this study it was unfortunately not possible to determine the values of societal risk on the pipeline due to limitation in research resources. However, IR value was used in recommending risk mitigation strategy. The implication of not having a SR value is such that the study is limited in its development of strategies for communicating risk aversion within a specified SR contour. It also limits the ability to demonstrate how SR risk criteria can be used in finding solutions to land use issues.

4.5 Mapping pipeline accident/incident causal factors

The risk associated with the Nigerian petroleum product pipelines was assessed (in Section 4.3 and 4.4) using historic and site specific data.

The failure frequency of the pipelines was found to be extremely high (0.351 per km-yr) when compared to failure frequencies of international pipelines (e.g., the UK and USA). This is mainly due to pipeline interdiction. Consequently, the ignition frequencies, fatality, and product losses from the Nigerian pipelines are found to be high. This ultimately made the values of Individual Risk for these pipelines to fall outside tolerable limits.

This section explores the “faults” within the holistic pipeline socio-technical complex systems and how theses faults “line up” or interact to cause pipeline accidents/incidents.

Pipeline operate under a combination of complex systems including: organisational systems, regulatory systems, operating systems, etc. these complex socio-technical systems comprise of a hierarchy of actors, individuals and organisation. Their interaction can also result in intangible faults at various levels (Rasmussen, 1997). These latent faults were explored using thematic cross-content analysis of semi structured interviews with stakeholders, results of ROW inspection and information from the risk assessment conducted in section 4.3 and 4.4 above.

The analysis was done using AcciMap but also integrates the Swiss Cheese concept discussed in Chapter 2. This provided a basis for discussing the complexity of accident/incident as the notion of latent factors simply cannot be reconciled with the simple idea of a causal series, but requires a more complex interaction of a causal network.

The result of the analysis is shown in Figure 4-17. From the figure, two component of pipeline risk were explored. The first component shows faults and casual factors while the second illustrates the reasons why pipeline failure records high consequences.

4.5.1 Hierarchical multi-barrier failure causes

The first failure-causal theme explores governmental and regulatory issues. At both levels, the limitations in the regulatory framework of the pipeline is attributed to government’s sole involvement in the operations and regulations of the pipelines. The regulator (DPR) appears to be deliberately weaken as they equally receive administrative directives from the Minister of Petroleum Resources whom also gives directive to the operator (as illustrated by interview citation below).

> *"There was a time when DPR was buried right inside NNPC, at that time it was just a small office in Lagos, their salaries, and everything was together…so, I am sure once DPR steps-in by attempting to be strict, some people will tap them on the shoulder and say: hey slow it down. This oil is getting Nigeria about 80% of its income, so we don't want any hustle" (NNPC interviewee, 24th July, 2013).*

This strategic organisational misalignment indirectly gives more powers to the operator as they fail to adhere to best pipeline industry practices. The cited interview above also shows how the national interest vested on the petroleum industry downplays safety priorities. This may also be the reason why even with the exclusion of interdiction data, the failure frequency of the pipelines remains considerably high.

Strategic misalignment of agencies and regulators also explains the reason why there is evidence of conflict of regulatory interests (Ambituuni *et al.*, 2014) at both State and Federal governmental levels. From the perspective of the limitation of laws, it is evident that the construction of the pipelines by the government (PPMC) took no consideration of the host communities and, over the years, this has become a point of grievance. Both the operator and community leaders agreed that the pipeline was constructed without proper Environmental and Social Impact Assessment (ESIA). The locals are agreeved that their ancestral lands are being used without any form of benefit. This, therefore, leads to in vandalisation of the facility to register their grievances or turning blind eyes on the activities of interdictors. Some even see the existence of the pipeline as a curse as spills pollute their means of living including farmlands and fishing waters.

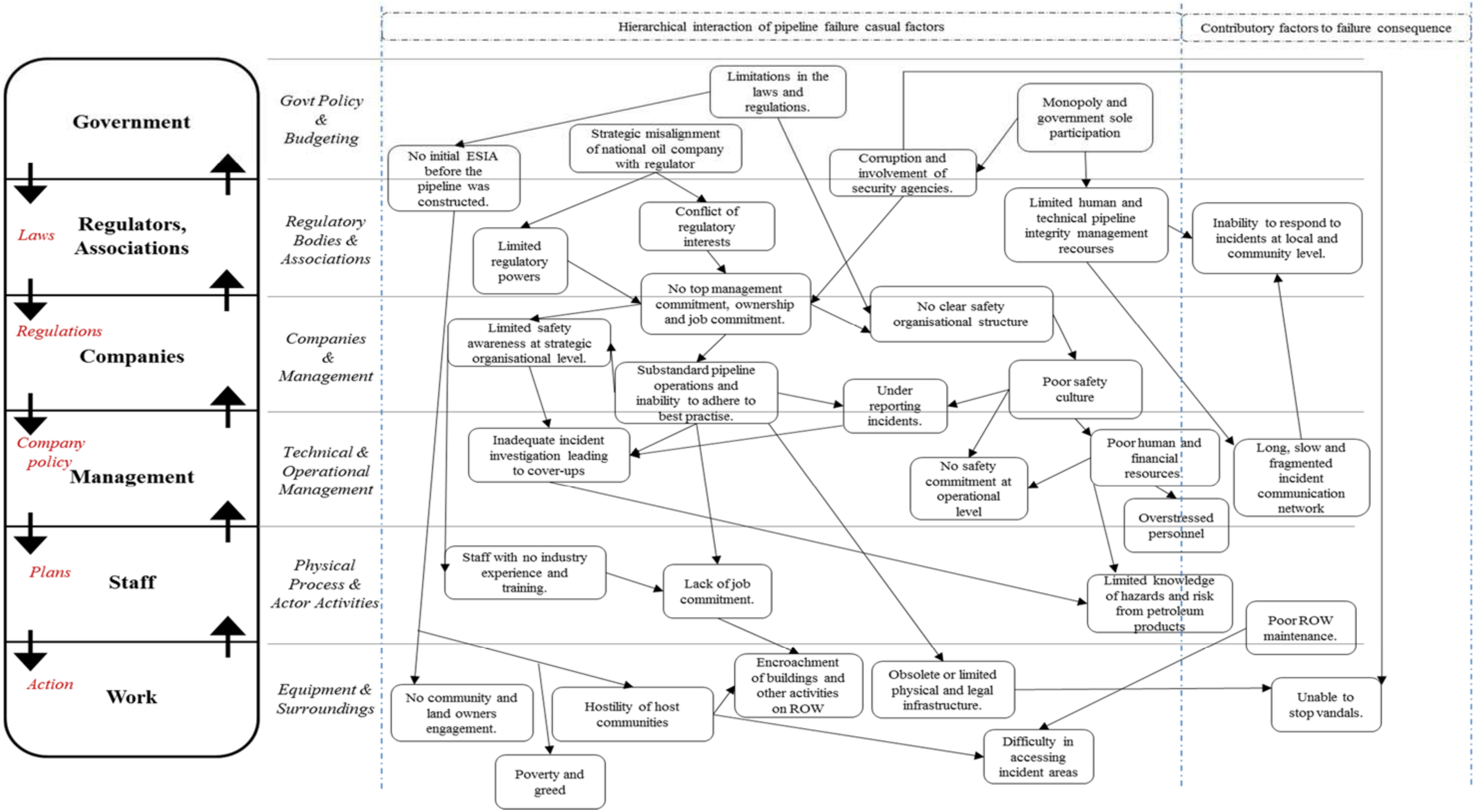


Figure 4-17. AcciMap showing the interaction of pipeline failure causal factors and factors contributing to elevated failure impact

Deduction from this synthesis should, therefore, trigger planning implications such that the operator and communities must share legitimate safety and environmental concerns about the pipelines and ROW condition. An Environmental and Social Impact Assessment (ESIA) should be performed along the pipeline ROW. The assessment should critically engage locals and possibly empower them via royalty payment arrangements. This is further discussed in section 4.6.2

The next failure causation theme explores faults at company (PPMC) level, not surprising, issues such as poor safety culture and limited safety awareness came top of the list. These issues can be traced to the lack of top management commitment as even the operator admits the inadequacy in their safety organisational structure. When asked about their organisational challenges, the responders replied:

"Almost every aspect of implementing the Health Safety and Environmental Management System, there is a challenge for us….The (organisational) structure: there is also a problem there." (PPMC interviewee, 26th July, 2013).

"The major challenges we have is the structural position of the HSE department. If you look that the organisational structure of HSE department in Shell or other multinational oil and gas company, the position of the HSE department is a direct link to the CEO of such organisations. It is not the case in NNPC…" (NNPC interviewee, 24th July, 2013).

This lack of commitment gives rise to poor safety culture and constrains allocation of resource (human and financial) which also limits the technical know-how of maintaining and optimising the performance of the pipelines.

The last theme cluster identified issues associated with operational and technical level and the pipeline operating environment. For instance, the PPMC laments that its ROW maintenance staff are stressed and sometimes inexperienced and this makes it practically impossible to effectively patrol the ROW.

"Go and check…Is there any part of the world where you have over 5000 Km of pipelines and the number of people maintaining it is less

than 100? Will they be able to go round and ensure that it is safe? There is even no funds to do the job." (PPMC interviewee, 26th July, 2013).

Table 4-10. Findings from risk based inspection of ROW

ROW Condition	Description
Evidence of spills or discharge from pipeline	No active leaks or spills were detected. However, there were about 3 spotted evidence of spills, possibly from past incidents as shown in Figure.4-18A. There are also vast areas of oil films on both land and water around Ijegun area. The researcher found no evidence of clean-up activities within that location. In one location, close to Onilu Village, the vegetation is vastly burnt (see Figure.4-18B), possibly from a fire incident from spilled product. In Dec 2012, NNPC reported a fire within the Mosimi region. Onilu village is located within this region.
Forest encroachment on ROW	While some sections of the ROW along country-sides remain clear, some sections alone Amuwo Odofin and Ije Ododo area are completely overgrown by grasses and trees. Also there are evidence of farming activities, timbering and excavation alone the ROW in Ije Ododo area. A section of the pipeline right of way is now used as access road, popularly called "the pipeline road" by the locals
Encroachment of development	A more disturbing aspect of the ROW condition is the indiscriminate and uncontrolled developments of buildings and roads on the ROW especially within Amuwo Odofin area, Ije-Ododo area, and Ijegu area. In some cases, shops and residential buildings are located less than a metre away from the pipeline markers which suggested that such development are sadly located on the ROW.
Blasting within distance that could impact the pipeline	No evidence of blasting or mining activities were detected
Damage to pipeline makers and signage	At various locations around the Ijegu area, pipeline markers have been found either damaged, blocked with overgrown vegetation or worn-out and unreadable (see Figure.4-18C)
Exposure of pipeline	While no evidence of pipeline exposure was found, there is evidence of deliberate attempts to dig up and expose pipeline for pilferage (see Figure.4-18D).
Active act of interdiction	The researcher did not experience any active act of interdiction within the inspected area. However, evidence in the form of pictures were given by the ROW department of PPMC.

This links back to the issues of management commitment. A more disturbing issue identified within this theme is that even when pipeline accident happen, investigations are tempered with and sometime there are clear traces of cover-ups even at strategic level. Surely, this will not allow the industry to learn from mistakes and past incidents. Hence, with this bad practice, the system can only be expected to decay further.

Failure in the pipeline may also be attributed to issues related to poor maintenance of the pipeline ROW. The condition of the ROW is an important factor in understanding the degree of control the operator has in maintaining good industry practice and avoiding third party interference. ROW condition also influences incident impact on safety and environment based on proximity of receptors and accessibility for emergency response. In table 4-10, the key findings from the risk based inspection are illustrated.

From the inspection result, there is an obvious case of inadequate maintenance of the pipeline right of way. There are issues with encrouchement of buildings. This situation may increase the vulnerability of the pipeline to threats from third party activities and also the consequences of failure as close proximity to pipeline increase the values of Individual and Societal Risks of the pipelines. Incident response can also be constrained by the proximity of buildings to ROW. The operator however, claimed, that it has became difficult to maintain the ROW (as shown the the following citation) due to the hostile attitute of host communities.

"Sometime when we hear about a break in our line, we get there, and the community will not allow us access the line. In some cases they tell us to pay access fee, or to pay for compensation before fixing it".
(PPMC interviewee, 26th July, 2013).

Lack of contextual pipeline regulatory codes affects the regulators ability to deploy and adhere to best practice operational and technical procedures. Consequently, the PPMC operates with obsolete technology with implications for the safety performance of the pipelines.

Moreover, poor technical capabilities generated as a result of poor adherence to standards meant that PPMC is unable to employ and retain staff with the required experience and skills. Again, this may have negative implication for the quality of maintenance operation on the pipelines. For instance, if the cathodic protection of a section of the pipeline gets damage from interdiction and the maintenance of the pipeline is not properly done (due to lack of skills), the external wall of the pipeline will be exposed to the threat of corrosion. This will *further reduce the integrity of the pipeline and subsequently result in another failure.*

A: Polluted vegetation showing evidence of spills or leaks from inspected pipeline

B: Showing vast burnt vegetation possibly from fire incident involving petroleum product spill from pipeline

C: Showing the condition of pipeline marker

D: Showing evidence of attempt to dig up pipeline by interdictor (source PPMC-NNPC)

Figure 4-18. Condition of sample pipeline ROW

4.5.2 Relationship between latent conditions and failure in pipeline accident prevention barriers

In all, the discussed latent conditions are present within the pipeline system. The influence of these factors gives rise to multiple failure and accident causation. Active events such as interdiction on the pipeline although seen from the risk assessment results in 4.6 as the immediate cause of most failures are in fact a manifestation of interactions between latent causes within the socio-technical operating structure of the pipeline.

The latent conditions identified such as organisational and regulatory issues, lack of human and technical capabilities, limited safety commitment, poor safety culture, obsolete technologies, and inappropriate ROW acquisition and maintenance have rendered accident prevention barriers ineffective within the entire pipeline systems in three ways. First, lack of barriers or existence of weak barriers such that the preventive measures required are either missing or ineffective. These missing or weakened barriers are both in the form of physical and procedural conditions. For example, from the physical perspective, the encroachment of buildings and other infrastructures into the ROW has weakened the “barrier” in the form of buffer zone which is required to restrict the activities of third parties by reducing their proximity to the pipeline. Similarly, issues related to regulation of the operator also present procedural weakness and effectual operational and maintenance regulation. Second, the latent conditions also limits the availability of resources so that necessary means to counter or neutralise pipeline failure is missing. Lastly, precarious conditions are also generated from these latent conditions such that small active failure results in high consequence accident due to inappropriate response and spill clean-up strategies. This will be further discussed in section 4.5.3 below.

There is also a likely link between people’s safety behaviour and their quest to fulfil the five basic needs: physiological, safety, social, esteem and self-actualization as suggested by Maslow’s theory (King, 2009). These needs can create internal pressures that can influence a person's behaviour. The need for attaining ones physiological needs required for human survival such as food, and shelter may influence people living in poverty prone communities to engage in pipeline sabotage.

Similarly the complete lack of interface with host communities suggests that individuals lack knowledge on the risk and hazards associated with the pipeline. This results in unbalance risk perception. As defined in Laboy-Nieves *et al.* (2010) individual learns about the rules governing behaviour through social interaction. The host community feel that their safety is compromised by the presence of the pipeline asset and this hierarchical need must to be addressed by the PPMC which must encourage the development and education on safety and risk. Without this knowledge, a satisfactory organisational approach to people management or safety management is not possible. This will form part of the key recommendation for risk mitigation.

However, risk knowledge alone will not be the ultimate solution because when people perceive that their safety is compromised by the risk at hand, risk communication will not be possible until the need is satisfied (Branstrom and Brandberg, 2010). Currently, evidence revealed that the actual benefit of pipeline risk is out of the context of perceived benefit as communities are deprived of the opportunity to make decision having a real view of the risk. Therefore, it is necessary to refashion and reduced the pipeline risk to ALARP levels with the involvement of key stakeholders in order to make effective communication which should not be aimed at changing perception in a false way, but demonstrating how the pipeline risks are reduced to ALAP levels.

4.5.3 Factors contributing to high consequences

Having established how various faults within the complex socio-technical systems of pipeline operation interact and results in pipeline failure, the reasons why such failure usually record high consequences are further explored in this section.

4.5.3.1 Incident response capabilities

A number of factors are responsible for poor incident response. This include lack of responses capabilities at community and local levels. First responders such as the local fire services are constrained by lack of infrastructure and limited human and financial resources. This has resulted in a system where incidents are mostly responded to by federal responders (e.g. NEMA). These federal responders are mostly stationed in large cities hundreds of miles away from incidents spots. As a result, incident communication and response is often slow, fragmented and laden with long bureaucratic processes.

Furthermore, federal responder are often unfamiliar with the local environment. This also affects accessibility to incident sites as indicated by a NEMA interviewee.

> *"…if an incident happen in a remote village, and I am called upon, I will go, I will do my best but I cannot be efficient. I can be effective but not efficient. But you see the man that is there (in the village), that grew-up in there, that know the short cuts to all the locations and where each house is, will be more efficient. But if left for me to handle, even if you tell me now to move, and I jump into my helicopter and start moving, it will still take me hours before I get there" (NEMA interviewee 15th, June, 2013).*

A typical example of how these faults unfolded a disaster involving product pipeline is the case of 1998 Jesse fire disaster in Delta State, Nigeria. A leak was noticed on Friday 16th, Oct from a 16 inch petrol pipeline. The leak was not attended to and villagers trooped out to scoop the leaking fuel. On Saturday 17th Oct, a large explosion occurred on the site killing over 1500 people including women and children. Habitually, such isolated rural communities are poorly prepared for such incidents, lacking the experience, equipment, and personnel required to respond to spill emergencies (Aprioku, 2003).

Further complicating the picture in rural areas is that populations typically are isolated and transportation networks are not well developed. Corruption, social inequalities and cutbacks in public services in parts of rural Nigeria make it even more unlikely that many rural communities will be capable of sponsoring improvements in emergency management.

Even with the existence of a federal legislation in Nigeria that mandates all communities to develop emergency response plans regarding spills (Ambituuni *et al.*, 2014), it remains unclear how effective rural communities will carry out the federal mandate without federal financial support. Community response capabilities therefore needs to be improved with collaboration from both state and federal governments and the pipeline operator, especially in known incident hot spots.

4.5.3.2 Poor knowledge of risks and hazards

There are also issues related to people's lack of knowledge of the risks and hazards from product release. Some people within the host communities are not aware that petroleum products have flash points – defined as the lowest temperature at which a liquid (usually a petroleum product) will form a vapour in the air near its surface that will "flash," or briefly ignite, on exposure to an open flame. As a result, they engage in risky activities such as scooping petroleum products from failed pipelines or even coming out to look as products leaks out.

> *"Our people don't know the danger of this fuel. They think fuel is just like the water they fetch from the river or their wells. They hear of fuel, fuel, fuel, fuel, so when a leak occurred, they logically went to take a look at it." (Community leader, 18/06/2014).*

This lack of risk knowledge also makes people to encroach into pipeline ROW with buildings and other construction and farming activities. There is, therefore, a need for effective risk communication at community level.

4.6 Framework for pipeline risk management in Nigeria

Notably, the primary issues regarding the poor safety performance of the pipelines and the problems of interdiction are socio-economic and political in nature. Therefore, a top priority in the proposed risk management framework is the engagement of communities along the ROW of the pipeline. The aim of the framework is to integrate activities that will improve legislation, enhance pipeline inspection and vigilance and engage communities in formulating risk management recommendations and deploying actions. Figure 4-19 illustrates the key actors within the framework and the lines of communication via which regulation and operation of the pipelines can be enhanced. The figure also shows the line-up of risk mitigation activities required, starting from the need for a detailed ESIA, public awareness and risk communication, strategies for surveillance, involvement of local response agencies and some pipeline technologies that can be used for optimising the integrity profile of the pipelines.

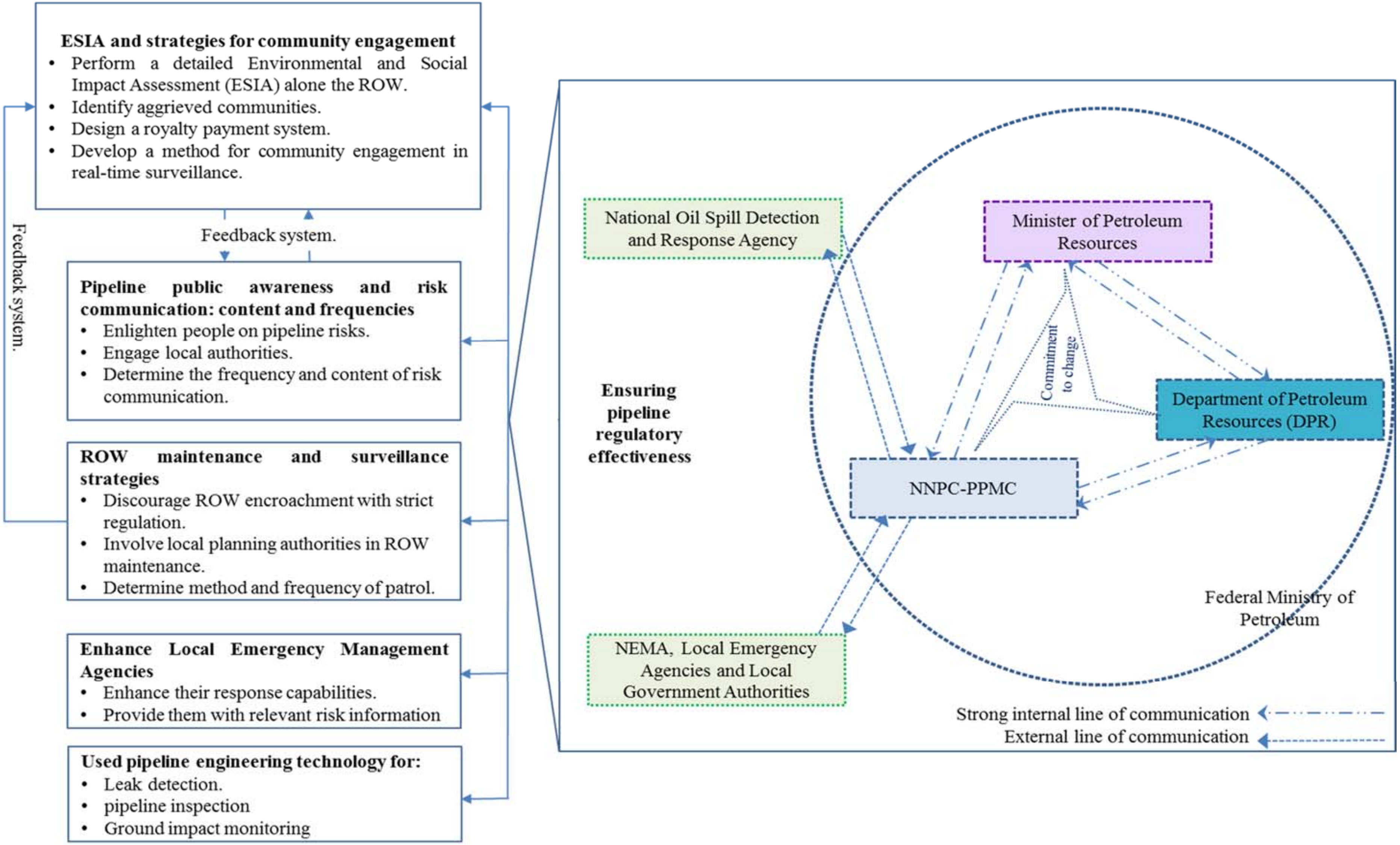


Figure 4-19. Pipeline risk management framework

4.6.1 Ensuring pipeline regulatory effectiveness

The review of regulatory framework in Chapter 2 revealed the mandatory responsibility vested on the Nigerian government for protecting it citizens and the environment from all petroleum activities including pipeline operations. This in addition to the legislative power given to DPR and NOSDRA should form the backbone of their regulatory operations. However, empirical evidence revealed that key limiting factors responsible for their inability to attain this mandate is the current misalignment of the national oil company (NNPC-PPMC) as an integral part of the Federal Ministry of Petroleum Resources with DPR (the regulator). Although this has been acknowledged as a problematic structure, this arrangement can in fact offer some advantage as both organisations receive directives from the Minister of Petroleum Resources. Consequently, with this structure, best practice safety, risk and environmental management directives can be easily cascaded to the operator as shown in the figure 4-20 below. Similarly, PPMC can easily communicate operational concern to DPR under the watchful guidance of the Minister.

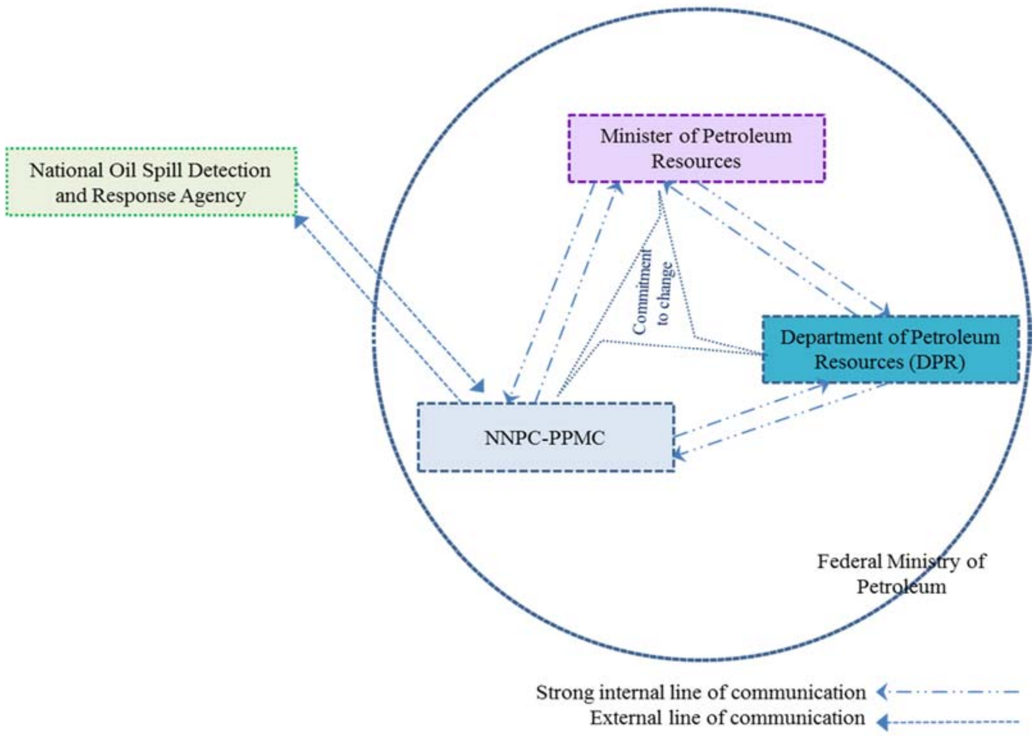


Figure 4-20. Structure of communicating and ensuring safety risk and environmental management directives

The only constrain to achieving this is the lack of commitment and willingness to change mainly due to excessive national vested interest in the petroleum industry. Therefore, the parties involved need to consider the negative safety and environmental impact of the current system, change their commitment levels and build appropriate systems that will clearly define risk management responsibilities and accountabilities in both technical and administrative strata of the pipeline integrity and safety management systems. This can only happen with political will at the highest levels of government.

Notably, there are still issues regarding poor funding and the effectiveness of national regulatory coverage which DPR can enhance by collaborating with state and local government authorities. By doing so, the authorities can also be involved in regulating third party activities such as construction and farming along the pipeline right of way. Logistical resources for this operation can be provided by the PPMC in a collaborative manner and under the supervision of DPR. This arrangement will allow DPR to focus on regulating more technical aspect of the pipeline such as the requirements for in-line inspection and monitoring of corrosion defects. Ultimately, this will perhaps solve the issues related to resource availability.

From a reactionary perspective, incident response by NEMA can be enhanced by decentralising the current practise where NEMA (mostly visible a federal level) are overburden with the responsibilities of responding to incidents which mostly happen in remote rural areas. Thankfully, the NEMA legislation allows for the creation of State (SEMAs) and Local (LEMAs) emergency management agencies (Ambituuni *et al.*, 2014). However, interview findings reveals that while there are available resources from the National Ecological Fund (NEF) (as part of the requirement from the NEMA Act) aimed at improving the capabilities at state and local levels, there is little awareness regarding the existence of such funds or how to access it as indicated in the below citation.

“You know we run a federal structure of government. And we are not an integrated system with the local and state Emergency Management Authorities….it took the Director General (of NEMA) almost a year to convince the national executive council to talk to them (i.e. the president and all governors and ministers). From the report of the meeting he encouraged them to form SEMAs and told them about the

existence of the funds. And some of them were surprise that such a thing even exist" (NEMA interviewee 15th, June, 2013).

From this citation, all that is required is the political will by the country's executive to access such funds and enhance risk management capabilities within pipeline integrity systems. NEMA therefore needs to carry out a complete review of the capabilities of local response agencies especially in known incident hotspots and put in request for funds. This can in fact be included as part of ESIA of the existing pipeline as defined in the 4.6.2 below. Based on the findings from the review, NEMA can collaborate with DRP and PPMC to train state and local agencies on pipeline accident response and emergency evacuation strategies. A line of communication and feedback with the state and local agencies should be defined to ensure sustainable collaboration and capability building.

As NOSDRA is responsible for ensuring spill clean-up and adequate compensation to victims, they can also be involved in training state and local responders on how to contain spills and reduce impact areas, whilst also obtaining first-hand information from local authorities about the people affected and their demands for compensation.

4.6.2 ESIA and strategies for community engagement

The pattern of interdiction on the pipelines revealed how the pipeline industry is affected by socio-political and socio-economic issues. Therefore, these issues should be an integral part of the pipeline risk management strategies.

To better understand the dynamics of these issues, a detailed Environmental and Social Impact Assessment (ESIA) should be conducted across the entire network. ESIA should have been carried out before the construction of the pipeline. However, evidence shows that this was not the done. Hence, a "reactive" ESIA is recommended as a physical starting point for ensuing an effective management of pipeline failure and the risks involved.

Notably, in addition to the socio-environmental problems associated with pipeline failures there are obvious concerns associated to potential spills on land and pipeline river crossing locations. These and other issues such as atmospheric pollution from incidents of fire, effect on soil fertility and crop yield, odour, noise, waste, cultural aesthetics and economic activities should be addressed in the ESIA. The typical concerns to be addressed are shown in Table 4-11.

Table 4-11. Environmental and social concerns to be addressed in the ESIA

Components		Description
Environmental	Ecological concerns.	The effect of pipeline existence on flora and fauna should be assessed.
	Water Resources.	Surface and ground water, seasonal flow regime, river channels and water ecology should be assessed especially were there has been recorded incident of failure. Appropriate clean-up should be deployed.
	Landscape and aesthetic sensitive.	Relied and land forms, topography, soil, vegetation cover/land cover and visible human impact should be assessed.
	Housing and residency.	Proximate houses especially those below the ALARP risk limits defined (40m for workers and 120m for public) should be identified and their occupants properly informed of the risk within their area of residence.
	Air quality (ambient).	Assessment of spatial air quality data, onsite monitoring of air quality and hydrocarbon charged air; modelling of emissions especially at existing pump and booster stations locations should be established.
Socio-economic	Land tenure and land ownership.	Agricultural and subsisting farming practices should be identified and the impact of pipeline assessed. Grazing areas and fishing zones should be protected from adverse pipeline operations.
	Royalties and rent systems.	Appropriate royalty and rent system should be established with inputs from the host communities.
	Community land and conflict management	Areas of conflict within and between communities and PPMC should be identified and analysed and adequate conflict management system developed
	Community incident response capabilities	Identify the capabilities of community incident response agencies and develop a strategy for enhancing their capabilities

By carrying out the ESIA, aggrieved communities will be identified, a royalty payment system can then be designed as compensation to land owners since many of the communities mostly express concern about the lack of benefit from the pipeline. Empirical evidence from the hierarchical multi-barrier failure causes analyses suggests that vandalism thrives in the pipeline communities because those within the pipeline host communities have no role in its management and the operator (PPMC) which has lawful ownership of the pipelines and the associated ROW lacks the capacity to maintain real-time surveillance. Hence, collaboration-based approach to pipeline ROW management is needed.

Such collaborative tactic e.g. Ekwo (2011), should integrate local policies, planning and regulations as this approach can be an effective tool in promoting bottom-up, grassroots approaches that would not only act to eliminate vandalism but also contribute to pipeline community development. The community management action at this level should be facilitated by providing the legislative support in the form of regulations and standards to ensure that community actions are legitimate and also facilitate access to resources to fund the additional responsibility vested in them. Using this approach, community incident reporting and response system can be enhanced via a 'one-call' system.

The activities at this level of the ROW management initiative should promote public enlightenment (as designed in section 4.6.3) and co-operation. Community and local authority actions should promote education, public awareness and training at the community level, by focusing on incremental infrastructure upgrading as a means of winning over the confidence of the people and motivating the development of group-oriented activities. This education is much needed considering the fact that the study revealed that some people have little or no understanding of the risks involved in handling petroleum products.

While community-based organisations and local governments will provide public awareness and education services, and a legal reporting structured for collaboration, at federal level, NOSDRA should design a structured compensation scheme for victims. While NEMA need to enhance the local capabilities of SEMAs and LEMAs to ensure proper rescue, first –aiding, evacuation and re-instalment of disrupted services. The role of each stakeholder within this framework is further discussed in chapter 6.

Identifying the pipeline host communities as a stakeholder will give the people the needed locus to take action for warding off interdictors and vandals from the pipelines. Appropriate royalty payment may in addition act as a means of motivation. Interview with community leaders showed that the communities are ready to participate in the management of the pipeline, asserting that it is in their best interest to do so as the pollution from pipeline failure affects their source of livelihood. They opine that a new wave of environmental challenges has arisen in their communities because the pipeline, which is also the reason for increased violence by vandals and thieves, is outside their purview by the operation of law. However, evidence has shown that the widespread cases of vandalism on the pipelines portrays the government's lack of capacity to effect implementation of a strict policing policy. Therefore, as stakeholders with interest in the safe operation of the pipelines, community involvement may prove effective.

Interpretation from the results discussed in Sections 4.4.2 and 4.4.3 suggests that security risk management, though outside the scope of this study, needs to form part of the integrity management system of the pipeline asset. As discussed in Reniers *et al.* (2015), there needs to be proper integration of the security architecture of the pipeline systems with rings-of-protection. Further research should, therefore, explore and integrate the risk management strategies in this study with the security context of the pipeline surroundings, geographical, as well as socio-technical systems with rings defined and constructed according to security sensitivity of the pipelines. Rings-of-protection should translate into a number of measures, such that is combines physical security equipment, people, and procedures in order to offer the best chance of adequate asset protection against theft, sabotage and terrorism (Reniers *et al.*, 2015). This forms part of the study recommendation for future research.

4.6.3 Pipeline public awareness and risk communication: content and frequencies

The public awareness and risk communication programme proposed in this section is designed in line with the requirements in API 1162 and integrates the interest of stakeholders shown in Figure 4-21. Public awareness and risk communication of pipeline operation is vital to the continued safe operation of pipeline. For the case pipeline, public awareness programmes are required to establish communication between the operator and the communities, and also provide information with respect to the hazards associated with petroleum products. This is especially needed as evidence shows lack of risk and hazard awareness within host communities.

For effective public awareness, the operator (PPMC) having established and identified the community interests via the suggested ESIA, should then collaborate with local authorities and community leaders to decide on the content and frequencies of risk communication. Such communication needs to also consider the need for different audience within the various communities. The communication should be flexible enough to change as the pipeline system changes or as the public needs changes. Communication should neither be treated as a bolt-on extra, nor approached solely in the context of one-way provision of public information. The information should be aimed at:

1. Enhancing public safety
2. Improving pipeline safety and environmental performance
3. Building trust and better relationship with the public
4. Ensuring preservation of ROW
5. Enhancing emergency response coordination.

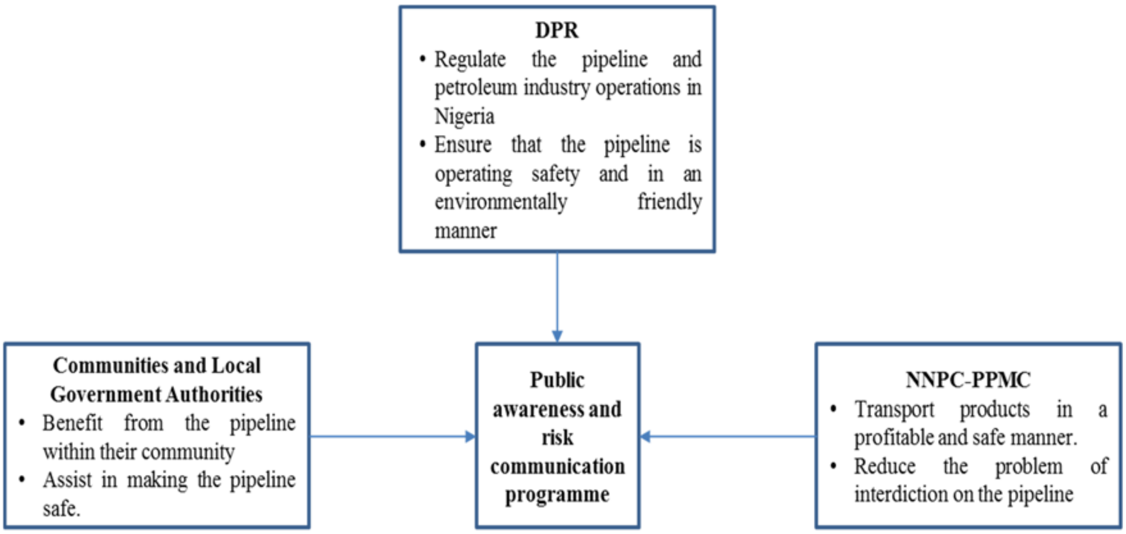


Figure 4-21. Stakeholder interest in pipeline public awareness and risk communication

The IR calculation in section 4.4.4 shows the pipeline ALARP risk limit (for public) to be about 110 meters along the pipeline ROW. Therefore, while public awareness should be done throughout the host communities, priority needs be given to people living within the intolerable risk contour. For these persons, public awareness and risk communication needs to provide information about the workability of the pipeline, the hazards that may result from activities within close proximity to the pipeline and the possible hazards from pipeline operations. The hazards and consequences of activities of interdictors should be clearly communicated and good reporting systems should be designed and also communicated.

People living within high consequence areas also need to be aware of the measures taken to prevent pipeline failure and its impact to public safety, properties or the environment. The communication should also promote the dissemination of information and knowledge that will change the perception of the populace about the pipelines, which currently they see as a curse rather than a blessing for their communities. Currently, there is no structure for public education and risk communication within the pipeline operation systems, hence the structure in figure 4-22 has been proposed to be used in meeting communication requirements.

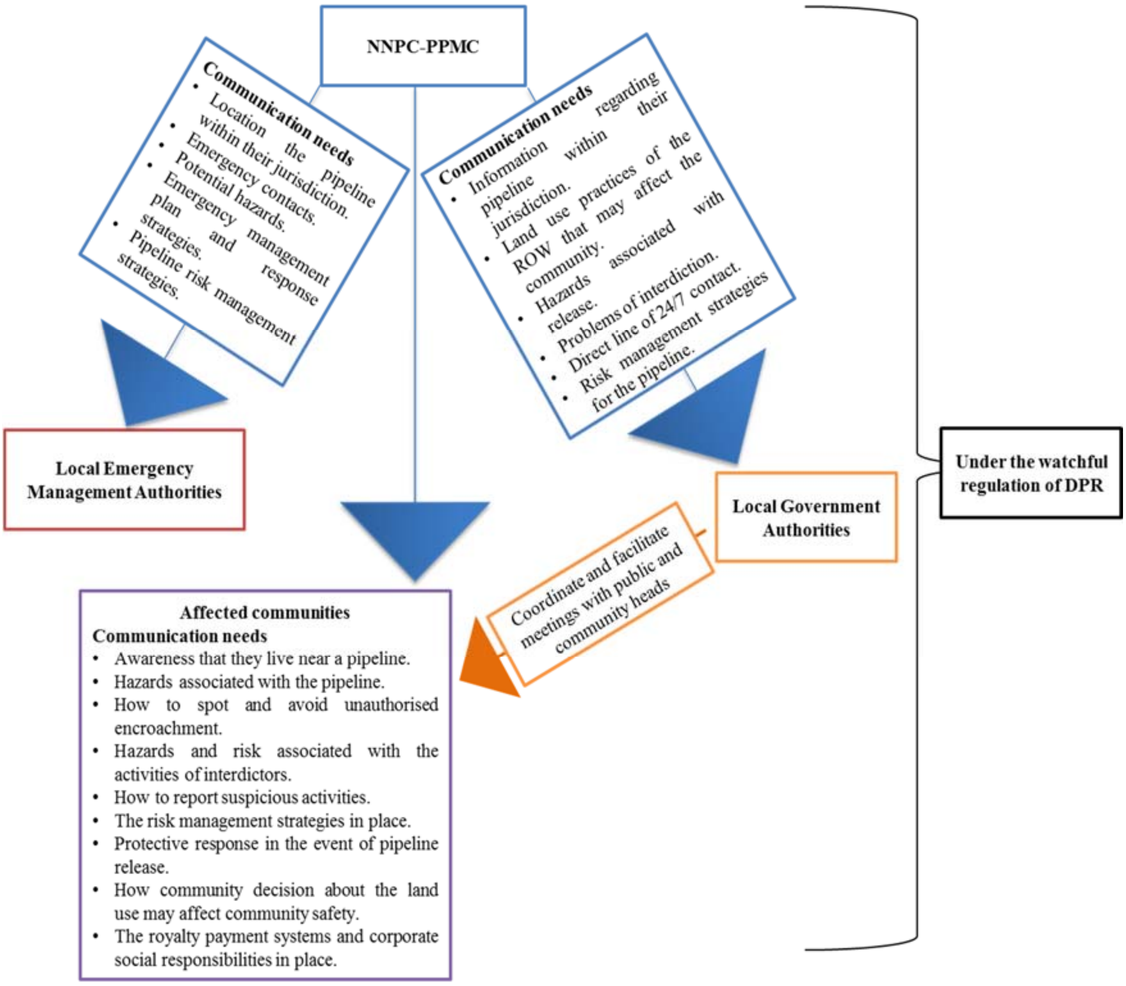


Figure 4-22. Meeting public awareness and risk communication requirements

At the top of the communication chain is the PPMC. Being the operator of the pipelines, PPMC should develop and deploy the required information to both local authorities and local emergency management agencies. Since the local authorities are closer to the communities, they (the local authorities) can assist in facilitating meetings and other methods of communication between PPMC and the communities. These activities should be regulated by DPR as they have the statutory mandate to regulate and supervise all petroleum industry activities in Nigeria. DPR can also take into consideration the contextual characteristics of the pipeline and mandate the frequencies at which all parties within the communication structure should be provided with adequate information. As the purpose of risk control measures includes providing public assurance, it is important to develop a method of measuring and monitoring the effectiveness of risk communication to determine the extent to which this has been achieved.

Inter-organisational risk communication within the framework should involve cascading risk management policies from the Minister of Petroleum Resources to both DPR and NNPC-PPMC. Similarly, DPR can communicate regulatory directives to NNPC-PPMC. NNPC and PPMC can also use the same structure to communicate operational concerns and limitations, whilst also interacting with other stakeholders such as NOSDRA, NEMA, FFSD and local authorities. Risk communication needs to also recognise the need for community based engagement with people to ensure people participate in their own decision about risk. Therefore, across all levels (inter and intra-organisation) of the frameworks risk communication should be in line with the following principles (API 1162, 2003):

Know the audience: In formulating risk communication messages, the audience should be analysed to understand their motivations and opinions. Beyond knowing in general who the audience is, it is necessary that PPMC actually get to know them as groups and ideally as individuals to understand their concerns and feelings and to maintain an open channel of communication with them.

Involve the scientific experts: Scientific experts, in their capacity as risk assessors, must be able to explain the concepts and processes of risk assessment. They need to be able to explain the results of their assessment and the scientific data, assumptions and subjective judgements upon which it is based, so that risk managers and other interested parties clearly understand the risk. They must be able to clearly communicate what they know and what they do not know, and to explain the uncertainties related to the risk assessment of petroleum transportation. In turn, the risk managers and decision makers must be able to explain how the risk management decisions are arrived at.

Establish expertise in communication: Successful risk communication requires expertise in conveying understandable and usable information to all interested parties.

Risk managers and technical experts may not have the time or the skill to perform complex risk communication tasks, such as responding to the needs of the various audiences (public, industry, media, etc.) and preparing effective messages. People with expertise in risk communication should therefore be involved as early as possible.

Be a credible source of information: Information from credible sources is more likely to influence the public perception of a risk than is information from sources that lack this attribute. The credibility accorded a source by a target audience may vary according to the nature of the hazard, culture, social and economic status, and other factors. If consistent messages are received from multiple sources then the credibility of the message is reinforced. Factors determining source credibility include recognised competence or expertise, trustworthiness, fairness, and lack of bias. Trust and credibility must be nurtured and can be eroded or lost through ineffective or inappropriate communication.

Effective communications in the framework needs to acknowledge current issues and problems, and should be open in their content and approach, and remain timely. Timeliness of the message is most important since many controversies pertaining consequential pipeline failure is always focused on the question, “why didn't you tell us sooner”, rather than on the risk itself.

Share responsibility: Regulatory agencies of governments at the national, regional and local levels, have a fundamental responsibility for risk communication. The public expects the Nigerian government to play a leading role in managing public risks. This is true when the risk management decision involves regulatory controls, and is even true when the government decision is to take no action even though they remain active players in the industry. In the latter event, communication is still essential to provide reasons why taking no action is the best option. In order to understand the public concerns and to ensure that risk management decisions respond to those concerns in appropriate ways, the government via its regulatory agencies needs to determine what the public knows about the risks and what the public thinks of the various options being considered to manage those risks.

The media play an essential role in the communication process and, therefore, shares in these responsibilities. Communication on immediate risks involving human safety and the environment, particularly when there is a potential for serious consequences, cannot be treated the same as less immediate safety concerns. PPMC and NNPC also have responsibility for ensuring effective risk communication, especially because the risk is due to their activity. All parties involved in the risk communication process (e.g. government, and industry) have joint responsibilities for the outcome of that communication even though their individual roles may differ. Since science must be the basis for decision making, all parties involved in the communication process should know the basic principles and data supporting the risk assessment and the policies underlying the resulting risk management decisions.

4.6.4 ROW maintenance and surveillance strategies

The pipelines' rights of way (ROW) need to be properly maintained. Encroachment of buildings should be stopped, with strict regulations and appropriated land compensations. This will reduce third party activities, and also enhance effective incident responses. As noted during the ROW inspection, substantial section of the ROW has been over grown by vegetation, thereby obstructing patrol access and providing cover for activities of vandals. PPMC, therefore, needs to improve the condition of ROW by removing over the grown vegetation.

Importantly, ROW maintenance should be accompanied by adequate and frequent surveillance systems. Ground patrolling of the pipeline can be dangerous, as the theft is sometimes conducted by armed and organised gangs. The use of armed police and military should be considered. However, it is worth noting that the police may have been involved in pipeline interdiction as reported in Omodanisi *et al.* (2014). Therefore, there will be a need for substantial reform in the entire security architecture of the pipeline surveillance. This can in fact be an area for further research as discussed in Chapter 7.

Surveillance for ground disturbances can also help. For instance, optical intrusion electronic detection systems can be used to monitor activities of interdictors. The system includes a fibre optic, usually installed 12 to 24 inch above the pipeline. Should the cable become damaged, the monitoring device issues an alarm to the pipeline logic controller and/or the supervisory control and data acquisition system. Appropriate response can then be initiated. However, it is known that some theft is achieved by mining under the pipeline which avoids any visible ground disturbance.

Aerial surveillance can perhaps offer a more achievable approach as thefts occurring both in daylight and at night can be detected using infrared cameras on aerial surveillance. This method, however, requires that the ROW remains free of trees and grass overgrown. The frequencies of surveillance can be extrapolated from the assessed pattern of failure frequencies in section 4.4.1. However, again, aerial surveillance is not a guaranteed system of detection as interdiction and product theft is carried out at random and even where an enhanced surveillance frequency is achieved, such operation can be expensive. Hence, the best approach to surveillance needs integrate aerial surveillance with local community vigilance.

4.6.5 Using pipeline engineering technology to enhance integrity

In addition to the surveillance methods described above, popular engineering methods such as CCTV, barriers (e.g. fences), motion detectors, etc., may also have a role in detecting the activities of interdictors and vandals, but will have little efficiency in remote locations where they are easily disabled.

For leak detection, the acoustic leak-detection technology (De Febbo, 2013) can be used. The system – also known as negative pressure wave (API 1130, 2002) have quick response time (in the range of seconds) and accurate leak detection capabilities (in the range of meters). The acoustic or sonic methodology is based on identification of hydraulic transients created by a pipeline wall rupture at the leak onset. The transients propagate through the fluid in both directions, in the form of wave fronts at the speed of sound within the fluid. These low-frequency transients thus produced travel along the pipeline in the fluid guided by the pipeline wall, and can travel long distances before losing energy (attenuation).

Special transducers (sensors) are positioned at both ends of the monitored section to capture the transient signals. The sensors track the dynamic pressure signals and convert them into electrical signals that are read and analysed by dedicated electronics running sophisticated detection and filtering algorithms for proper leak-pattern recognition. The detection time at each sensor is precisely determined and registered, and since the propagation velocity in the media is known, the leak-location can be calculated based on the arrival times and a few other known parameters gathered from the pipeline. In most cases it is possible to detect leak holes as small as 0.2 per cent of the cross sectional area of the pipeline. However, experience has shown that thieves are capable of vandalising field equipment or sending false signals (especially if they are working with insiders and pipeline staff) if they know the pipeline is monitored (Hopkins, 2008). Other systems such as the mass balance, rate of change method, pressure point analysis, pressure deviation, etc., can also be effective in leak detection.

For the purpose of pipeline inspection, inline inspections systems should be designed and implemented. Inspection can be carried out internally by X-ray or Gamma ray crawlers or intelligent pigs. These enable the detection of internal and external corrosion, drill holes, and cracks within the wall of the pipeline. They mainly rely on ultrasonic and magnetic flux leakage to detect the defects. Similarly, most recently, drones have come on the scene as a way to monitor pipelines from the sky – without hiring a helicopter pilot. Drone operations offer the potential to monitor the conditions of these networks, report back any issues, and will offer PPMC cost savings.

4.7 Chapter summary.

The risk associated with the downstream petroleum product distribution pipeline has been assessed and some strategies for risk management proposed. The assessment clearly shows that interdiction and third party interference are the major causes of failure to the pipelines, accounting for over 96% of pipeline failure. This may be attributed to socio-political events in the country. The pipelines recorded a failure rates of 0.35 per km-year which have been found to be well above failure rates reported on other pipeline systems around the world (e.g., the UK and USA). Consequently, the ignition frequencies, fatality, and product losses from the Nigerian pipelines are found to be high. This ultimately made the values of Individual Risk for the pipelines to fall outside tolerable limits. Fatalities from pipeline failures range from 0.04 to 0.38 per km-yr, depending on the region of operations in Nigeria. Additionally, on average, the operator of the pipeline system loses about $US100million/year due to these failures. This value does not consider the costs associated with payment of compensation, fines, environmental clean-ups, litigation, etc.

Based on the results of risk assessment, interview analysis and ROW inspection, an analysis of the complex socio-technical pipeline operating and regulatory systems was conducted and a risk management framework proposed. The management framework focuses on interdiction being the predominant pipeline incident/accident causal factor.

The risk management strategies consist of a collection of technical and social tactics. The social tactics leverages on the potential solutions that partnership with all stakeholders offers, particularly local communities to determine the issues and problems, and gain 'intelligence' by conducting an ESIA. The framework also recommends PPMC to work with local communities to recognise the benefit of the pipelines, engage the host communities and involve them in local surveillance.

The next chapter presents the risk assessment and management framework for road truck tanker operation as an integral part of the petroleum product transportation and distribution system within the downstream structure of the Nigerian petroleum industry.

5 CHAPTER FIVE: RISK MANAGEMENT FRAMEWORK FOR TRUCKING PETROLEUM PRODUCTS

5.1 Chapter introduction

Three previous chapters (Chapters 1, 2 and 3) have respectively defined research objectives, developed a methodological approach for the scoped risk management study, and identified/analysed the legislation for downstream operation (including transportation of products by road) in Nigeria. In Chapter 4, a risk management framework for pipeline operation was designed and proposed. As noted in Chapter 1, the two systems of transportation of products in Nigeria are pipeline and road trucking. These systems are interconnected and function as multi-nodal transport systems within the downstream structure of the petroleum industry. Like the pipeline system in Nigeria, transportation of petroleum products by road trucks also creates numerous opportunities for hazardous materials to be accidentally released. Depending on the volume upon LOC, chemical properties, sensitivity of host environment and proximity of human presence, such releases have consequences to human safety and the environment. This is especially a problem were roads often pass through populated areas (Fabiano *et al.*, 2002; Anifowose *et al.*, 2011). In this chapter, the data collected (with respect to truck operations) from the methods discussed in Chapter 2 was analysed using a tailored risk assessment model. This chapter is aimed at *developing a risk management framework for road-truck system of transportation and distribution of petroleum products*. The identified legislations in Chapter 3 grounds the risk management initiatives designed, whilst also integrating stakeholder inputs. Ultimately, this chapter sets out to:

- *Define the risks associated with distribution of petroleum products by road.*
- *Identify the factors contributing to accident frequencies and consequences.*
- *Propose risk management initiatives and also identify the stakeholders responsible for the risks.*

This chapter is based on two published papers under the following titles:

Ambituuni, A., Amezaga, J.M., Werner, D. (2015). "Risk assessment of petroleum product transportation by road: A framework for regulatory improvement." *Safety Science 79(0): 324-335.*

Ambituuni, A., Amezaga, J. M., Werner, D. (2015). "Risk management framework for safe transportation of petroleum products in Nigeria: Learning from past accidents and good practices*." Risk Management 17(4): 329-351.*

5.1.1 Setting the context

As seen in Chapter 3, petroleum product trucking operation in Nigeria is overlaid by complexity of multiple players, multiple regulators, product with varying volatility, multiple hazards and multiple transport routes. Based on the findings of Chapter 3, the current regulation of trucking downstream operations (including trucking petroleum products) is fragmented and lacking in effectiveness. This is evident in the number of petrol tanker related accidents (Dare *et al,* 2009 and Ambituuni *et al*, 2015) recorded in Nigeria. This, therefore, calls for a comprehensive risk management approach so as to better enhance regulatory programs and also to assist individual companies in developing tailored approaches to achieve cost-effective risk reduction beyond the regulations.

This is particularly needed due to the highly articulated, small, but politically sensitive nature of operators (Ehinomen and Adeleke, 2012; Majekodunmi, 2013) and rampant incidents of accidents (SAVAN, 2002). This context, therefore, typifies a case for development of an innovative risk management approach as trucking operations as this transport system accounts for approximately 95% of the country's petroleum product transport volume moving on the road system (Anifowose *et al.*, 2011; FRSC, 2011). This is the reason why this chapter sets out to assess the risks involved in petroleum road trucking and develop pragmatic mitigation strategies based on regulatory requirement and stakeholder interests.

5.1.2 Risk assessment models applicable to trucking of petroleum products

It is worth stating that road trucking of hazardous material (hazmat) have received considerable research attention in the last 20 years (Yang *et al.*, 2010). Various research (Verter and Kara, 2001; Fabiano *et al.*, 2002; Fabiano *et al.*, 2005; Gheorghe, 2006; Lieggio Junior, 2008; Centrone, 2009; Guo and Verma, 2010; Tomasoni *et al.*, 2010; Yang *et al.*, 2010) have focused on managing, preventing and reducing the impact of accidents involving truck tankers carrying hazmats (including petroleum products). Within this research, three approaches can be distinguished.

- First, is the development of frameworks for improving emergency responses in specific countries based on road factors, metrological factors and traffic factors e.g. Fabiano *et al.* (2005).
- Second, is the trend of conducting survey and accident risk analysis based on historic data to divulge accident characteristics (Oggero *et al.*, 2006; Yang *et al.*, 2010).
- Lastly, is the development of decision making frameworks aimed at improving choice of truck capacity (Guo and Verma, 2010) and route selection (Verter and Kara, 2001; Fabiano *et al.*, 2002; Volkovas *et al.*, 2005; Lieggio Junior, 2008)

This research is discussed below, with the aim of identifying elements that can be used to develop a tailored risk assessment model that will suite the data collected.

5.1.2.1 Frameworks for improving emergency response

Fabiano *et al.* (2005) defined the risks of dangerous good transport by presenting a site-oriented framework for risk assessment and developing a theoretical approach for emergency planning and optimisation. Their research obtained data on a pilot highway and developed a database to allow a realistic evaluation of the accident frequency on a given route using multivariate statistical analysis. Consideration was given to inherent factors (such as: tunnels, bend radii, height gradient, slope etc), meteorological factors, and traffic factors (traffic frequency of tank truck, dangerous good truck etc.) suitable to modify the standard national accident frequency. Based on this, an approach was developed to identify optimal consistency and localisation in the pilot area of prompt action emergency vehicles.

5.1.2.2 Data driven risk assessment

In Oggero *et al.* (2006), Theodore (1991) and Yang *et al.* (2010), survey and accident risk assessment were conducted based on historic data to reveal accident characteristics.

For instance, a study of 1932 accidents that occurred during the transport of hazardous substances by road and rail from the beginning of the 20th century to July 2004 was carried out by Oggero *et al.* (2006). Their research gave a statistical profile of accident frequencies, consequence senarios and causal factors and risk characterisation aimed at enhancing development of effective risk mitigation strategies.

Similarly, using the problem and regulatory instance of New York City, the impact of container and route choice was assessment by Theodore (1991) in risk factor analysis. According to Theodore, condition release and accident probabilities must be calculated so that expected outcomes can be determined. This study focused on the use of two different containers, two routes (one considered typical and the other considered the most hazardous) and two risk scenarios (average and worst case). The scenarios were then analysed to determine the risk of a release, a release that leads to fire and an explosion. Fatalities were then estimated based on the expected accident scenario outcomes.

Yang *el al.* on the other hand studied 322 accidents that occurred during the road transport of hazardous materials (hazmat) in China from 2000 to 2008 to identify accident frequencies, accident hot spots, the most frequent types of accident and the causes and consequences of the accidents. They concluded by making arguments on the need to improve certain safety measures in the road transport of hazmat in China.

These research shows that it is possible to use historic data to develop a risk profile based on accident occurrence frequencies, fatalities and other consequence. This profile can then be used in making risk management decisions.

5.1.2.3 Decision making frameworks

Some truck-tanker risk assessment research focus on the development of decision making frameworks aimed at improving choice of truck capacity (Guo and Verma, 2010), and route selection (Verter and Kara, 2001; Fabiano *et al.*, 2002; Volkovas *et al.*, 2005; Lieggio Junior, 2008).

Guo and Verma (2010) formulated a mathematical model for risk minimisation in transportation of flammable materials by reducing vehicle capacity. Guo and Verma also considered impact radius in hazardous material accident for TNT equivalent law which was defined as the weight of a standard explosive (TNT) required to produce a shock wave parameter of equal magnitude to that produced by a unit weight of the explosive in question. This was then considered as a factor in choosing the capacity and volume of flammables and explosive materials in truck tanker transportation.

In order to develop risk based knowledge on transport routs, Verter and Kara (2001) on the other hand developed a risk mathematical model for petrol transportation where they presume a set of route of petrol transportation $R = \langle r_1, r_2,\ldots,r_n \rangle$ and a set of parameters common to these routes $P = <p_1, p_2,\ldots,p_n>$. Each route was further divided into segments $S = <s_1, s_2,\ldots,s_m>$ and each i route was composed out of particular set of segments $r^i = <s^i_1, s^i_2,\ldots,s^i_k>$. Also, the tank trucks technical state of $T = <t_1, t_2,\ldots,t_l>$ was established.

From a statistical view point, risk analysis of the entire route was then obtained by assessing the risks on each segment that made the route. This implies that risk assessment of whole route equals the sum of risk assessment of separate segments in the route.

Similarly, in the quest to achieve safer transportation of hazmats Fabiano *et al.* (2002) asserted that because hazardous materials transport by road is often more dangerous as roads tend to travel through higher populated areas, data should be collected to describe the population on potential transport routes. Fabiano *et al* then created a model to analyse the impact of route choice in various populations. In their research instance, a route can be determined to have a small, yet vulnerable population. This could influence transportation planners and policy makers to avoid this smaller population and steer hazardous materials towards a larger population with a greater chance of survival. Many of these decisions are entirely subjective and political, but the model offers an objective look at the potential impacts of various route choices.

A weighted risk analysis methodology was proposed by Suddle (2009) in order to balance safety measures with aspects, such as environmental, quality, and economical aspects. His research provides a theoretical background regarding the scope of safety assessment in relation to the decision-making in complex urban development projects adjacent to or above transport routes of hazardous materials in the Netherlands. Suddle expanded on the quantitative risk assessment framework that the Dutch regulation requires to assess the safety of projects to allow other aspects of risk in the decision making process. The cost of risk was also factored in the consequence model. Based on this, the author asserts that the monetary value per considered loss can be found through research; hence, varying the values given for each considered loss in the weight can have a strong impact on the final weighted risk value and, thus, over the total decision-making process.

From all the truck tanker risk assessment approaches discussed in 5.1.2.1, 5.1.3.1 and 5.1.3.1, two aspects can be observed:

1. Risk assessment of road trucks has to be contextual, i.e., risk assessment is not generic and risk assessment result from a particular case cannot be used on another

case by default. Data and circumstantial information needs to be collected to a defined the problem instance.

2. Risk assessment needs to integrate the regulatory requirement of the case country. This is even more important if the framework goes beyond proposition of mathematical methodology to developing risk management initiatives.

Notably of all the research reviewed, there was no research conducted within the problem instance of Nigeria. The only research identified was the explanation of the reason for a fire outbreaks during fuel truck accidents in Oyo State, Nigeria by Dare *et al.* (2009). Although the study gave some likely explanation to accident occurrence such as the operators' carelessness, driver age and poor quality of truck construction, the research was not developed in the context of risk management and, therefore, offers no structured approach to accident prevention and response.

5.2 Method

In chapter 2, the methods used for collecting and analysing data in the general context of this study was discussed. This section presents the specific application of the data and model developed for data analysis. Using the model for accident investigation by Rasmussen, key risk management elements were identified from the results of accident risk assessment, analysis of the interviews, road inspections and industry reports. Risk management initiatives were then proposed and discussed within the context of regulatory requirements and participating stakeholders whilst also integrating relevant good practices from existing hazmat risk management frameworks.

5.2.1 Data

2318 accident reports (from 2007 to 2012) were sourced from FRSC, NNPC, NEMA and DPR and used to conduct accident risk analyses. Fortunately, the details (causes, consequences (fatality/casualties) and quantity of products spill) on each accident report obtained was comprehensive enough to give a contextual understanding of hazards, accident causal factors, accident frequency and severity. The reports cover accident/incidents involving truck tankers across the 36 Nigerian states and Abuja. Accident fatality statistics was used to obtain the number of deaths in a particular accident to the relative probability of that number.

Using document content analysis, the data was further categorised based on location of occurrence across the Nigerian states. Details of numbers of fatalities, injuries, and vehicles involved and type and quantity of products involved within each incident was also tabularised accordingly. Data representing yearly distribution and sales of petroleum products (PMS, HHK and AGO) across the states in Nigeria were obtained from 2012 NNPC report, while petroleum product price regime details was obtained from PPPRA (see table 5-1 for data and data sources). The data was them imported to SPSS where it was analysed using the risk assessment model developed.

Also, semi-structured interviews *(N=19)* were conducted with staff of the stakeholder organisations with interests in road trucking of petroleum products. Predominantly, interviews with key informants in most relevant position representing the official views of the organisation was used. Records of interviews were transcribed and analysed using thematic cross-context analysis techniques discussed in chapter 2.

Notes and photographs from road inspections were also used in developing understanding of road related accident causal factors.

Table 5-1. Data sources

S/N	Data Type	Data Source
1	Legislation, and stakeholder information	Literature and legal documents
2	Accident reports across 36 states and Abuja from 2007 to 2012.	DPR, NNPC-retail, FRSC and NEMA
3	Quantity/price of petroleum products consumed (PMS, HHK and AGO) in Nigeria.	2012 NNPC sale records and PPPRA report
4	Estimated cost of fatality, injury and environmental damage.	Battelle (2001)
5	Interviews	Stakeholders within identified organisations
6	Road inspection	Site visit

5.2.2 Defining truck tanker accident

Based on the accident report content, truck tanker accident is defined in this study as an event that occurs when the tanker transporting petroleum product is involved in a collision and/or any event that has led to spill or fire or explosion. Any accident involving the shipment is considered an accident regardless of whether there was LOC. This is represented in the event tree in figure 5-1.

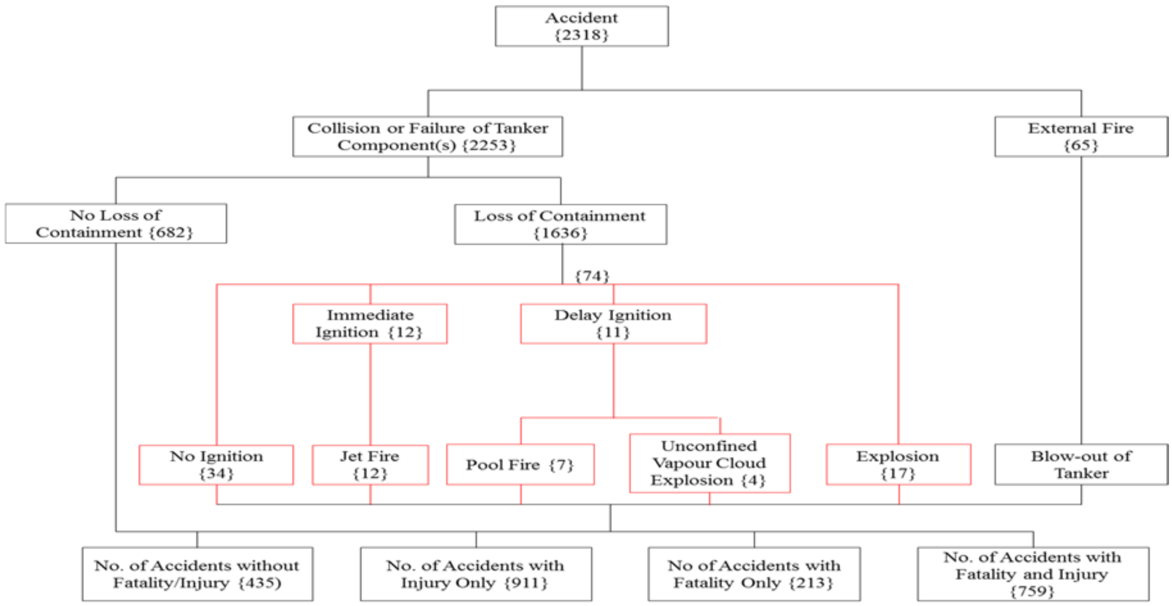


Figure. 5-1. Accident event tree. Note: Although many of reports clearly stated the quantity of loss product due to accident event, only 74 of the reports identified specific classification of accident phenomena. This was used in the classification highlighted in red.

5.2.3 Developing an accident risk assessment model for truck data

As an integral part of the risk management framework a tailored data driven risk assessment model was presented. The model consists of two key risk assessment elements:

1. Formulas for identification of accident causal factors; and equations used for the computation of accident frequencies and accident casualty consequence, later used for accident risk quantification.
2. Cost impact element comprising formulas for estimation of direct and indirect costs of accidents and computation of the yearly cost impact of accident and losses.

The model is aimed at providing means to effectively conduct risk assessment using data from different sources and to prioritise resources for accident mitigation. The financial dimension can be used as strong regulatory incentive for improving safety in trucking operations. This is because regulatory enforcement is often lacking as operating companies cling to the perception that adhering to good safety and environmental standards is expensive. Hence there is a need to uncover the real and often high but hidden costs of poor safety standards to operators via risk assessments.

5.2.3.1 Causal factor identification and classification

Based on the reported cause of accident to regulators, accident causal factors were classified into human, non-human and unknown factors. Accident causal factors are factors that contribute to the frequency of accident in a given year. Total causal factor classification was therefore computed as:

Human factor (*Hf*) + Non-Human factor (*Nf*) + Unknown factor (*Uf*) **(5.1a)**

Hf, *Nf,* and *Uf* values were extracted as:

$$Hf = D_{GD} + T_{PI} + A_{VA} \tag{5.1b}$$

where D_{GD} is the factor caused by dangerous driving, wrongful overtaking, speed violation, route violation, drink driving and other traffic violations. T_{PI} is accidents caused by third party interference on the road, i.e. human factors not caused by the driver and A_{VA} is armed and violent attack such as armed robbery

$$Nf = Mf + Br + Bw \tag{5.2}$$

where *Mf, Br* and *Bw* are causal factors due to mechanical faults, bad road and bad weather respectively.

5.2.3.2 Accident frequency

Since *n* number of accidents were reported in a geographical region (state) *j* in year *y* and the total quantity of petroleum product distributed and sold in that state in year *y* was recorded as $\mho_j$ litres, then the total number of tanker trips k_j to the state can be estimated by diving $\mho_j$ by 33,000 litres (a typical tanker load). Using the formula of relative frequency, the frequency of accident per trip per year across each state was identified as:

$$\textbf{Accident frequency per trip } (p) = \frac{n_j}{k_j} \tag{5.3}$$

Where n_j is the number of accident in a state *j* and k_j the number of trips to that state. The frequency value, however, depends on the assumption that the truck involved in the accident in that state was assigned to deliver product to the state and not just passing by.

5.2.3.3 Relative accident consequence between states

The data showed various accident locations *i* through to *m* across state *j* (i.e. $i = 1, 2\ldots m$ accident locations within state *j*) and casualty consequence *q* was recorded at each accident location *i* in state *j*. By defining $q_{i,j}$ per accident in terms of total numbers of: fatalities ($q_{F,i,j}$) and injuries ($q_{I,i,j}$), it was possible to evaluate the accident casualty consequence i.e:

$$q_{i,j} = q_{F,i,j} + q_{I,i,j} \tag{5.4}$$

And total casualty consequence *Qj* per year across state *j* is;

$$Qj = q_{1,j} + q_{2,j} + q_{3,j} + \ldots + q_{m,j} = \sum_{i=1}^{m} q_{i,j} \tag{5.5}$$

Using equation 5.5 relative accident casualty consequences in different states were computed and compared to determine high risk states.

The relative frequency of an accident having a given number of deaths was calculated using the accident totality statistics. Accordingly, accidents were grouped based on number of fatalities and the cumulative frequencies calculated using the following equation:

$$p_a = \frac{\sum_{c=a}^{x} N_c}{\sum_{c=1}^{x} N_c}. \tag{5.6}$$

Where *N* is the number of deaths, P_a is the frequency of an accident with more than *N* deaths, *x* represents the total amount of categories or rankings, and N_c is the number of accidents in a given category *c*. This method was also used by Yang *et al.* (2010).

5.2.3.4 Accident and fatality/injury rate correlations

Using a 2-tailled Kendell's tau non-parametric correlation, it is possible to evaluate the direct relationship between accident rate, fatality rate and injury rate. The Kendall correlation statistics described the difference between the probability that the observations are in the same order for both variables and the probability that the observations are in a different order. The mathematical formula is shown in equations 5.7.

As a nonparametric test, the statistical correlation is not based on parameterised families of probability distributions. They include both descriptive and inferential statistics. The typical parameters are the mean value of accidents per state.

$$\boldsymbol{\tau} = \frac{\boldsymbol{s}}{\sqrt{\left[\boldsymbol{n}\left(\frac{\boldsymbol{n}-\mathbf{1}}{2}\right) - \sum_{\boldsymbol{i}=\mathbf{1}}^{\boldsymbol{t}} \boldsymbol{t_i}\left(\frac{\boldsymbol{t_i}-\mathbf{1}}{2}\right)\right]\left[\boldsymbol{n}\left(\frac{\boldsymbol{n}-\mathbf{1}}{2}\right) - \sum_{\boldsymbol{i}=\mathbf{1}}^{\boldsymbol{u}} \boldsymbol{u}\left(\frac{\boldsymbol{u_i}-\mathbf{1}}{2}\right)\right]}} \tag{5.7}$$

Where, t_i is the number of observation tried at a particular rank of *x* and u is the number tried at rank of y. s is the observed sum of the +1 scores (agreement) and – 1 scores (disagreement) or simply, s is C – D (Concordant Pairs – Discordant Pairs). If the agreement between the two rankings is perfect and the two rankings are the same, the coefficient has value 1. If the disagreement between the two rankings is perfect and one ranking is the reverse of the other, the coefficient has value – 1. For all other arrangements the value lies between –1 and 1, and increasing values imply increasing agreement between the rankings.

5.2.3.5 Accident and financial loss

Using *t* as the value representing the corresponding financial consequences associated to accident in location *i* through to *m* within state *j*, *t* was defined with respect to fatalities *(tF,i,j),* injuries *(tI,i,j),* number of vehicles involved *(tV,i,j),* quantity of product loss *(tPl,i,j),* etc.

The financial accident consequence at location *i* in state *j* was therefore estimated as:

$$\boldsymbol{t_{i,j}} = \boldsymbol{t_F} . \boldsymbol{q_{F,i,j}} + \cdots . \tag{5.7}$$

Total financial consequence *T* in state *j* per year was obtain using Equation 5.8

$$\boldsymbol{T_j} = \boldsymbol{t_{1,j}} + \boldsymbol{t_{2,j}} + \boldsymbol{t_{3,j}} + \ldots + \boldsymbol{t_{m,j}} = \sum_{\boldsymbol{i}=\mathbf{1}}^{\boldsymbol{m}} \boldsymbol{t_{i,j}} \tag{5.8}$$

The total monetary sale value of petroleum product per year in state *j* is given as T_{psj}. Accident impact on sales in state *j* was then computed by deducting the total accident financial consequence (T_j) in that state from the total year monetary sale value of petroleum products (T_{psj}) in that state.

5.3 Result and discussion

5.3.1 Accident causal factor identification

Table 5-2 shows a summary of parameters extracted from accident reports. Using the tailored risk assessment model, it was possible to identify the percentage distribution of the classification of causal factors in equation 1a and 1b. From figure 5-2 human factors are the most causal factor of accident occurrence. From the 2318 accidents 1830 (79%) originated from human factors (D_{GD} = 74%, T_{PI} = 3.8% and A_{VA} 1.2%). Further analysis at State level also shows human factor as the most frequent causal factor across all States and Abuja. These findings are revealing because, contrary to general perception, the bad condition of Nigerian roads (Anifowose *et al.*, 2011) and armed robbery and violent attack are not in fact the major contributing factors to accidents. In this category, there is a variety of causes including: speed violation, dangerous and wrongful overtaking, route violation, and driving under the influence of alcohol and other intoxicants.

Being an integral part of a transport system which consist of operating personnel, organisation (regulators and the regulated), equipment, procedure and environment, human factors may be connected to underlying failures rooted in issues developed by at various socio-technical levels. These issues have been explored in section 5.3.6.

429 accidents (19%) originated from non-human factors (i.e. Mf = 16%, Br = 2.77% and Bw = 0.23%). However, the consistency of this factor classification remains unclear. A part of the non-human factor classification mechanical failure creates a grey area in this classification. It is not clear to what extent mechanical failure remains independent of underlying human or organisational malfunctions. For example, poor maintenance culture may be an underlying accident causal factors. Clearly, this is a human or organisational factor that manifests as mechanical faults. Hence, while mechanical fault is reported as the initiating cause, the underlying factor can be as a result of human or organisational failures. This means that in real sense, the percentage human accident causal factor may be higher than 79% if underlying factors are considered

Table 5-2. Summary by year of parameters extracted from accident reports

Yr	No. of accidents	Fatality	No. injured	No. of persons involved	No. of veh. Involved	No. caused by human factors	No. caused by non-human factor	Un-known factor	Quantity of PMS loss (,103ltr)	Quantity of AGO loss (,103 ltr)	Quantity of HHK loss (,103 ltr)
07	232	369	741	1639	342	191	37	4	4095.4	510.7	528.4
08	352	434	1124	2467	518	281	62	9	6712.4	1029.4	893.4
09	486	434	1345	3038	665	390	82	14	9600.0	1045.5	642.2
10	415	519	1405	3108	686	317	85	13	7943.4	891.3	908.8
11	354	374	931	2383	625	251	96	7	7456.5	1153.6	772.9
12	479	614	1562	3745	997	384	84	11	8328.26	820.37	789.0

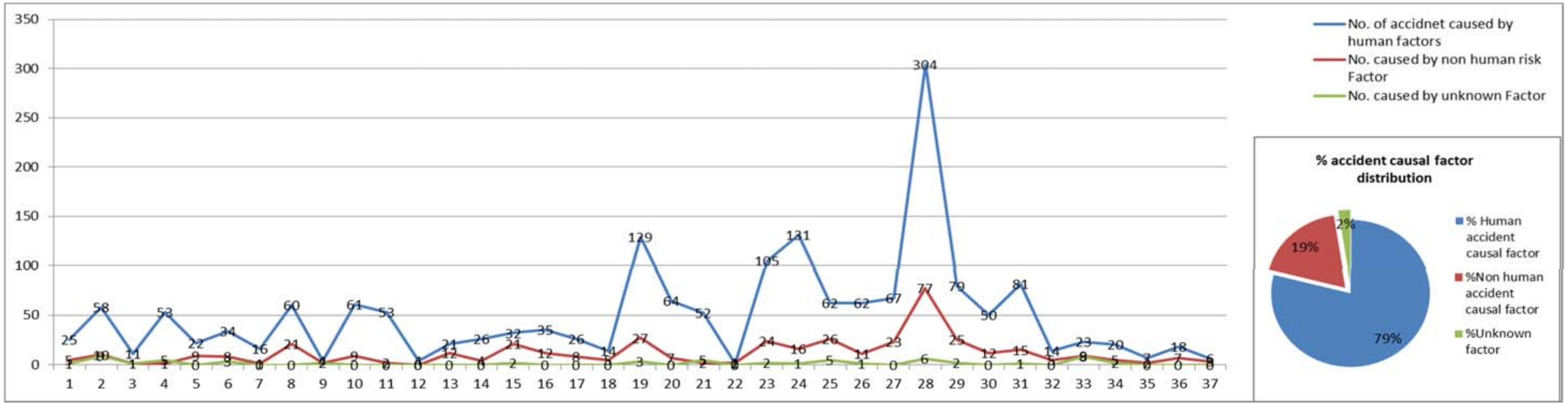


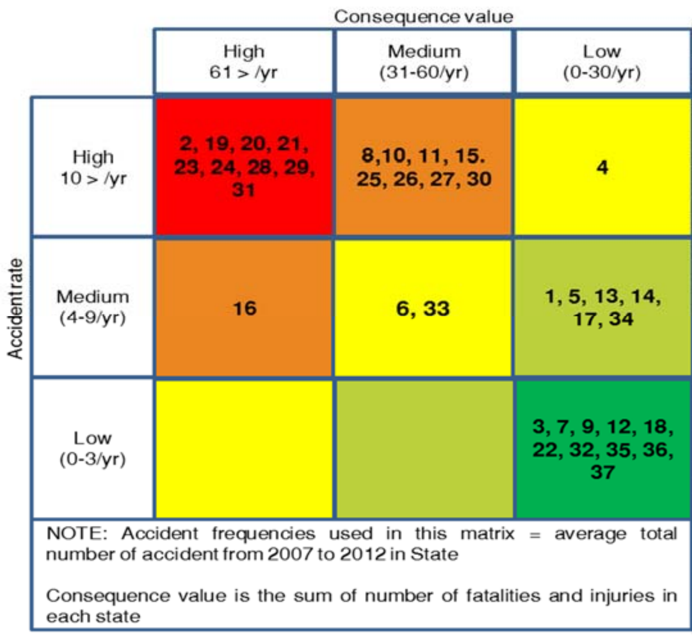
Figure. 5-2. Showing the distribution of accident figures (2007 to 2012) across the 36 states and Abuja categorised based on equation 1a, 1b and 2. Note the % distribution of causal factors with human factor having 79%

High percentage of human or human related causal factors presents opportunity for formulation and deployment of tailored risk mitigation strategies. Regulators and operators can take advantage of this and a target risk management strategy to address the specific nature of the causal factor by designing an inclusive and interactive Safety and Environmental Management Systems which targets improving culture, behaviour and perception towards risks. This is further discussed in section 5.4.

5.3.2 Identification of accident hotspot

The 3×3 risk matrix shown in figure 5-3 was developed using equation 5-5. States were classified in the matrix based on their relative accident-consequence values. The figure illustrates the average relative value for all States and Abuja within the years under consideration. The distribution of accidents across the nation was also plotted in a map of Nigeria in figure 5-4. Using the matrix, high risk states can easily be identified.

Not surprising, in this instance, states with refineries and import jetties such as Kaduna, Delta and Lagos were identified as high risk states, i.e. states with either high accident rate (>10/yr) – high consequence value (>61/yr) or high accident rate (10>/yr) – medium consequence value (31 – 60/yr). Ogun state, Abuja, Kwara, Kano and Oy o were similarly of the same classification. This could be attributed to their positions along key transport corridors and high concentration of economic activities within the states.



ID. No.	State	Consequence value	avarage accident rate
1	ABIA	27	5
2	ABUJA	66	13
3	ADAMAWA	18	2
4	AKWA-IBOM	26	10
5	ANAMBRA	16	5
6	BAUCHI	41	8
7	BAYALSA	9	3
8	BENUE	47	14
9	BORNO	11	1
10	CROSS RIVERS	36	12
11	DELTA	31	9
12	EBONYI	2	1
13	EDO	12	6
14	EKITI	11	5
15	ENUGU	50	9
16	GOMBE	63	8
17	IMO	17	6
18	JIGAWA	23	3
19	KADUNA	117	27
20	KANO	69	12
21	KATSINA	89	10
22	KEBBI	3	1
23	KOGI	103	22
24	KWARA	115	25
25	LAGOS	55	16
26	NASARAWA	44	12
27	NIGER	44	15
28	OGUN	180	65
29	ONDO	79	18
30	OSUN	58	10
31	OYO	95	16
32	PLATEAU	8	3
33	RIVERS	33	7
34	SOKOTO	25	5
35	TARABA	4	2
36	YOBE	17	4
37	ZAMFARA	7	2

Figure. 5-3. 3 × 3 risk matrix showing average relative accident-consequence values for all states and Abuja

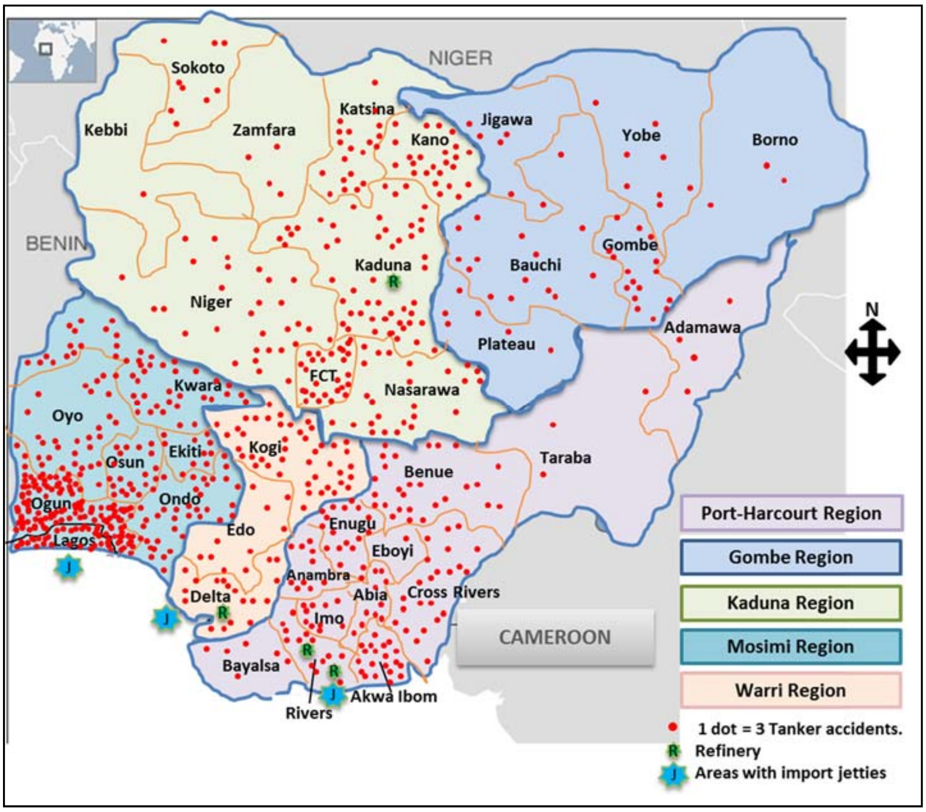


Figure. 5-4. Map of Nigeria showing distribution of accidents (2007 to 2012) across all states and Abuja within the NNPC petroleum product distribution regions. Note that the dots are not in exact accident positions.

Equation 5-3 was used for accident frequency quantification to evaluate the relationship between accident occurrences and develop a platform for comparison with acceptable risk limits for societal risk, (i.e. the risk or threats from hazard which impact the society) and individual risk, (i.e. how individual personally see risk from a hazard).

In figure 5-5 four maps of Nigeria were developed using ArcGIS based on established accident frequencies for 2009, 2010, 2011 and 2012 for all states. Relative accident frequencies for 2007 and 2008 were not computed because only four years (2009-2012) records of total product distribution by state can be traced. Hence, relative accident frequency was computed with 4 years data only. The values were then classified into four limits for each year independent of preceding or succeeding year using the quartile frequency values (Armitage et al., 2008) obtained across the 36 states and Abuja. This classification was used in the map to classify states as: very high, high, medium and low accident frequencies states. The aim here is to have a broad view of accident distribution across each state using normalised data so as to identify patterns that can be used for regulatory purposes.

The figure shows consistency in the pattern of accidents, with states such as Ogun, Kwara, Kogi, Oyo, Benue, and Akwa-Ibom maintaining either very high or high accident frequency per truck tanker trip over the four years considered.

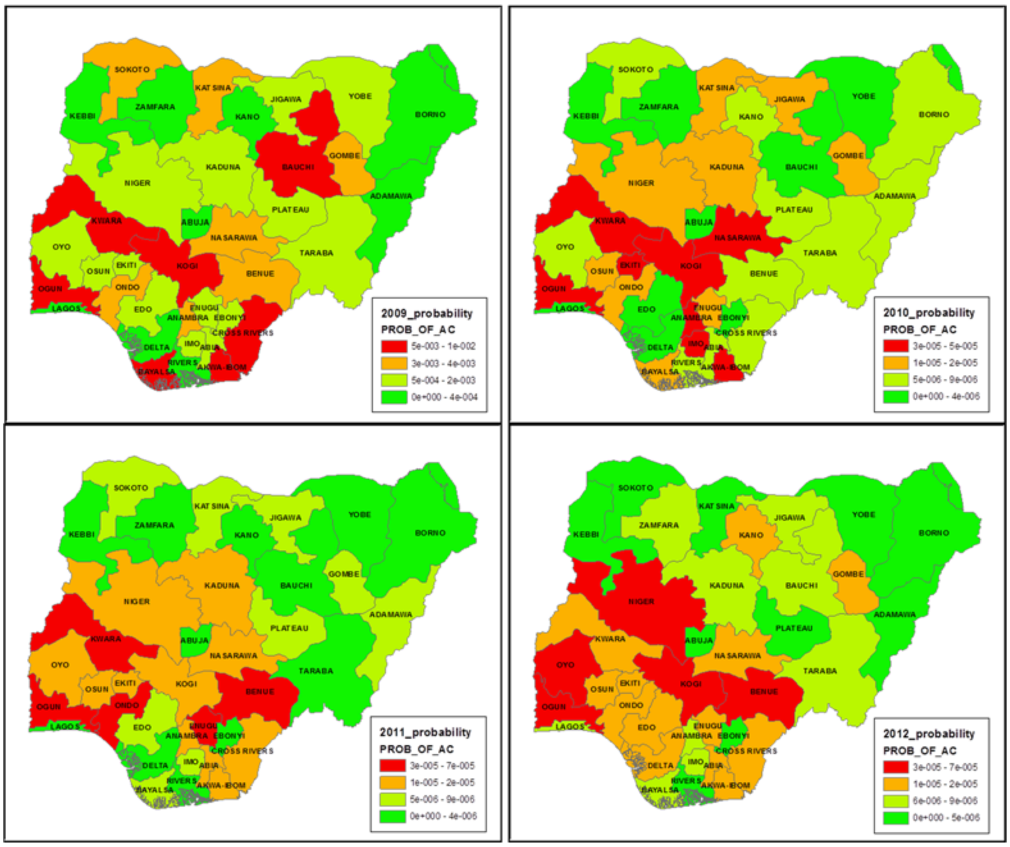


Figure. 5-5. Accident quartile probability classification per state per year

By identifying accident risk hotspots, regulatory authorities can channel scarce resources to such locations (Löbmann, 2002). Hence with this knowledge, FRSC can invest in traffic management strategies by enhancing the frequency of patrols specifically in such states while also integrating lessons from state with low accident probabilities.

Similarly, NEMA, NOSDRA and Fire Departments can strategically position their stations so as to improve emergency preparedness, accident response and spill clean-up operations. Operators can also design driver training manuals and integrate considerations for these high risk locations.

The time series graphs (in figure 5-6), shows consistent high accidents in the month of December of the years under consideration. This can be associated with the traveling culture in Nigeria during the Christmas season which results in more demand for petroleum products and elevated traffic volume. This result can also help in yearly distribution of regulatory activities.

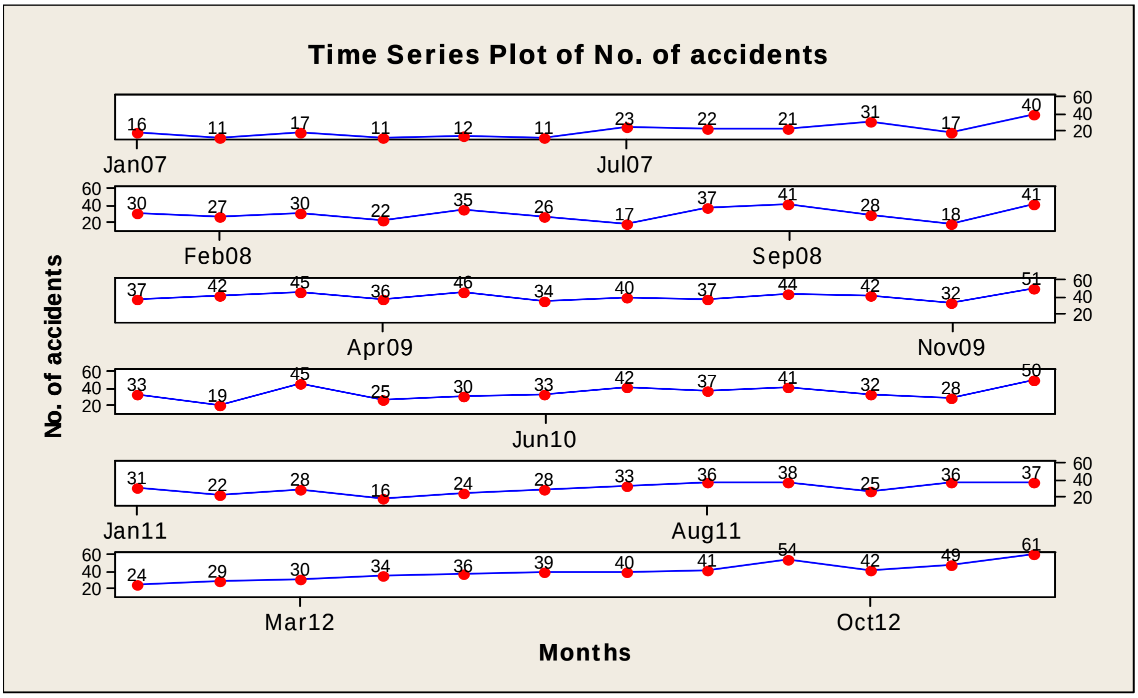


Figure. 5-6. Time series of monthly accidents

5.3.3 Accident consequence

From the 2318 accident reports analysed, 39% resulted in injuries of various degrees, 9% resulted in only fatalities while 33% resulted in both injuries and fatalities. Using equation 5-6, to calculate the cumulative frequency of the number of death, accident consequence were categorised based on fatalities i.e. (Yang *et al.*, 2010):

- Category 1; accidents with 1 – 5 deaths
- Category 2; accidents with 6 – 25 deaths
- Category 3, accidents with over 25 deaths.

Most of the accidents with deaths fall under category 1 with approximate cumulative frequency of 0.89, while category 2 accidents have an approximate frequency of 0.11. Notably, the accident that caused the most fatalities was the Altoada 07 December, 2012 disaster which resulted in the death of 93 people including women and children most of whom were scooping fuel from a leaking overturned tanker. This is not surprising as poverty has been linked to accidents involving petroleum products in Nigeria (Anifowose *et al.*, 2012).

Factors such as: substandard fabrication of tanker trailers (Dare et al., 2009) and poor emergency response regime in Nigeria (Aprioku, 2003) often results in fire, explosions and uncontained toxic releases which contributes to health and safety consequences (Udonwa et al., 2009). In addition to issues regarding safety and personal wellbeing of accident victims, the environment in accident area are usually severely disturbed. Plants and animals have been killed and the extent of pollution is vast.

At least 70 % of the accidents resulted in LOC with PMS accounting for 81.55%, AGO 10.07% and HHK 8.38% of the LOC classification by product type (see event tree in Figure. 5-1). Lack of adherence to quality standards in tanker construction has largely been associated to high percentage of LOC in accident (Dare *et al.*, 2009) which increases safety and environmental consequences. This can also in part be attributed to the fact that being a developing country, Nigeria depends largely on imported technology. Hence, where this technology is inaccessible local manufactures make do with substandard local technology. Clearly, broader socio-economic issues need to be addressed in managing accident risk in Nigeria.

It is not clear if LOC is often cleaned-up as none of the analysed reports indicated that accident site was cleaned-up afterwards. Uncleaned hydrocarbon LOC increases the likelihood of toxic hydrocarbon compounds spreading over long-distance and reaching receptors outside the accident domain (Citro and Gagliardi, 2012). This perhaps explains the reason why in many cases, community livelihoods are lost as fish in rivers die of pollution and groundwater pollution makes potable water inaccessible (Adewuyi and Olowu, 2012). The photos in figure 5-7 taken during this study fieldwork (July 6th to September 11th, 2013) show destruction on natural environment and pollution due to spills, fire and explosion from trucking activities. This vast record of accident consequences calls for a robust stakeholder collaborative accident prevention and response strategies that integrate both safety and environmental concerns as a fundamental part of a risk management framework.

A: Fire fighting an exploded truck alone Lagos-Ibadan express way (source FRSC)

B: Burnt truck creating vast environmental damage on Gbara road (source NNPC)

C: An accident recovery operation along Kaduna – Abuja express way (source author). Notice the absence of regulators or any of the accident management agencies on the scene

D: Locals tried to avoid contamination of their farms by containing a pool of PMS from LOC involving truck accident (in C) along Kaduna – Abuja express way (source author)

Figure.5-7. Fieldwork photos showing accidents involving petroleum product truck tanker

5.3.4 Accident and fatality/injury rate correlations

Using a 2-tailled Kendell's tau non-parametric correlation between (a) accident figure and fatality figure and (b) accident figure and injury figure shows positive correlation between both comparisons (see figures 5-8 and 5-9). As expected, the results – illustrated in tables 5-3 and 5-4 show minimum positive correlation strength between accident rate and fatality of +0.435 and maximum correlation strength of +0.650 in 2011 and 2009 respectively.

Similarly, 2008 and 2010 recorded peak correlation strength between accident figure and injury figure of +0.677 while a minimum strength of +0.532 was recorded in 2011 at 0.01 confidence levels. The strength of this relationship may depend on contributory factors such as; poor emergency planning and response, and the concentration of population along the road. To ensure effective accident response and possibly reduce this correlation strength, local capabilities needs to be enhanced. Using the strategies for regulatory distribution discussed in section 5.3.2, these capabilities can be enhanced based on priorities for accident hot-spots and within accident prone months.

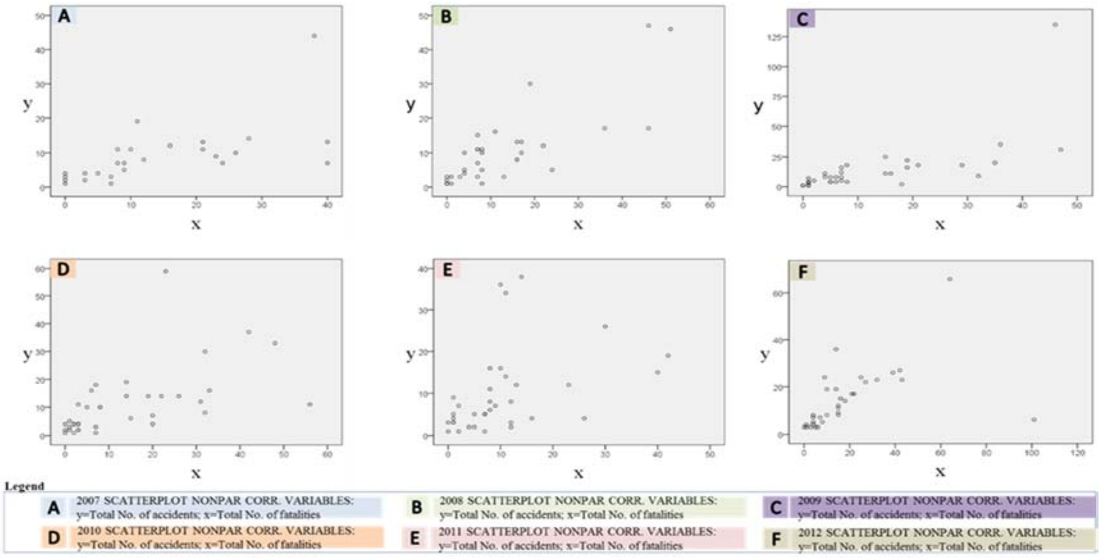


Figure. 5-8. Scattered plot showing correlation between accident figure and fatality figure across all 36 state and the Abuja (2007 to2012)

Table 5-3. Correlation coefficient of 2 tailed Kendall's tau nonparametric between accident figure and fatality figure (2007 to 2012)

Correlation coefficient (accident fig. vs fatality fig)	2007	2008	2009	2010	2011	2012
	0.595**	0.606**	0.650**	0.539**	0.435**	0.621**
	N=26	N=33	N=34	N=37	N=36	N=33

**Correlation is significant at the 0.01 level (2-tailed).

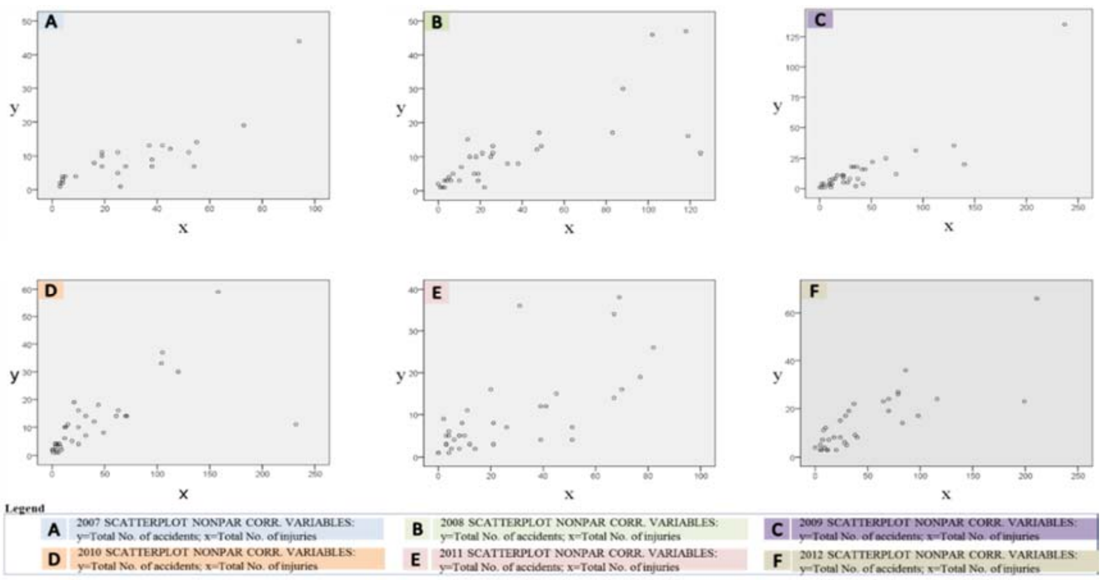


Figure. 5-9. Scattered plot showing correlation between accident figure and injury figure across all 36 state and Abuja (2007 to2012)

Table 5-4. Correlation coefficient of 2 tailed Kendall's tau nonparametric between accident figure and injury figure (2007 to 2012)

Correlation coefficient (accident fig. vs injury fig)	2007	2008	2009	2010	2011	2012
	0.669**	0.677**	0.659**	0.677**	0.532**	0.636**
	N=26	N=33	N=34	N=37	N=36	N=33

**Correlation is significant at the 0.01 level (2-tailed).

5.3.5 Accident and financial loss

Table 5-5 compares the total national quantity (by year) of petroleum product sold/distributed and the corresponding quantity loss from truck tanker incidents. From the comparison, it can be seen that 2009 recorded a peak loss value of 11,287,700 litres accounting for 0.12% of the total distributed volume for that year while a minimum loss value of 51,345,000 litres (0.05%) was recorded in 2007. The table also shows the corresponding vehicle assets damaged. The extent of damage to the assets was not reported hence further cost evaluation was not considered.

Table 5-5. Percentage (%) product loss and property damage

Year	Product sale/distribution per year (PMS, HHK and AGO) (10^3ltr)	Recorded product loss due to truck accident. (10^3ltr) (PMS, HHK, AGO)	% Loss	Damaged Assets (No. of vehicles)
2007	10111166.2	5134.5	0.05	342
2008	10429768.43	8635.2	0.08	518
2009	9423715.55	11287.7	0.12	665
2010	13423297.54	9743.5	0.07	686
2011	12662114.38	9383	0.07	625
2012	12527533.79	9937.63	0.08	997

By multiplying the quantity loss for each product type with the pump price of product as at the year under consideration, an estimated monetary value of loss was obtained as shown in table 5-6. In table 5-7, the cost impact of fatality and injury figures was estimated using the figures extracted from a study by Battelle (Battelle, 2001). In the study, injuries and deaths were valued to be the amount the United States Department of Transport (USDOT) would be willing to spend to avoid an injury or death. This averaged out to be \$200,000 to avoid an injury and \$2,800,000 to avoid a fatality. Similarly, the study estimated that for a typical full tanker spill of 33,000 litres (8000 gl), \$7,000 of environmental damage would be incurred. The study, however, considered the dollar value as at 1996 and the cost of environmental damage was evaluated after an assumption that the spill was cleaned up.

Hence, for this study the extrapolated 2014 dollar value was used. From the analysed accident reports, it is unclear whether spills were cleaned up. Therefore, for the purpose of simplicity, similar assumption was made on spill clean-up and the extrapolated 2014 dollar value for environmental damage was also adopted.

Table 5-6. Cost estimation of product loss @ $1 = N150.

	2007			2008			2009		
	Pump price (N)	Product loss 10^3L	Cost (N10^3)	Pump price (N)	Product loss 10^3L	Cost (N10^3)	Pump price (N)	Product loss 10^3L	Cost (N10^3)
PMS	65	4095.4	266201	70	6712.4	469868	65	9600	624000
HHK	50	528.4	26420	50	893.4	44670	50	642.2	32110
AGO	60	510.7	30642	150	1029.4	154410	150	1045.5	156825
	Total (N)		323263			668948			812935
	Total ($)		***2155087***			***4459653***			***5419567***

	2010			2011			2012		
	Pump price (N)	Product loss 10^3L	Cost (N10^3)	Pump price (N)	Product loss 10^3L	Cost (N10^3)	Pump price (N)	Product loss 10^3L	Cost (N10^3)
PMS	65	7943.4	516321	65	7456.5	484672	97	8328.3	807841
HHK	50	908.8	45440	50	772.9	38645	50	789	39450
AGO	150	891.3	133695	150	1153.6	173040	150	820.4	123056
	Total (N)		695456			696357			970347
	Total ($)		***4636373***			***4642383***			***6468977***

Table 5-7. Accident cost impact estimation. Note: the dollar value used = extrapolated dollar value in 2014. Where $1 ≈ N84.58 in 1996 and $1 ≈ N150 in 2014

Year	Fatality	Estimate cost impact ($)	Injury	Estimated cost impact ($)	Quantity loss	Environmental damage cost impact ($)
2007	369	1832347728	741	262827513	5134500	13648985.02
2008	434	2155119008	1124	398674932	8635200	22954857.42
2009	434	2155119008	1345	477062085	11287700	30005969.07
2010	519	2577204528	1405	498343665	9743500	25901039.15
2011	374	1857176288	931	330219183	9383000	24942725.95
2012	614	3048947168	1562	554030466	9937630	26417092.8
Total cost ($)		13625913728		2521157844		143870669.4

From tables 5-6 and 5-7, the accident cost impact categories considered, i.e. fatality, injury, environmental damage and product loss cost transport operators in the downstream sector of the Nigerian economy an approximate sum of $16.32b US dollars from 2007 to 2012. Notably, of the total evaluated amount, fatality account for $13.63b.

Further evaluation also shows that the downstream sector losses are on average $2.72b per year on accidents with each accident costing an average value of $7,040,001.85. This has negative investment implications to the estimated $106.7b (Okulaja, 2013) economic value of the downstream sector. The amount could even be more if other direct cost variables such as; clean-up cost, property damage, cost of evacuation of victims and traffic incident delay cost or indirect cost variables such as cost of litigation and persecution, fines, reputational damage, increase in insurance premium, etc. were considered.

Taking these observations into consideration, it should be noted that cost analysis results were integrated in the context of establishing a general estimate or bound on the financial impact of this problem rather than a precise valuation. Clearly, in Nigeria, accident cost is not as high as estimated based on U.S. data and this perhaps could be the reason many transport company pay less attention to human safety and the environment in their operations. If the cost here was applicable to the Nigerian system, then companies will have strong incentives to adhere to good safety measures. Therefore, by using this model regulators can represent a systematic attempt to benchmark the financial implications of the problem based on the best available data. Hence meaningful policy inferences can be derived for risk management purposes.

5.3.6 Mapping accident causation data into Rasmussen's Risk Management Framework.

To explore and understand the relationship between causal factors across the socio-technical levels of truck tanker operations, the information from accident risk assessment, thematic analysis of semi-structure interviews analysis, road inspections and industry reports was used in the AcciMap shown in figure 5-10. The aim here is set a structured holistic view of the factors that need to be integrated into the risk management framework.

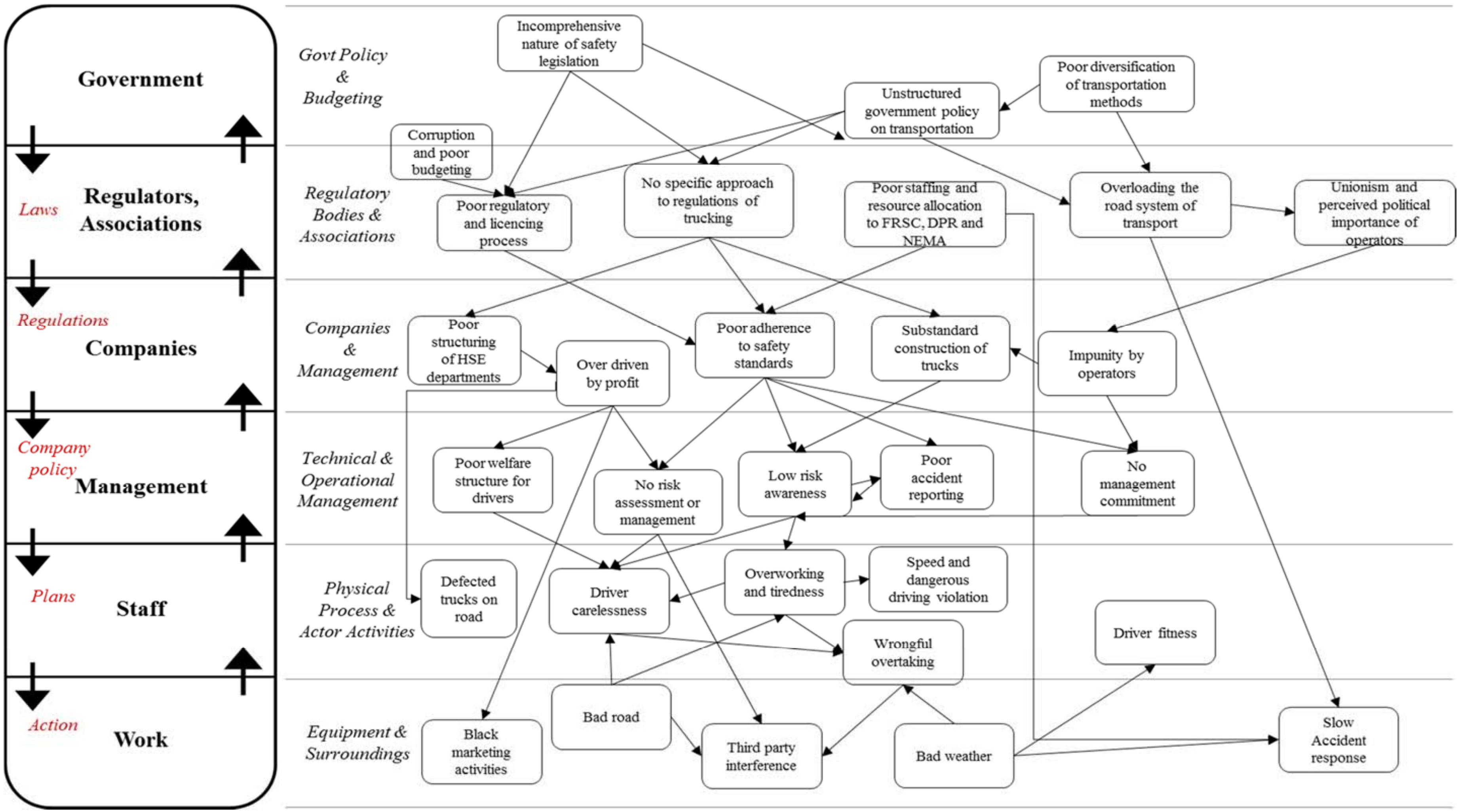


Figure 5-10. AcciMap for trucking petroleum products in Nigeria

Similar to the findings in pipeline AcciMap analysis, at government level, the AcciMap in figure 5-10 shows how faults in government policies results in poor national transport strategies and defective legislations which makes the regulatory approach by FRSC and DPR ineffective. Moreover, based on the review of regulatory framework in Chapter 3, these agencies have no clear or structured approach to dealing with the regulation of petroleum product distribution. Evidently, issues such as poor regulation and licencing of trucking operations may have emanated from faults at this level.

Also from Table 5-8, all the regulators also recognised that poor staffing and resource allocation form part of underlying issues limiting the effectiveness of truck tanker regulation. This limits regulatory spread and companies often see that as opportunity to operate whilst adhering to poor safety standards.

Table 5-8. Thematic cross-content analysis of semi-structured interview with regulators

Underlying accident causal factors	**Challenges of regulatory enforcement**	**Stakeholder collaboration in regulation**	**Existence of risk management strategy**	**Contributing factors to lack of efficacy of strategy**	**Approach proposed for managing risk**
Lack of risk knowledge and awareness (1, 3, 4) **Lack of adherence to safety rules (1, 2, 3)** **Lack of maintenance and adherence to tanker construction standards (1, 3)** **Poor accident reporting culture (1)**	Poor staffing and resource allocation (1, 2, 3, 4, 5) Unionism of operators and political issues (1, 3) Cabals and rent seeking culture (3, 4) Not learning from past incidents (1, 3, 4) Over reliance on one mode of transportation system (3, 5)	Existence of interface (1, 3) Existence of collaboration (2, 3)	Safety meeting with stakeholders (1, 3, 5) Trucking Policy and standards (1, 3) Issuing monthly directives and trainings (1)	Lack of appreciation of safety and environmental knowledge (1, 4) No specific method of regulation is applied (1, 3, 4) Impunity and perceived importance of operators (3, 4) Lack of top management commitment by operators (1)	Creation of adequate safety and environmental awareness (1, 4) Collaboration with other regulators & trade unions (1, 2, 3, 5) Improve regulatory compliance (1, 2, 3, 4) Diversify transport system (1, 2, 3)
Number in bracket represent respondents, where 1 = DPR, 2 = NEMA, 3 = FRSC, 4 = NOSDRA, 5 = FSD.					

Even when it is possible to forestall regulatory compliance using strict regulatory means, companies often resist such approach via their strong trade unions.

Poor resource allocation also have possible effect on the efficiency of accident response. From first-hand experience, the researcher witnessed a truck tanker accident recovery operation on the Kaduna-Abuja express way whilst conducing the road inspection. There were no visible presences of regulators or response agencies even with claims by the truck driver that he has put a call through to them. A follow-up interview on that accident revealed that the accident responders (FRSC, FFSD and NEMA) simply lack the resource to respond to every accident.

Perhaps a more disturbing contributory factor to ineffective regulation is the issue of corruption within the licensing structure – as is illustrated by the following quotation from an interview with a transporter:

> *"These are the faults attributed to government. You see, back in the days before you become qualified to drive a truck tanker you will have to go to a Vehicle Inspection Officer (VIO) and get tested before getting a licence. But today if you pick 1000 Nigerian drivers at random you will not find 1 that has gone to do driving test before getting his/her licence. So he may not know the rules and regulations of driving. In fact as I am talking to you, today is Sunday right, if you have 5000 Naira (about \$33), by tomorrow Monday or Tuesday, you'll get a valid driving licence, and you can even choose the classification you want to be given" (IPMAN interviewee, 17th August, 2013).*

The cited comment rises concern about the risks associated with obtaining a licence without going through any form of test and the way individuals can practically buy a licence of the shelf even with on evidence of demonstrating their driving abilities. There are also concerns as to whether the \$33 paid is being remitted to government coffers or hijacked by few corrupt officials thereby encouraging such illegal licencing procedure for selfish again. This problem was also acknowledged by FRSC and NOSDRA. There are claims of licencing reforms as the FRSC appears to be restructuring its procedure for obtaining drivers licence (FRSC, 2012). The challenge, however, is whether it has the capacity to deal with this amongst the economic and political sensitivity of the industry.

The total collapse of other transport system such as rail and inland waters mainly due to poor government policies results in overloading of road transport system. This affects the effectiveness of accident response as accident prone transport corridors are often overloaded. Also, by overlying on road system, union bodies have somewhat been strengthen to the point that they sometimes hold the entire national supply chain to ransom in order to resist any strict regulation. This perhaps is the reason why companies under such union bodies operate with impunity. Consequently, operations at management, staff and work levels are affected by this sheer lack of adherence to rule and regulations. The situation is the same for self-employed truck owners/drivers.

Although the regulatory agencies (see table 5-8) appear to have some form of risk management strategies such as safety meetings, safety policy documents and issuance of monthly safety directives, evidence show that they all operate in a fragmented manner with very limited cross-organisational communication and collaboration. For instance, when ask if DPR can enhance their regulatory capacity via regulatory collaboration, the responder replied:

'You see, the law does not allow for DPR to collaborate while carrying out its statutory functions, but we relate to a limited extent with fire agencies during construction and we ask for post construction fire certificate before issuing licence' (DPR interviewee, 5th August, 2013).

This blur nature of regulatory collaboration has negative implications to the effectiveness of accident prevention and emergency preparedness and response which ultimately increase the intensity of safety and environmental consequences.

Not surprising, at company management and operational level, there are evidence of low risk awareness and poor accident reporting and investigation. Perhaps due to these reasons, risk management and safety is not taken seriously as evident in poor driver behaviours such as dangerous driving and speed violation. Table 5-9 also show how all the operating stakeholder groups identified lack of top management commitment to safety as challenges for adhering to regulations.

Table 5-9. Cross-content analysis of semi-structured interview with operators

Underlying accident causal factors	**Challenges of adhering to regulations**	**Reasons for high accident/ consequences**	**Existence of HSE internal policy**	**Contributing factors to lack of efficacy of policy**	**Approach proposed for managing risk**
Poor regulatory and licencing procedure (1, 2, 3) Over emphasis on profit and not safety culture (2, 3) Poor welfare arrangements for drivers (1, 2) Bad road (2)	Bribery and corruption (2, 3) Poor staff capabilities, funding and lack of top level commitment to safety (1, 2, 3) Low risk perception and level of education (1, 3)	Carelessness and driver tiredness (1, 2, 3) Poor response by emergency response agencies (1, 3) Black marketing activities (2) Poor construction of tanker trailers (2, 3) Poor town/route planning (2)	Yes (1, 3)	Lack of Leadership commitment (1, 3) Poor positioning of HSE department in organisational Structure (3)	Better structure of national transport system (2, 3) Robust safety policy (2,3) Repositioning of HSE department within organisation (3) Better knowledge of operations (1, 2, 3)
Table Key: 1 = MOMAN, 2 = IPMAN, 3= NNPC					

The work environment in most of the companies is overdriven by profit. This approach to operation limits management attention to risk management and driver welfare. For instance, because driver welfare is poor, drivers indulge in dangerous driving mainly due to the pressure exerted on them to deliver and also in their quest to make more money as the amount allocated to them as their travel allowance is too small (as seen the citation below by a driver).

> *"Our companies don't care about driver welfare. This is because they are aware of the employment situation in the country. They underpay the drivers. Currently the traveling allowance for drivers of tankers is NGN 10k ($67) per trip. This trip can sometime take up to 3 days…. Because the traveling allowance is so small, you find out that drivers work overtime, travel at night, and get themselves over used and tired" (MOMAN interviewee, 23th July, 2013).*

The contribution of human factors to accident occurrence is captured in the above citation. As a result, drivers show trends of blatant disregard and deliberate breaking of rules, mostly by a desire to deliver products despite any prevailing constraints such a bad road or weather conditions. This routine violation has become a normal way of working within the work group, which may largely attributed to: the desire to cut corners to save time and energy or even to steal products and sell in the black market; the perception that legal driving rules are too restrictive or that the rules no longer apply; and lack of adherence to driving rules both at regulatory and operating organisational levels. Based on the Maslow's theory of needs, this assertion may be yet another reason why drivers behave in an unsafe way. The motivation here is hinged on survival as the drivers are mainly working to meet their most basic needs in life. A driver whose lowest level needs have not been met will not make job decisions based on compensation, safety, or stability concerns. Such a person will revert to satisfying their lowest level needs when these needs are no longer met or are threatened (King, 2009). The callous allowances currently being paid by operating companies will cause the drivers to feel threatened about the ability or desire of the organization to continue to meet their physiological and security needs. Driver welfare, therefore, needs to be addressed as part of risk mitigation strategy. Similar levels of hierarchical needs should be addressed for employees in regulatory context as there may also be a relationship between the need to address their psychological needs and the corrupt practices within the licencing structure of trucking operations. Regulatory officers may be motivated by their psychological needs that all they think about is their survival in terms of what to eat and/or wear. Once this need is attain via adequate salary compensation, they may begin to think about the next hierarchy of need, i.e. their safety and the safety of people around them.

5.4 Risk management framework for truck tanker operations

The risk mitigation initiatives discussed in this framework were inspired by key findings from risk assessment in Section 5.3 and inputs from regulatory requirements and engagement with stakeholders informed its scope. The framework (visually illustrated in figure 5-11) presents an approach via which key issues identified within the current transport system can be addressed to enhance risk management for safe petroleum 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, as critical success factors in accident prevention and response. The framework advocates 'action' as an important element of risk management and should comply with regulatory requirements.

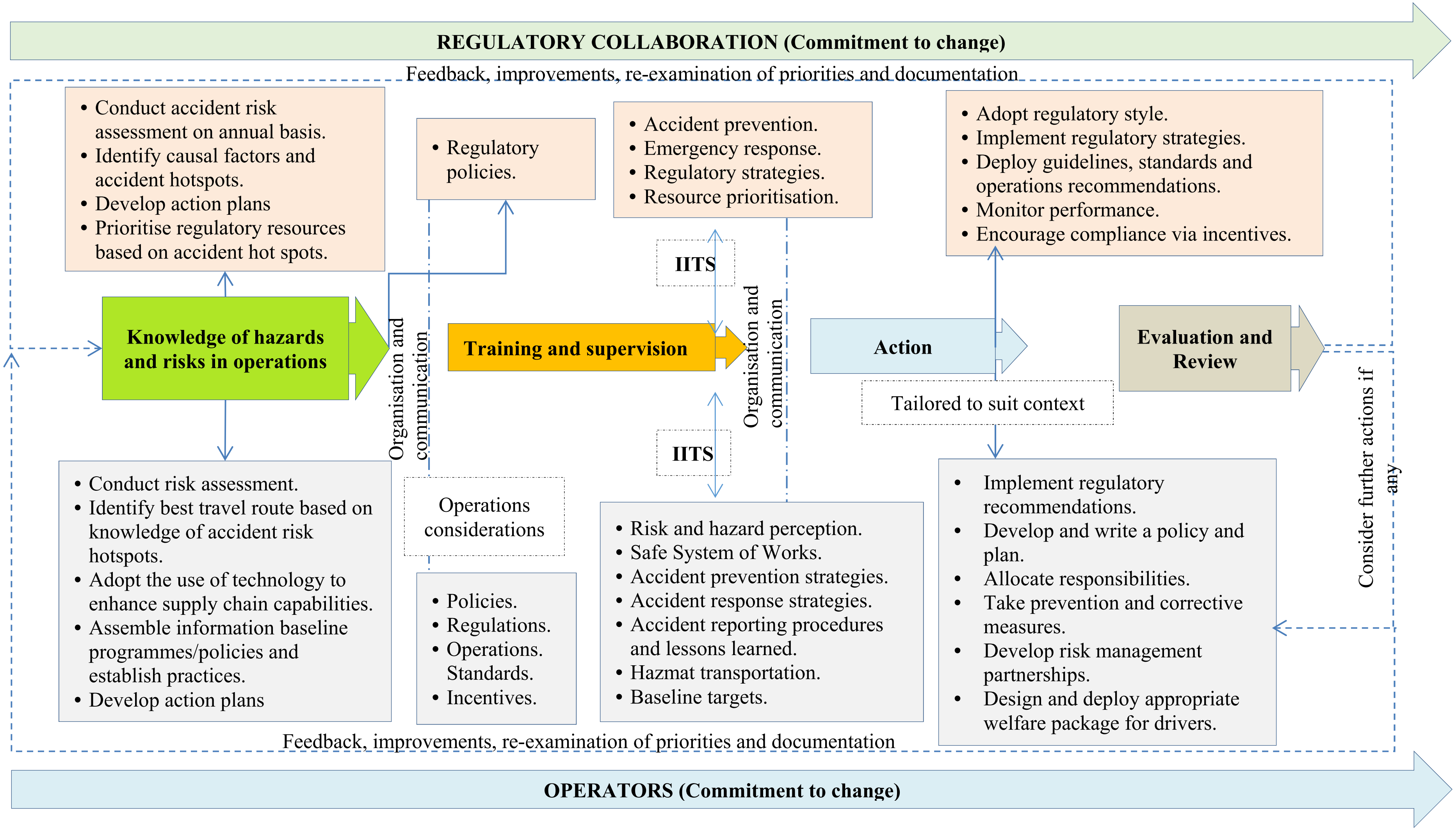


Figure.5-11. Stepwise approach to risk management for petroleum product transportation using tuck tankers

5.4.1 Regulatory collaboration

Accident causal factor analysis in Section 5.3.1 reveals human factors as the main contributory factor to accident causation. To address this issue, adequate regulatory coverage of trucking activity will be needed. However, all the interviewed regulators acknowledged lack of resources and poor staffing as factors limiting regulatory coverage as illustrated in the following citation.

'…We find ourselves in a situation where we don't have enough vehicles to cover the length and breadth of the country and to be able to do that we need mobile patrol, heavy duty vehicle to work with.'
(FRSC interviewee, 10th July, 2013)

Such weakness in accident management practices, particularly the impact of limited regulatory resources has been reported as a contributory factor that limits road safety monitoring activities and also constraints the ability of first responders to respond to an accident immediately upon notification (Al-Kaabi *et al.*, 2012). Therefore as an integral part of this framework, the regulatory collaborative structure (in figure 5-13) is proposed based on statutory requirements to aid inter-agency collaboration at all levels. It is hoped that with this approach, all the stakeholder organisation with regulatory responsibilities can integrate their interest, share information and increase their presence from both preventive and responsive perspective.

For instance, in reactive terms, loading and unloading operations can be regulated by DPR in depots, tank farms and retail station while FRSC monitors truck movement on roads. Similarly, in reactive terms, DPR can investigate and impose fines on defaulter reported to them by FRSC via their collaboration. This way, all the nodes (Loading – Transporting – offloading) will be properly regulated since DPR is statutory required to only covers petroleum installations and FRSC covers roads. Similar collaboration should be encouraged across all the agencies.

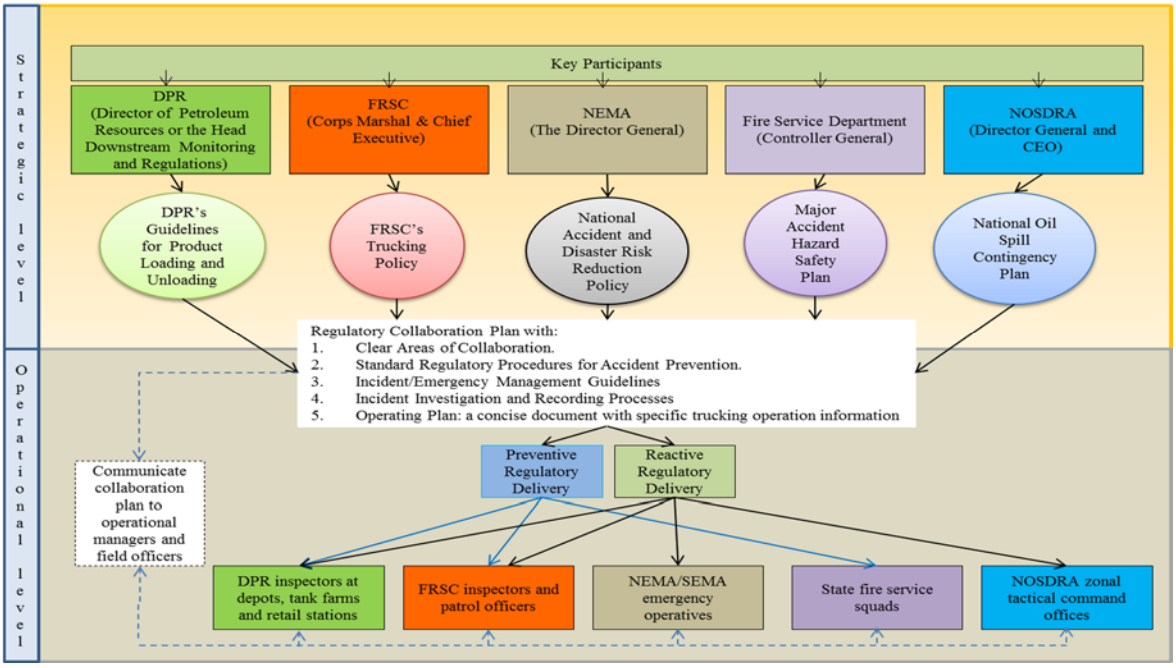


Figure 5-12.Collaborative framework for regulators

The workability of the framework will require commitment at the strategic levels, of regulatory organisation. Governed by the consortium of the heads of the regulatory agencies, safety targets can be set and reviewed on a quarterly basis. Top managers should integrate their guidelines and policies into a regulatory collaboration plan with each agency having clear inclusive statutory roles that should be properly communicated to field offices. Furthermore, the regulatory collaboration plan, guidelines and policies should be developed in consultation with trade union bodies i.e. IPMAN, MOMAN and Transporters Association.

Evidence also show that the efficiency of the current regulatory framework is greatly limited by the lack of specific and structured approach to regulation. Consequently, neither prescriptive nor performance-based (goal-setting) best practice regulatory approach can be traced. As a result, there are no fixed standards, norms and criteria that operators must fulfil to guarantee minimum levels of environmental protection, safety, and occupational health as found in the prescriptive regulatory approach. Similarly, there no obligation of continuous improvement and best available techniques adopted by the operators to ensure safety as low as reasonably practicable. Regulators in Nigeria need to determine what system will best suit the characteristics of truck tanker operators. The adopted system should however be integrated, simple and devoid of unnecessary complexity such that safety legislations are adhered to with minimal resource demand where possible.

Regulation can be developed and deployed similar to the European ADR regulation for carriage of dangerous goods (ADR 2015). ADR is highly prescriptive but structured logically with a guiding principle which follows that if care and time are taken, the answer to most problems can be found. Therefore, there is little or no need for explanatory guidance. 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. This will make it easier for the regulators to monitor both vehicle road worthiness and driver capabilities.

ADR also integrates a requirement that mandates companies (including self-employed) to appoint a safety advisor to guide them on the legal, safety and environmental aspects of hazmat transportation. If a similar approach is taken in the Nigerian context, the trade union bodies can play a vital role particularly in issuing safety advice to small companies and self-employed truck drivers. Regulators on the other hand can concentrate on ensuring that the union bodies are certified, capable and legally allowed to issue safety advice.

Under the European Agreement on ADR, drivers of vehicles with tanks and certain tank components, and some drivers of vehicles carrying dangerous goods in packages, must hold a special vocational certificate of training, sometimes referred to informally as an 'ADR Certificate'. Similar approach can be taken by FRSC and DPR in ensuring that tanker drivers are well qualified to deal with petroleum products and the hazards associated with its road trucking.

All drivers of petroleum truck tankers should be mandated to attend an approved basic training course. The courses can be used as a means of equipping drivers with information and tools so that they:

- are aware of the hazards in the carriage of petroleum products
- can take steps to reduce the likelihood of an incident taking place
- can 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
- have individual practical experience of the actions they will need to take

Moreover, certification similarly to the Safety and Quality Assessment System (SQAS) can be designed and deployed as part of peer and regulatory review. SQAS is a system used to evaluate the quality, safety, security and environmental performance of logistics service providers and chemical distributors in a uniform manner by single standardised assessments carried out by independent assessors using a standard questionnaire. An SQAS assessment offers a detailed factual and objective report, which each chemical company needs to evaluate according to its own requirements. It shows the company areas for improvement and offers a guideline towards these improvements.

SQAS can also be used in the Nigerian context to eliminate the current fragmented approach and multiplicity of safety programs in petroleum trucking which has been inefficient for both the regulators and operators. Although the SQAS assessment system does not guarantee the safety, quality, and value of the company, it does offer a mechanism for promoting and monitoring continuous improvement. Hence while the ADR approach will guarantee safety of petroleum trucking in Nigeria, monitoring of continuous improvement can be achieved with the SQAS assessment. Again, this can be used by trade union bodies as a means of conducting safety peer review via the following process:

1. In responding to a request from a retailer or NNPC, the trucking company (logistic provider) can contracts an independent qualified assessor to carry out an SQAS assessment. The independent assessor can be either IPMAN or MOMAN.
2. The assessor will then carry out the assessment and produce a factual, signed and dated report.

3. The truck company can supply the report to any requesting company it serves or agrees that the assessment data can be accessed from a central trade union database.
4. The individual client (retailer or NNPC) will then evaluate the factual assessment results against his or her own requirements and agree with the trucking company on priorities for continuous improvement.
5. Periodic improvement reassessment can then be scheduled as a follow-up process.

Overall, SQAS will provide downstream petroleum trucking companies and their trade union bodies with a single concerted industry approach which will encourage mutual understanding and also allow company (and self-employed) objective evaluation adapted to individual needs. This will then result in achieving a systematic focus on issues requiring attention in a cost-effective (in money and time) manner with capabilities for continuous improvement.

5.4.2 Commitment to change

To ensure effective development and deployment of the collaborative approach and stakeholder engagement discussed in section 5.4.1, there needs to be commitment to change across both classification of stakeholder organisations, i.e. regulators and operators. This should be supported by top management commitment as both regulators and operators acknowledged the strategic need for top management commitment.

Commitment levels in operating companies can be tracked by assigning duties, risk communication strategies, level of training and how risk might be incorporated into personnel reviews. Management can create the environment and organisational structure that stresses the importance of safety and risk management within the organization in everyday operations. An example is making safety records of an employee one qualification for hiring and promotion.

Regulators on the other hand need to hold top managers in operating companies personally accountable for accidents. Notably, this can be difficult to achieve due to the small structure and financial size of most operators in Nigeria. Nevertheless, commitment levels have to be maintained and motivated by ethical morals and strict collaborative regulatory application irrespective of the company size.

There are research debates as to the style of management that best enhances effective safety and risk management within organisations (Garrett and Perry, 1996; Wirth and Sigurdsson, 2008) and the required safety commitment at various management hierarchy (Flin, 2003). Perhaps this needs to be investigated within the context of petroleum product trucking business in Nigeria. Notwithstanding, Cox *et al.* (2004), Fruhen *et al.* (2013) and Flin (2003) agreed that top management commitment influences safety at all levels in an organisation and is key to accident prevention as it encourages identification, observation, intervention, review, monitoring and improving safety culture. Hence, operators need to go beyond writing policy statements to influencing culture via the physical participation backed with financial commitment.

5.4.3 Organisation and communication

It is essential that management communicate policies adequately to all employees, whether fulltime and/or contract. As it is common practice within the industry, large retail companies such as the NNPC-retail outsource 100% of product transportation to small transporting companies or self-employed tanker drivers. These companies bear the NNPC trademark, but are laden with poor safety culture, yet NNPC remains reluctant in forestalling their safety standard. For instance, when asked about the poor safety characteristics of outsourced NNPC trucks, the responder replied:

> *"For our own image to be protected we are working on how to take the responsibilities of putting some safety measure while leasing the trucks such as: tracking systems; education and awareness on loading; speed limit restrictions; and guidance on discharging and offloading in retail stations. But, with all due respect, the calibre and level of education and literacy of the drivers is also a challenge".*
> *(NNPC interviewee, 24th July, 2013)*

This practice needs to change; operators need to function with integrated safety management and performance systems across all parties involved in their activities (especially contractors) so that everyone has clear understanding of what the company is trying to achieve and why. The regulators in this case should also hold the mother company responsible of any violation from its contractors.

5.4.4 Operational hazards and risk awareness

As seen throughout the result and discussion section good knowledge of risks and hazards involved in trucking operation is lacking. The citations below illustrates operators understanding of how this remains an issue.

"To a large extent, as you are aware, accidents don't just happen accidents are caused and the factors of such accidents are all cantered on issues of awareness, and lack or risk knowledge…" (NNPC interviewee, 24th July, 2013)

"…you will see people involved black marketing activities, selling fuel in cans. And these people don't know anything about the risk involved in selling petroleum products…" (IPMAN interviewee, 15th July, 2013)

Hence, the framework recommends that operators should provide staff with relevant information via routine risk assessment in the form of material safety data sheets and clearly labelled trucks with standardised FRSC classifications. This element can be enforced even with issues of poor regulatory staffing which leads to ineffective regulator coverage. Using the accident distribution mapping method presented in section 5.3.2, regulator can prioritise and enhance regulatory coverage based on history of accident occurrences and identification of accident hotspots.

By identifying accident hotspots, accident risk knowledge of high risk states can be integrated into national regulatory planning and management framework (Löbmann, 2002). Hence, with this knowledge, FRSC can perform detailed road audits and impose traffic compliance by enhancing the frequency of patrols specifically in high accident risk states. Similarly, NEMA, NOSDRA and Fire Service Departments can strategically position their stations 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.

In addition, companies should be encouraged to conduct simple process reviews and risk assessment such as "What If Analysis" to identify high risk points. Although less formal, this also contributes in evaluating risks on routes, travel time and supply chain needs based on regulatory requirements for loading, transport and delivery. Such analysis should provide drivers with information about: exposure to vibrations and prolonged sitting (design of seat, cabin and other equipment); manual handling; falls from heights; exposure to noise – when loading and unloading, when driving trucks (motors, tyres, ventilator, etc.); inhalation of vapours and fumes, handling dangerous substances (exhaust fumes, chemicals on-board, fuel, road dust exposure while loading, unloading and at rest stops, washing and preparing vehicle); climatic conditions (heat, cold, draughts, rain, etc); adopting ergonomic work conditions and healthy lifestyles. This should be checked by DPR who are mostly present at the point of loading. Regulators can also expose the hidden but often high direct and indirect cost of accidents to operators so as to motivate them into adhering to good safety systems.

5.4.5 Information, instruction, training and supervision (IITS)

In addition to legal and insurance requirement for training, operators also need to see IITS as an integral part of their professional and moral responsibilities. Companies should look outside for additional training resources from emergency response services such as the Fire Service Departments and Trade Union Bodies. This control point is vital considering the fact that 79% trucking accidents are caused by human factors.

While training has been found to improve technical and operational capabilities, training alone is not a sufficient means of improving and maintaining good safety culture (Komaki *et al.*, 1980). Behavioural programmes, particularly those employing nonmonetary consequences such as feedbacks and supervision, have been found effective as motivational strategy and readily acceptable to employees (Komaki *et al.*, 1980). This should form the context of safety culture improvement across operating companies.

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. This information can then be used to identify the priority of safety over competing goals such as speed of product delivery. The same information can be used to communicate (high) safety priority and to design training needs. Where the operator is a ‘one man business’ or a self-employed driver, safety awareness training and monitoring can be done via partnership with trade unions. Regulators should produce operator's training logs which should form part of documentation for licencing renewal. Reactionary training on emergency response should also be considered by all stakeholders.

5.4.6 Action

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). Therefore, the underlying philosophy of this framework emphasises "action" as the backbone for effective risk management.

For regulators, action should entail identification and deployment of the best regulatory style obtained from the regulatory collaboration plan to suite the Nigerian context. This should be followed by deployment of operation standards, guidelines and recommendations whilst also monitoring performance via annual reviews. Importantly, safety regulatory incentives and penalty systems needs to be introduced due to the strong articulated nature of operators and their union bodies. Agreed risk limits should be established in collaboration with the operators. A reward is then given for prompt effective control of risks below the agreed limits on annual basis. The reward can be in the form of waver for cost of licence renewal. Similarly, penalties should be issued where risk limit is exceeded by an operator. However, care needs to be taken because even though this system could encourage continuous safety improvement via planned proactive risk controls, it can also encourage under reporting of accident (Pransky *et al.*, 1999).

Action for operators should entail implementing regulatory requirements. This should be done through clear definition of roles and responsibilities across the organisation. Where the operator is a 'self-employed driver', the owner should be solely responsible for upholding good safety standards in his/her operations. This can be done via partnership and peer engagement with their trade union bodies, i.e. IPMAN and MOMAN. It will also entail improving driver welfare packages as discussed in 5.4.7 below.

For both regulators and the operating companies tacking corruption in the industry should be an integral part of their actions. To reduce corruption, official discretion needs to be limited and government need to make clear the rules of the game. There may also be the need to put in policies that will deter corruption.

5.4.7 Driver welfare

The necessity of prioritising driver welfare within the truck transport systems cannot be overemphasized. Among the strategies for action that will contribute directly to an improvement of the safe driving attitude is a sustained investment in the professional development of the drivers and the improvement of their working and employment conditions as well as their allowances. Many interviewed drivers revealed that the status of welfare and the safety concerns are closely related. For example, when pressured to deliver within very limited work pay, drivers cut corners and engage in unsafe black marketing activities such as product diversion.

Driver welfare also needs the intervention of the trade unions, there should be a minimum welfare package for truck drivers set by these unions. The union bodies need to make the member companies realise that driver welfare is a valuable assets in the companies since their primary aims are productivity and profitability. There also need to be adequate training programmes offered to increase driver competencies, efficiencies and performance.

5.4.8 Evaluation and review

To ensure that the action strategies taken are actually accomplishing its risk reduction goals, it is necessary to periodically evaluate and review the effectiveness of the risk management strategies. Actual targets should be compared with baseline targets. For regulators this should be established on a national scale. Hence annual national accident records should form basis for identifying appropriate indicators. Operators on the other hand should establish and measure targets using agreed limits, their records and records from peers to establish useful improvements in their action strategies and to identify changes to either enhance effectiveness of risk reduction or to reduce implementation cost.

5.5 Chapter summary

The risk assessment conducted in this chapter shows the scale of problems within the context of road transportation of petroleum products which contributes to elevated accidents and associated disasters. Analysis of accident reports shows that 79% of the accidents were caused by human factors such as dangerous driving, wrongful overtaking, and speed violation. From the 2318 accident reports analysed, 39% resulted in injuries of various degree, 9% resulted in only fatalities while 33% resulted in both injuries and fatalities. Most of the accidents with deaths had 1-5 fatalities, with approximate cumulative frequency of 0.89, while 0.11 was obtained as the approximate cumulative frequency of accidents with 6-25. Accident hotspots across Nigerian states were identified. 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, unionism as a means of resisting strict regulation, 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.

Although the framework covers key risk mitigation points within the purview of the statutory requirements and contextual operational practices in Nigeria, issues such as over reliance on one mode of transportation can only be fixed through government's willingness to deal with these issues. Similarly, issues relating to unavailability and slow adoptability of technology needs enhancement using rigorous policies that attracts technological improvements. Perhaps the recent policy on ban of importation of used vehicles into Nigeria will promote regulated standard truck manufacturing within the country. This, hopefully, will improve the standard of truck tanker construction and maintenance.

6 CHAPTER SIX: IMPLEMENTING THE FRAMEWORKS

6.1 Chapter introduction

Chapters 4 and 5 outlined the difficult tasks required for optimised safety and environmental performance in petroleum transportation and distribution operations in Nigeria. Throughout the chapters, a mix of social, managerial and engineering solutions were proposed based on the findings from risk assessment and accident/incident causal factor analysis. The proposed mitigation strategies may be effective because they were developed to function in spite of the limitations identified within the current downstream structure in Chapter 3. The strategies provides ideal solutions by improving regulatory and operational practises with the involvement of all stakeholders.

The risk management frameworks in Chapters 4 and 5 need to be deployed using appropriate policies by both the regulators and the regulated (operators). The policy design should be aimed at improving the integrity of petroleum product transportation and distribution in Nigeria by ensuring that the pipeline and truck systems operate safely while optimising product supply across the country. The target triangle shown in figure 6-1 illustrates the main focus areas for all policy directions.

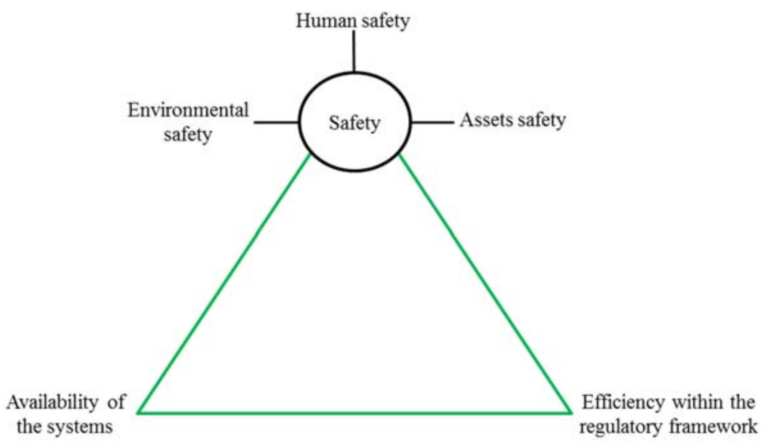


Figure 6-1. Target triangle for risk management policy proposals

Safety within the policy target triangle considers human, environmental and assets safety as key determinant of the systems integrity optimisation in compliance with regulatory requirements in order to ensure that the systems (pipeline and truck) remain available for assured product supply in Nigeria.

This chapter proposes possible policy directions for the implementation of the designed risk management frameworks. The briefs builds on the developed risk mitigation strategies and the statutory interests of various stakeholders and are presented as a concise summary of petroleum transportation and distribution issues, and include some recommendations on the best policy options (Lavis, 2004; Colby *et al.*, 2008; Lavis *et al.*, 2009b; Rosenbaum *et al.*, 2009).

The risk assessment of both pipeline and truck systems illustrated the issues that regulators and operators within the context of downstream petroleum transportation and distribution are faced with. Risk assessment results also guided the development and proposition of risk mitigation strategies. Therefore, it is possible to argue in favour of a particular course of actions and/or give balanced information for policymakers to make up their minds using empirical evidence. Policy briefs are effective ways of providing general background information quickly as a means of addressing decision makers who may or may not know much about the safety, risk and environmental challenges related to petroleum transportation and distribution.

The justification for selecting this tool (policy briefs) came from the researcher's experience when engaging decision makers during the data collection stage of the research. Notably, policymakers move in restricted contexts for decision making – especially regarding time – and that is what the policy briefs aim to bring them, in a brief and simple manner, evidence and action recommendations to help them in the risk management decision making process. The emphasis is on communication that can prompt change.

The policy briefs were developed using the SUPporting POlicy relevant Reviews and Trials (SUPPORT) tools for evidence-informed policy making (Lavis *et al.*, 2009a; Lavis *et al.*, 2009c). The SUPPORT tools sets out a list of questions that needs to be addressed when writing an evidence-informed policy brief. They include:

1. Does the policy brief address a high-priority issue and describe the relevant context of the issue being addressed?
2. Does the policy brief describe the problem, and the consequences of options to address the problem, and the key implementation considerations?

3. Does the policy brief employ systematic and transparent methods to identify, select, and assess synthesised research evidence?
4. Does the policy brief take applicability considerations into account when discussing the research evidence?
5. Was the policy brief reviewed for both scientific quality and system relevance?

Following this introduction, section 6.2 examines the assurance on the developed risk mitigation strategies. Assurance on the risk mitigation provides reasonable assessment that evaluates whether the proposed strategies are effectively designed to achieve its objectives if deployed as policies. Then, in section 6.3, the role of key stakeholders within the frameworks is defined whilst proposing specific policy directions using policy briefs. Section 6.4 illustrates how monitoring and evaluating the cost effectiveness of safety measures can be achieved and 6.5 identifies some implementation challenges.

Throughout this chapter, the pipeline risk management framework in chapter 4 will be referred to as PRMF and the truck tanker risk management framework in chapter 5 TRMF.

6.2 Reflection on the assurance of the risk mitigation strategies

6.2.1 Risk mitigation strategies and top management commitment

PRMF and TRMF will attract adequate commitment from stakeholder organisations from both a regulatory and operational perspective. As regulators are interested in ensuring safe and environmentally friendly operations, the use of evidence-based assessment of risk and environmental impact of both pipeline and truck operations presents factual results that will motivate top management in regulatory organisations to buy into the proposed mitigation strategies.

Similarly, since operators are interest in functioning profitably, exposing the cost of truck accidents and pipeline failure in monetary terms should attract the commitment of management within operational organisations as both frameworks show how operators are losing in financial terms. For many of the stakeholders, availability of fund remains a key challenge to risk management, but risk assessment of both pipeline and truck tanker operations revealed that they are in fact, likely to make more profit with reduction in accidents and incidents.

Because stakeholder risk management interests were assessed via interviews and their statutory responsibilities also evaluated to inform the discussions on the proposed risk mitigation strategies, this will encourage their participation in deploying the proposed strategies. The discussed limitation of risk management legislation (in Chapter 3) may be a restricting factor, however, commitment should be motivated by the magnitude of the effects of these operations on human safety and the environmental problems created.

For the pipeline risk management framework, the host communities present a category of stakeholders (also with a "top management" structure) in the form of community heads or leaders. These leaders are mostly local and have influence on the community risk perception and the level of participation that can be obtained from their communities. Using a royalty payment system, these stakeholders can be economically empowered and engaged in surveillance and vigilance of the pipeline. Moreover, public enlightenment and risk communication will ensure the support of the host communities.

6.2.2 Appropriateness of the risk management frameworks for the context of the operations

The context and structure of the petroleum product supply chain in Nigeria was initially designed such that products were distributed nationwide via the network of 5001 km pipelines from refineries/ import jetties to depots and then transported to retail stations using trucks. However, as illustrated in Chapter 1, this structure currently incorporates the concept of bridging which has been defined as the process of moving products using trucks from refineries, depots and/or jetties to retails points, typically within distance exceeding 450 km (explained in Chapter 1). This is the context within which the risk management frameworks in this study were developed.

From Chapter 1, it was understood that although the pipeline and truck transport systems are interconnected from both an operational and regulatory perspectives, it was vital to have two separate, yet interrelated approaches to risk management. Consequently, the risk management context for PRMF emphasises the need to prevent loss of tightness of the pipelines as this has consequential effects on safety. Optimisation of the pipeline integrity, therefore, needs to be achieved using the PRMF as the mitigation strategies suggested are based on factual assessment of risks and stakeholder inputs. The operator (PPMC) can use the framework in meeting regulatory requirements and making the system available for product supply.

In order to effectively sustain product supply across the country, TRMF was developed such that it operates as a separate entity but also as a part of a holistic approach to ensuing safe and optimised product supply. Though independent of PRMF, the operational criticality of TRMF will 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.

TRMF 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. The framework also looks at strategies for effective distribution of regulatory, monitoring and accident response resources. The aim is not to prescribe a risk management approach to stakeholders, but to provide insight as to how these stakeholders can harness resources to better understand the operational challenges and optimise their operations using the suggested approach. There is, however, the need to state that operators within the TRMF context can vary from a one man truck owner to large multinational companies, the assumption, therefore, is that small operators may lack the capacity to adopt the framework. This is why the stakeholders in this TRMF were approached within their trade union context (IPMAN and MOMAN). Presumably, small operators can have their capabilities improved if TRMF is adopted as part of IPMAN and MOMAN's operational strategy. Therefore, via such collaboration, the union bodies can put in place internal policies, set and peer review their safety objective as suggested in the policy brief No. 3 in section 6.3.3.

6.2.3 Definition of communication requirements for risk mitigation implementation

Communication and accountability for risk management implementation has been recognised as an essential element of risk mitigation. Whether risk management is personal (i.e., for optimisation of commercial operations) or in line with regulatory requirements, or a combination of the two, communication is central to making and implementing risk management decisions. Consequently, in both PRMF and TRMF, lines of communication were established with careful consideration of stakeholder interests and areas of operational participation.

While emphasis was laid on inter-organisational communication and collaborations, recommendations on intra-organisational communication were also made. The involvement of multiple players in pipeline and truck transportation system in Nigeria and regulatory funding issues necessitated this approach.

Across both frameworks, the fundamental aim of communication is to provide meaningful, relevant and accurate information in understanding terms to target audience. Such communication may lead to better understanding of the issue surrounding regulations, commercial operations of pipeline and truck transport systems, and community safety so as to understand and accept risk management decisions. It should be aimed at building trust and confidence, and facilitate higher degree of consensus.

6.2.4 Adequacy of legislative compliance of proposed risk mitigation strategies

The review of the regulatory framework in Chapter 3 provides a detailed analysis of the pieces of legislation within the context of safe operation of downstream petroleum industry facilities (pipeline and truck transport systems included). Importantly, the analysis identified stakeholders with statutory responsibilities as well as those with operational safety and risk management interests. This shaped the proposed frameworks. Hence, risk mitigation strategies that required the inputs of these stakeholders were designed in line their statutory interests.

However, because the legislative framework has been identified to be incomprehensive, some elements of both PRMF and TRMF adopted certain international best practices. For instance the individual and societal risk limits of pipeline in Nigeria has not be defined in any Nigerian pipeline regulatory requirement, hence, the limits used in risk assessment adopts the UK limits. This is also in line with regulatory compliance as the Mineral Oils (safety) Regulations encourages utilisation of international best practices and standards in petroleum industry operations. The challenge, also, is not limited to developing risk mitigation strategies with adequate legislative compliance, but developing the strategies that are deployable. Therefore, section 6.3 identifies key stakeholders with both PRMF and TRMF and proposes some policy directions.

6.2.5 Flexibility of the risk management frameworks

Managing risk is not a one-off fixed event. PRMF and TRMF were therefore designed to be flexible and operated such that they adopt to the changing nature of risk factors. Figure 6-2 describes how flexibility can be achieved within the frameworks to adapt to uncertainties. Within the flexibility figure, policies are designed following risk assessment and development of risk mitigation strategies. The policy translates mitigation strategies into high level statements of commitment upon which risk management objectives are set.

Figure 6-2.Flexibility of risk management the frameworks

For PRMF and TRMF, these objectives can be set against regulatory targets agreed upon by industry players. With this approach, there exist a means to change or react when necessary as risk factors changes. For instance the main causal factor for pipeline failure is interdiction. This may change over time especially if community engagement and other detection technologies prove to be effective in reducing the risk factor. Key performance indicators such as data on the pipelines optimised product delivery can therefore be used to measure the extent of achieved objectives. However, other unknown risk factors may surface over time. This can be evaluated at the review and re-examination of priorities stage, and new policies can then be designed to address the new risk factor.

Similarly, within the TRMF, the evaluation and review stage provides the needed flexibility element required for understanding new hazards and risks in trucking operations. Subsequently, policies can be developed for regulatory enhancement and safe operations. This provides commitment for setting objective which is then cascade through training, information instruction and supervision.

6.2.6 Complexity of stakeholder relationship for risk management

PRMF amalgamates stakeholder interest in the safe operation of the 5001 km downstream pipeline asset. Within the context of its ownership (NNPC), operations (PPMC) and regulation (DPR), the pipeline and all petroleum industry operations is govern by the Minister of Petroleum Resources who chairs the Petroleum Resource Board consisting of NNPC, PPMC and DPR. Therefore, PRMF is recommend to be owned and implemented by the Minister. As part of his/her statutory duty, the Minister should ensure there is a critical commitment to change across both the operator and the regulator. Based on the structure of relationship between the Minister, DPR and NNPC-PPMC, PRMF is considered to have a simple and direct communication line. This offers potential for effective issuance of directives. This relationship is further discussed in section 6.3.1.

The TRMF has a more complex stakeholder structure. From the regulatory perspective, there is a change in regulatory jurisdiction from DRP (when the trucks are within depots, refineries and retail stations) to FRSC when the trucks are on the roads. This makes sole regulatory ownership of TRMF difficult. Therefore, a collaborative accident prevention regulatory approach will be required between DPR and FRSC while other stakeholders such as NEMA, FFSD and NOSDRA contribute in ensuring adequate emergency response.

There is also an observed difference in regulator–operator relationship within PRMF and TRMF. While PRMF has a simple DPR to NNPC communication and instruction line, TRMF has DPR and FRSC to MOMAN/IPMAN/NNPC relationship. Moreover, DPR/FRSC will have a more complex regulator–operator relationship within TRMF as the size and complexity of truck tanker operators can range from one-man operator to large companies with hundreds of trucks in their fleet. Activities of the public (e.g. pipeline host communities or other road users) can also influence the effectiveness and operability of both frameworks. While the potential for safety improvement can be enhanced by reducing accident frequencies from truck tanker operations on road, the inherent risk from poor driving attitude of other road users remains a problem. Therefore, TRMF should be implemented as a means of improving and optimising road safety in addition to other general road safety improvement strategies. Similarly, for PRMF, considerable inputs from host communities and local authorities is required to make the framework effective. The role of all relevant stakeholders within both frameworks is discussed in section 6.3 below.

6.3 Mandates and responsibilities: recommended policy directions

The effectiveness of both PRMF and TRMF will be determined by the extent to which the frameworks are implemented with consistency and commitment at the levels of policy, strategy and operations across relevant stakeholder organisations. As stated in 6.2.6 above, the responsibilities for the strategic planning of the implementation of PRMF lies with the Minister of Petroleum Resources, while the DPR and FRSC will be responsible for implementing the TRMF. The concepts, practices and applications should be agreed across agencies at the national level, and disseminated to key stakeholders at the appropriate stages. The managements of the stakeholder organisations should be responsible for setting the organisational attitude regarding risks across both frameworks. The following sections, therefore, defines the role of various stakeholders within the frameworks and proposes policy directions.

6.3.1 The Minister of Petroleum Resources, ownership and stakes in PRMF

Being the head of the Petroleum Resource Board comprising NNPC, PPMC and DPR, the Minister is responsible for providing governance oversight of PRMF. Policy Brief No.1 provides the Minister with evidence-based risk management policy directions. The first priority of the Minister is to ensure the conduct of ESIA recommended within the framework to better understand key socio-political and economic elements of the pipeline systems. The ESIA should also be aimed at identifying potential ways of engaging local communities in pipeline surveillance and vigilance. It should be performed by an independent organisation to eliminate any conflict of interest. The Minister should enhance and retain the overall responsibility for ensuring that pipeline risks are managed and that there is an adequate risk management system in place within PPMC. This also needs to include deployment of relevant pipeline engineering, inspection and monitoring technologies.

Policy Brief No.1. June, 2015

DESIGNING PIPELINE RISK MANAGEMENT POLICIES

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Sponsored by the Petroleum Technology Development Fund. With risk pipeline assessment input from Prof Phil Hopkins of Penspen UK., J. M. Amezaga., D. Werner and J. M Wood.

KEY POLICY RECOMMENDATIONS

- **To perform an environmental and social impact assessment of the pipelines. Identify risk hotspots and potential ways to engage local communities in pipeline surveillance and vigilance.**
- **To empower DPR to effectively regulate NNPC and PPMC operations.**
- **To direct PPMC-NNPC to set-up risk management funds for capacity enhancement, royalty payment schemes, corporate social responsibilities and pipeline risks public awareness.**
- **To set a pipeline failure reduction target for both NNPC and PPMC. This should be monitored by DPR and reviewed yearly.**

PROBLEMS OF THE DOWNSTREAM PRODUCT DISTRIBUTION PIPELINE

The 5001 km downstream pipeline is characterised by frequent loss of tightness which often results in **accidents with high impact on human safety, the environment and availability of the pipeline asset**.

From 1998 to 2012, **the pipeline killed over 4600 people and injured many**. On average, **the pipeline loses about $100M worth of products yearly**. The effect of these losses to the environment is vast and affects the quality of arable land, surface and ground water quality.

RESEARCH RESULTS

Pipeline risks:
The failure frequency of the pipelines was found to be extremely high (0.351 per km-yr) when compared to failure frequencies of international pipelines (e.g., the UK and USA). **This is mainly due to activities of vandals and interdictors**. However, failure due to mechanical faults was also found to be at high rate. Consequently, the ignition frequencies, fatality, and product losses from the Nigerian pipelines are found to be high. This ultimately made the values of Individual Risk for these pipelines to fall outside tolerable limits.

Failure causal factors
About **96%** of failure on the pipelines are caused by activities of vandals and interdictors. The pattern of pipeline failure apparently increases with history of socio-political events such as elections. The impoverished pipeline **host communities are evidently not benefiting from the pipelines**. They therefore vandalize the facility to register their grievances or turn blind eyes on the activities of interdictors. Some even see the existence of the pipeline as a curse as spills pollute their means of living including farmlands and fishing waters.

NNPC-PPMC own and operate the pipelines with poor adherence to safety management standards. Their staff capacity is overstressed and they lack human and technical pipeline operation capabilities. This is further complicated by the **lack of top management commitments**, and **poor safety and risk management structure at strategic levels**. DPR is also unable to strictly regulate NNPC and PPMC because of vested interests. The safety and environmental laws within the downstream petroleum industry operations are also not comprehensive and laden with implementation challenges.

CONCLUSION

It is important that policies are designed to incorporate both social and technical risk mitigation strategies in operations and regulation of the 5001 km downstream pipeline asset. This is especially needed as PPMC lacks the human and technical capability for surveillance and vigilance of the pipelines, and local communities have expressed readiness to be involved. Thus, while local communities can be involved in the right of way vigilance, other engineering pipeline inspection and surveillance technologies can be deployed for optimised pipeline integrity and performance.

There needs to be better policies that supports effective risk communication especially within intolerable risk zones of the pipelines. This is because evidence has shown that **people are unaware of the hazards posed by pipelines and petroleum products**. Incident response capabilities also needs to be enhanced via a collaborative approach with local responders. It is therefore important to develop a policy that sets aside special risk management funds by NNPC and PPMC.

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The Minister needs to enhance DPR's regulatory capabilities for monitoring the operations and delivery of the pipeline risk management framework in practical terms. This can be achieved by giving DPR the required regulatory autonomy and improving their technical capabilities. There may be a separate function within DPR with specialised skills and knowledge that coordinates and monitors the royalty systems, public awareness and ROW surveillance and maintenance strategies and PPMC's engagement with local authorities and emergency management agencies.

The Minister should ensure that every stakeholder within the pipeline integrity management system is committed to change and, therefore, plays their role in ensuring successful pipeline risk management. The primary responsibility for achieving this rests on the managements of NNPC, PPMC and DPR.

At the launch of PRMF, the Minister can direct NNPC-PPMC to set-up risk management fund for capacity enhancement, royalty payment schemes, Corporate Social Responsibilities, risk awareness programs. The Minister should also set a pipeline failure reduction targets, which should be monitored by DPR. The target can subsequently be used as baseline for further failure reduction and as a means of measuring the performance of deployed risk management policies. The cost-effectiveness of the pipeline risk mitigation measures in relation to pipeline failure fatality reduction and the cost of investing can be evaluated, reviewed and communicated as explained in section 6.4.

6.3.1.1 The role of DPR in the implementation of pipeline risk management policies

By law, DPR have the responsibility of ensuring compliance to the petroleum laws, regulations and guidelines reviewed in chapter 3. The discharge of these responsibilities involves monitoring of all petroleum industry operations including drilling sites, producing wells, production platforms and flow stations, crude oil export terminals, refineries, storage depots, pump stations, retail outlets and all pipelines carrying crude oil, natural gas and the PPMC petroleum products pipeline. This gives DPR key roles to play in both PRMF and TRMF. The role of DPR in Policy Brief No.1, and their effectiveness within PRMF is dependent on the level of autonomy and regulatory strength given to it by the Petroleum Minister. This is because although the review of regulatory framework in Chapter 3 reveals some limitation within the downstream petroleum industry laws, even the existing legislations are poorly deployed by DPR due to vested interests which makes NNPC and PPMC more powerful than DPR.

Therefore, with adequate policies from the Minister to supports the statutory responsibilities of DPR, DPR will be able to deploy existing pipeline safety, risk and environmental management regulations such as the Petroleum Act, Harmful Waste Act, Petroleum Product Distribution Act, Oil Pipelines Act. These legislations cover key regulations relating to “good oil practices” in refining, transporting/distributing and marketing of products, and can also ensure safe and environmental friendly synergy within downstream facilities. And by collaborating with NOSDRA and NEMA via the NOSDRA Act and NEMA Act, DPR can achieve regulations that will provide adequate response in the event of an accident or incident involving the pipelines. DPR also needs to monitor the ESIA to be conducted to ensure adequate regulatory inputs. Their input is also required in any designed royalty and community engagement scheme designed by PPMC and NNPC. There is also the need to strongly involve independent accident investigation bodies so as to make void the current system which is plagued by cover-ups and corrupt practices

6.3.1.2 PPMC-NNPC and the implementation of pipeline risk management policies

PPMC is responsible for the safe operation of the pipelines under consideration. PPMC should, therefore, ensure that the risk mitigation strategies in PRMF are deployed and sustained in accordance with the Ministers policies. This should involve setting up the royalty payment scheme, ensuring proper risk communication and community engagement, maintaining the pipeline ROW and deploying proper technology for pipeline inspection and surveillance. PPMC needs to actively begin the development and deployment of Corporate Social Responsibilities (CSR) to redeem their poor image within pipeline host communities. The concept of CSR is underpinned by the idea that corporations can no longer act as isolated economic entities operating in detachment from broader society. Pipeline host communities have asserted that they do not benefit from the existence of the pipeline in their communities. CSR must, therefore, involve helping to solve important social problems, especially those they (PPMC) have helped create, in order to redeem their image and reputation. A successful process to implement CSR as a means for reputation management will involve (Maas and Reniers, 2014):

- Identifying a desired perception that PPMC wants to achieve,
- Recognition of the significance of image with all stakeholders,

- A critical awareness of the influence of interactions with stakeholders on the PPMC's reputation, and
- Strategic planning for continuous efforts at maintaining relationships with stakeholders.

Reputations take a long time to establish and can be destroyed quickly. Currently the reputation of PPMC within these communities has been tainted for a long time. This has become a liability on the pipeline integrity. PPMC must understand all the factors that affects their reputation and develop measures used to improve it.

6.3.1.3 Role of communities and local authorities

The pipeline host communities have vital roles to play in ensuring the deployment of pipeline risk management policies. These communities are mostly affected by pipeline failure from safety, environmental and economic perspectives. They have shown readiness in ensuring that the pipeline operate safety. Evidence also shows that incident and accident response operations can be better enhanced if the locals are involved in such operations. Local communities can therefore be involved in risk management from both preventive and reactive perspectives.

From the preventive perspective, local communities have the potentials for identifying vandals and reporting any such suspicious activities to security agencies. The structure of many Nigerian communities is such that most communities have a leader or a council of elders and a youth group who also have close interactions with the local elected officer and decision makers. This structure simply ensures the integration and dissemination of information on all the happenings in such communities. Therefore, in many cases vandals are supported or have gained the sympathy of these communities. If these communities are well understood and better engaged, and have an appreciation of the existence of the pipeline in their communities, the integrity of the pipeline can be enhanced as they will discourage interdictions. The communities also need to offer themselves and remain approachable. The current hostility between host communities and PPMC need to stop. Community heads and the management of PPMC have vital roles to play in ensuring this.

The responsibilities of promoting risk education, public awareness and training also rest on the local authorities and community leaders. Community-based risk communication should promote the dissemination of information and knowledge that will change the perception of the populace about the pipelines. Risk information should be based on the understanding of the peculiar social structure and the culture of the people in particular localities, in order to capitalise on the existing social coping mechanisms, and to enhance community participation. The local planning authorities also have vital incident prevention roles to play. Construction and third party activities also contributes greatly to pipeline failure. These activities can be regulated with proper pipeline risk information from PPMC. The ROW of the pipeline has currently been overtaken by infrastructural developments which suggest a weak planning and development control systems exist in the host communities. This is further influenced by lack of pipeline risk knowledge. Therefore, local planning authorities need to promote actions that will result in better development control. These actions should be facilitated by providing legal support in terms of local policies, regulations supported by industry standards and risk knowledge.

From a reactive perspective, since the communities are normally the first to be aware of pipeline incidents, they present a potential opportunity for quick response. However, their capacity remain limited by lack of available resources even though there exist a legal framework in the NEMA Act that can give such response strategy the required legal backing. Therefore, PPMC needs to consider enhancing local response agencies as part of their CSR especially within incident hotspots. This can be in the form of provision of training and firefighting equipment.

The challenge, however, is that with such arrangement, there is potential for PPMC to hijack the safety interest in these local response agencies. On the other hand, local response agencies can also encourage interdiction and vandalism in order to demand for more resources from PPMC. Therefore, care needs to be taken in such capacity enhancement scheme. Such schemes should be regulated and monitored by DPR.

6.3.2 Joint truck safety policy brief for DPR and FRSC

DPR is responsible for monitoring all petroleum industry operations in refineries, storage depots and retail outlets. These are the facilities were 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, and therefore the two agencies should jointly own the designed TRMF. Policy Brief No.2 provides DPR and FRSC with evidence-based truck tanker risk management policy directions.

Priority should be given to developing a defined collaborative risk management regulatory approach that takes advantage of DPR’s coverage within product loading facilities and FRSC’s presence on roads – which can be better enhanced using the accident hotspot identification in section 5.3.2. At the point of product loading, there needs to be policies that encourages checking the road worthiness of both drivers and their trucks before they are allowed to load. Loading points such as depot and refineries also present DPR the opportunity to disseminate safety information which they (DPR and FRSC) can use to enlighten drivers on the hazards associated with trucking petroleum products.

Unlike the current situation where the two (DPR and FRSC) regulate truck operations singly, the new risk management approach should be aimed at fostering strong collaborative relationships so that an integrated industry guideline on hazards and risk management of road trucking can be deployed to target driver behavioural change. Policies on the use of vehicle tracking technology can be used to monitor speed violation, dangerous driving and any hazardous black marketing activities that drivers may be involved in.

From an organisational management perspective, there needs to be a strong interface between DPR/FRSC and the top management of petroleum transport companies. Via engagement with their trade unions, DPR/FRSC can set national accident reduction targets and also set risk based operating standards that also target improving the safety culture of top managers. The cost associated with accidents can be exposed and used as a means of attracting change and where possible, top managers should be motivated to improve driver welfare.

PETROLEUM TECHNOLOGY DEVELOPMENT FUND

Newcastle University
School of Civil Engineering & Geosciences

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JOINT TRUCK TANKER SAFETY MANAGEMENT POLICY BRIEF FOR DPR AND FRSC

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Sponsored by the Petroleum Technology Development Fund. With research supervisory inputs from Dr J. M. Amezaga[1] and Dr D. Werner[1].

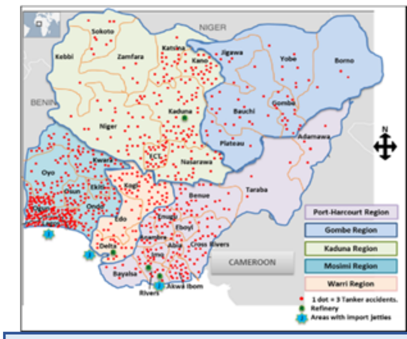
KEY POLICY RECOMMENDATIONS:

- **To have a defined collaborative regulatory approach for accident prevention and risk management between DPR and FRSC and consult with trade unions in setting regulatory targets.**
- **DPR to ensure the following:**
  - **Develop guide for dissemination of hazards information, and driver/management behavioural change with respect to dangerous driving.**
  - **To ensure trucks and drivers are licenced and FRSC certified roadworthy before engaging in activities within refineries, depots, and retail stations.**
- **FRSC to ensure the following:**
  - **Enhance regulatory distribution (road patrols, monitory and inspection) across the identified accident prone states.**
  - **Set accident reduction targets with operators and collaborate with trade unions for training, instruction and supervision, and dissemination of risk information.**
  - **Review the existing licencing structure and incorporate requirement for safety case**

PROBLEMS OF TRUCK TANKER PRODUCT TRANSPORTATION/DISTRIBUTION

From 2007 to 2012 **over 2700 persons died due to 2318 accidents involving petroleum truck tankers**. The accidents also injured over 7100 persons and damaged over 3800 vehicles. These accidents are mostly **caused by unsafe acts such as speed/route violation, dangerous driving and driving under the influence of intoxicants**. Poor quality of tanker construction also increases the frequencies of accidents with loss of containment of hazardous materials. This results in high consequent events. Consequently, of the fatal accidents, 89% resulted in 1 to 5 deaths. **The average cost of an accident is estimated at $7m.**

Some latent conditions within truck tanker operational and regulatory identified as contributory accident causal factors include: **lack of structured approach to dealing with the regulation of truck transportation**. **Poor budgeting, corruption, and resource limitation at government level** which affects regulatory capabilities. This makes it practically impossible to effectively regulate and monitor all trucking operations. Consequently, this results in **poor regulation and licencing of operations.** Companies, therefore, **poorly adhere to safety standards** (which are mostly lacking). At company managerial level**, there is clear evidence of low risk awareness and poor accident reporting and investigation, and poor safety culture**. Safety is not taken seriously and the work environment in most of the companies is **overdriven by profit**.



Kaduna, Abuja, Kogi, Kwara, Ogun, Ondo, Oyo, Delta, Benue, Akwa-Ibom, and Lagos states were been identified as high risk states. The time series of accident events shows **high accident rate in the month of December**. This can be associated with the traveling culture in Nigeria during the Christmas season which results in more demand for petroleum products and elevated traffic volume. Monthly distribution of regulatory activities can be enhanced with this information.

CONCLUSION

DPR and FRSC can develop collaborative approach for better safety regulation of truck tanker operations. Inputs from other stakeholders such as NEMA, NOSDRA Fire services, and trade unions can be used for better risk management integration.

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In addition to the current driving licencing reform by FRSC, there also needs to 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. Again, trade unions can be used to develop the technical capability of designing a safety case. 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. DPR can also carryout unannounced inspection on vehicles within their jurisdiction to monitor the application of safety case in practice.

6.3.3 Enhancing trucking risk management capability via peer engagement: the role of MOMAN and IPMAN

As state in section 6.3.2, Major Marketers Association of Nigeria (MOMAN) and Independent Marketers Association of Nigeria (IPMAN) have vital roles to play in the development and implementation of risk management policies for its member companies. It is, therefore, important that they avail themselves to FRSC and DPR for proper policy consultation. Their policy inputs should target balancing the operational interest of their members with good practice safety and environmental risk management standards.

Having developed collaborative regulatory targets and policy directions by DPR and FRSC, the trade unions can use peer engagement as a means of improving risk management capabilities. Policy Brief No.3 provides them some policy directions.

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.

Policy Brief No.3. July, 2015

ENHANCING TRUCKING RISK MANAGEMENT CAPACITY VIA PEER ENGAGEMENT

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Sponsored by the Petroleum Technology Development Fund. With research supervisory inputs from Dr J. M. Amezaga[1] and Dr D. Werner[1].

KEY POLICY RECOMMENDATIONS:

- **MOMAN and IPMAN to develop guidelines for development of trucking safety policies for member companies. Guideline should align with regulatory requirements from FRSC and DPR and include:**
  - **Requirement for simple risk assessment to demonstrate strategies are in place for accident prevention/response.**
  - **Demonstration of ownership by company head or truck owner.**
  - **A means of measuring cost savings from accident reduction.**
  - **Driver welfare schemes.**
  - **Accident investigation and penalties for defaulters**

- **To use peer review process as a means of monitoring, evaluating and reviewing the quality of developed risk management policies and implementation progress.**

- **To develop risk training and information dissemination strategies using regional, state and local union branch offices**

RESEARCH FINDINGS

There is an opportunity for building truck risk management capacity as part of trade union policies by MOMAN and IPMAN. Many tanker drivers have been involved in road traffic accidents which has recorded over 2700 fatalities (from 2007 to 2012). The accidents are also destructive on natural environment and petroleum assets.

Research shows that about 80% of these accidents are caused by preventable human factors such as dangerous driving and speed violation. The underlying factor has also been associate to the overdriven profit making companies within MOMAN and IPMAN. These companies overwork drivers within a poorly designed welfare system. The drivers lack basic risk knowledge of the hazards involved in trucking petroleum products. There is also a need to improve the quality of tanker construction and vehicle maintenance to reduce the frequency of accidents that results in loss of containment.

Trade union's resistance to adequate regulation has also been found to be costly and ineffective. Companies involved in downstream petroleum transportation lose over $2b per year on accidents. MOMAN and IPMAN can play important roles in improving the safety capabilities of transporters by encouraging regulatory compliance amongst member companies and developing safety training initiatives for company top managers and drivers at regional, state and local levels.

CONCLUSION

There is an opportunity for building truck risk management capacity as part of trade union policies by MOMAN and IPMAN. Trade unions can develop guidelines with regulatory inputs from FRSC and DPR and deploy the guidelines via peer engagement.

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The guideline should contain a simple hazard identification method as a means of improving the risk knowledge of petroleum trucking by road in addition to setting minimum welfare packages for drivers. Using such methods, the operators can have a risk register in each truck with concise demonstration of the identified hazards in each trip to be taken by a driver. This needs to inspected and reviewed at the point of loading by DPR. The risk register should also include details of what has already been done to control the risk (Safety Case), consideration for any further action required, who would do them, and by when. Every register needs to be contextual and not generic and should demonstrate ownership. Ownership can be demonstrated in the form of management sign-off or driver sign-off (for one-man truck owner).

Local branches of MOMAN and IPMAN can also encourage members with good safety records to demonstrate the cost saving they have attained via accident reduction and teach their peers the basic safety and risk management strategies they have applied to achieve such cost savings. The union bodies can also impose penalty measures for defaulting members and develop in-house accident investigation capabilities so that they can learn from accident events. There is also the need for MOMAN and IPMAN to develop minimum welfare standard for drivers, many of whom are currently underpaid and over used.

Against the current truck regulatory situation where there exist constant resistance to strict regulation between DPR/FRSC and trade unions (MOMAN and IPMAN), the risk management policy directions in sections 6.3.2 and 6.3.3 proposes a collaborative approach. With this approach, regulators can set regulatory targets with consultative inputs from trade unions and attain the targets by collaborating with them for development and deployment of training needs, hazard and risk information, operational instructions and regulatory supervision.

6.3.4 Accident/incident response: role of NEMA, NOSDRA and FFSD

There is the need to have a structured approach to accident and incident response involving both pipeline and truck tankers. As stated earlier, local capabilities need to be improved. As the main federal emergency management agency, NEMA should facilitate such initiatives and integrate the interest of NOSDRA and FFSD to develop a federal incident response plan which should be deployed at local and state levels with vertical communication for problem escalation. Such plans need to leverage upon the accident/incident hot spots identified in this study for effective utilisation of scarce resources. Also, based on the established pipeline IR contours, the plan needs to include ways of notifying the public of LOC incidents with intolerable risk contours. For truck transportation, the public around accident prone routes should be considered. The plan should also make requirements for maintaining training and exercising programmes for local emergency response by NEMA, NOSDRA and FFSD.

6.4 Monitoring and evaluating the cost effectiveness of safety measures

In monitoring and evaluating the effectiveness of safety measures a cost-effectiveness analysis is often adopted. In both chapters 4 and 5, the financial implication of the current poor safety and risk management systems in both pipeline and truck tanker operation was evaluated by estimating the cost of pipeline failure and truck tanker accident respectively. The chapters made some risk mitigation recommendations which were integrated into the policy briefs in this chapter. This section uses cost-effectiveness analysis (CEA) (Abrahamsen *et al.*, 2009) to show how the cost effectiveness of PRMF and TRMF can be measured, monitored and communicated to aid decision making. The CEA makes use of cost-effectiveness indices i.e., the expected cost per expected number of lives saved. These indices are presented so that the decision makers identified within the policy briefs are able to see how their decision (which is often influenced by its financial implication) improves safety.

If C_i is considered to be the cost associated with the introduction of safety or lack of safety measures and Z_i is the corresponding total effect related to loss of lives, then safety cost-effectiveness indices can be calculated using the following:

Let the current safety cost for pipeline operations be the cost associated to accidents/incidents estimated in Chapters 4 i.e., average yearly cost of product loss to PPMC plus cost of lives valued at $971.36m per year. Also, let the current safety cost for trucking (estimated in Chapter 5) be the average yearly cost of truck accidents be valued at $2.72b per year.

To see whether safety measures in both PRMF and TRMF is preferred to status quo or not, the cost-effectiveness ratio can be compared with the status quo reference value, *R*.

Implementation of the safety measures are preferred to status quo if the new safety cost-effectiveness ratio is less than the status quo indices. Therefore, for PRMF safety measures, yearly CEA status quo indices reference R can be expressed as:

$$R_{Pipeline} = \frac{Yearly\ cost\ of\ associated\ current\ safety\ measures}{\text{Yearly loss of lives from pipeline failure}} = \frac{971.36}{311.2} = 3.12$$

Currently, \$3.12m/life is the implied cost of averting a fatality within the pipeline operating system. For the PRMF safety measures to be considered cost-effective, $\frac{C_p}{Z_p} <$ 3.12

Where C_p is the cost associated with introduction of the recommended safety measures within the PRMF and Z_p is the corresponding total effect related to loss of lives.

Similarly, yearly CEA status quo indices for truck:

$$R_{truck} = \frac{Yearly\ cost\ of\ associated\ current\ safety\ measures}{\text{Yearly loss of lives from truck accidents}} = \frac{2720}{457.3} = 5.95$$

Again, \$5.95m/life is the implied cost of averting a fatality within the truck tanker operating system. For TRMF safety measures to be considered cost-effective $\frac{C_t}{Z_t} < 5.95$

Where C_t is the cost associated with introduction of recommended safety measures within the TRMF and Z_t is the corresponding total effect related to loss of lives.

If for example PPMC sets aside the sum of \$0.05m per km-year as risk management fund for the implementation of the safety and risk mitigation measures in PRMF, and achieves a fatality reduction of 50% for that year, CEA indices will be:

$$\frac{250.05}{(311.2-155.6)} = 1.61 < 3.12$$

From this example, it can be seen that by investing about 25% of the currently monetary loss value from the pipeline system, a reduction of the implied cost of averting fatality was attained from 3.12 to 1.61. This will give the Minister a view of the effectiveness of the new safety and risk management measure. The method can also be used for measuring the effectiveness of risk mitigation strategies in TRMF.

For this cost-effectiveness analysis, attention was given to the expected number of saved lives as the expected effect, but could easily be adjusted to cover other dimensions of losses such as environmental damage and asset damage.

6.5 Conclusion and possible policy implementation challenges

This chapter proposed risk management policy directions which relevant stakeholders within the developed framework need to deploy to ensure effective risk management within the context of pipeline and truck tanker operations in Nigeria. The policy briefs are based on the empirical findings of risk assessment and the designed risk mitigation strategies in Chapters 4 and 5. The regulatory and operational interests of stakeholder organisations also informed the policy recommendations.

While the risk management policy brief No.1 has potentials for risk reduction and optimisation of the pipeline integrity management system, some possible challenges are observed. First, policies developed for community engagement in ROW surveillance and vigilance, and royalty payment systems need be carefully crafted and deployed such that it does not encourage even more pipeline sabotage as a means of demanding more money from the operator. The process of empowering host communities need to be done with limits such that the system is not hijacked by a few powerful individuals. There needs to be mutual trust between PPMC and these communities. This should be developed via consistency, transparency and flexibility in communication. PPMC, needs to however remain in control of such negotiation.

Second, the need for risk management resources may compound the already existing limitation in resource availability as highlighted by some stakeholders. However, interview with stakeholders revealed that the challenge is not the lack of money but the absence of political will to access and allocate resources effectively, and also the lack of knowledge of the existence of funds. Moreover, the safety and environmental improvement, and the ethical adherence from the increased expenses justifies the higher risk management cost. On the long-term basis, reduction in pipeline failure will mean reduction in product losses and its financial implication. Possibly, there will be an even or lower risk management cost when compared to the current situation.

Last, the involvement of government as both regulator and operator remains a potential area of conflict within the policy propositions. Although the current stakeholder structure can be advantageous as the Minister have strong access and relationship with both the operator and regulator, optimising the pipeline integrity management system with this structure can only be achieved if the Minister operates ethically and unbiased even in the face of vested interests. The best approach for petroleum industry regulation in Nigeria and for PRMF is as proposed by the PIB, whereby government losses its grip on NNPC/PPMC and pays more attention to the regulation of the petroleum sector. Passage of the Bill will therefore be very important to pipeline risk management. Again, there is also the need to strongly involve independent accident investigation bodies so as to make void the current system which is plagued by cover-ups and corrupt practices.

7 CHAPTER SEVEN: CONCLUSION

7.1 Introduction

The overall conclusions 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.

7.2 Summary of main findings

The overall aim of the study is to develop a risk management framework for transportation and distribution of petroleum products in Nigeria. The research focused on assessing the risks associated with accident prone product transportation and distribution operations in Nigeria, i.e., pipeline and road truck transport in order to develop mitigation strategies. A number of objectives were defined. The main findings from each of the chapters, which address individual objectives are discussed below.

7.2.1 Conclusion of Chapter 2: achieving Objective 1

Chapter 2 addressed Objective 1 which was to develop an approach for risk management research within the context of petroleum product transportation and distribution in Nigeria. For a multidisciplinary risk research (such as the context of this study), it was decided that the research questions should drive the use of research method used. This is supported by the research philosophy of 'pragmatism' which was selected. This philosophical orientation should then guide the stepwise approach for risk assessment, risk evaluation and development of risk mitigation strategies. Similarly, Reason's Swiss Cheese Model and Rasmussen's Risk Management Framework were both identified as the most suitable accident analysis models for the study as the models are able to analyse accidents from the context of complex socio-technical systems and structure. The research data collected and the method used of data analysis were likewise discussed.

Chapter 2 also provided the general framework for risk management research and for the methods in Chapters 4 and 5. The chapter concluded by stating the ethical considerations taken to ensure that the study produced a valid and reliable research that can be applicable to real world risk management practice.

7.2.2 Conclusion of Chapter 3: achieving Objective 2

Chapter 3 addressed Objective 2 which was to analyse the safety and environmental regulatory framework for downstream petroleum industry operations (including transportation and distribution of products) in Nigeria. The analysis revealed the existence of 'apparent' laws and institutional frameworks which can be applied to the context of regulating petroleum transportation and distribution in Nigeria. Laws such as the Petroleum Act (2004), Harmful Waste Act (2004), Petroleum Product Distribution Act (2004), Oil Pipelines Act (1990); and the NESREA Act (2007) can be considered key regulations relating to "good oil practices". In addition, legislations such as the EIA Act (1996), Petroleum Act and DPR Guideline (2002) can be applied for proactive risk management, while the NOSDRA Act (2006) and NEMA Act (1999) can be used for reactive accident response. Based on the analysis, stakeholders organisations from the regulatory perspective (DPR, FRSC, FME- NOSDRA and NESREA, NSCDC and FFSD) and the operational perspective (NNPC, PPMC, MOMAN, IPMAN) were identified and stakeholders with interest in safe petroleum transportation. The pieces of legislations and statutory interest of the identified stakeholders shaped the risk management framework proposed in Chapters 4 and 5.

The analysis did, however, find that the current regulatory framework remains largely ad-hoc, patchy and incomprehensive. This contributes in part to duplications, overlaps and conflicts of interests amongst regulators. These result in lengthy bureaucratic processes, waste of resources, and ultimately, ineffective enforcement. It was recognised that there were some promising proposals in two Bills (the PIB and NOSDRA Amendment Bill) currently before the Nigerian National Assembly which would help address some of the gaps or deficiencies of the current laws. However, factors other than the weakness of the legislative and institutional structures were identified as contributing to poor enforcement. These include an entrenched rentier culture, weak governance, and lack of adequate funding of the regulatory agencies. These are arguably more challenging issues to resolve which, nevertheless, need to be addressed for the effective regulation and management of risks associated with petroleum transportation and distribution.

7.2.3 Conclusion of Chapter 4: achieving Objective 3

Objective 3 was to develop a risk management framework for the downstream petroleum distribution pipelines in Nigeria. This objective was addressed in Chapter 4. The chapter began by reviewing some existing pipeline risk assessment models to find components of risk assessment that will best suit the data collected and also overcome the limitation in the data required for risk assessment of long pipelines.

Through risk assessment it was discovered that failure frequency of the pipeline stands at 0.351 per km-year. This rate is very high compared to failure rate from other data base such as: the Oil Company European Organisation for Environment Health and Safety (CONCAWE) with a computed failure rate of 0.54×10^{-3} and 0.24×10^{-3} per km-yr from 1971 to 2011 and 2007 to 2011 respectively; UKOPA with failure rate of 0.23×10^{-3} per km-yr from 1962 to 2012; and US with failure rate of 0.135×10^{-3} per km year from 1994 to 2012.

96.46% of the pipeline failures were attributed to activities of interdictors (i.e. vandals, saboteurs and third party interference). It was also discovered that the pattern of failure frequency across the 13 years record analysed may be affected by socio-political events such as elections. The chapter went further to assess some of the techniques used by pipeline interdictors to tap into the pipeline.

Failure due to mechanical faults and corrosion was also found to be higher (7.57×10^{-3}) than what was reported in the UK (0.23×10^{-3}) and the US (0.135×10^{-3}). The age of the pipeline contributes to this as mean failure frequency due to mechanical faults and corrosion for the 1978/80 pipeline category was found to be about 0.02 per km-year, while 0.002 per km-year was computed as the mean failure frequency of the 1995 pipeline.

Consequence analysis of the pipeline revealed some significant elements of the magnitude of the pipeline failure. Across the pipeline operating regions, Port-Harcourt (PH), Warri (WR), Mosimi (MS) and Kaduna regions all have ignition per failure incidents within the same range (i.e., about 1 in 50), while Gombe (GB) region recorded the lowest ignition frequency of approximately 1 in 100 reported failures. Of the 106 ignitions recorded from 2007 to 2012, about three-fourth was as a result of deliberate arson after scooping fuel, unintentional fire as a result of illegal hot tapping or bomb attack. As a result of these ignitions, the pipeline systems in PH, WR and MS regions recorded lethality rates of 0.044, 0.071 and 0.38 per km-yr. It was also estimated that the operator loses 100 million USD per year on product loss. The high value of failure frequency and failure consequences ultimately made the values of Individual Risk for the pipelines to fall outside tolerable limits.

The chapter recognises that the pipelines operate under a combination of complex socio technical systems and these systems comprise of hierarchy of actors, individuals and organisations. Their interaction can result in faults at various levels. Therefore, the chapter combined the results of semi structured interviews with stakeholders, results of ROW inspection and information from the risk assessment conducted to map out the interactions of factors that may be attributed to the problematic nature of the pipelines using a combination of the concepts of Swiss Cheese Model and Rasmussen's Risk Management Framework. It was discovered that in addition to the limitations in pipeline legislations, the regulatory and governmental levels of the pipeline system is laden with national vested interest which has limited regulatory capabilities by strategically misaligning the regulator (DPR) and the operator (PPMC) such that PPMC appeared to be stronger than DPR, a phenomenon best described as regulatory seizure.

It was, therefore, not surprising to discover that at strategic levels of PPMC and NNPC, factors such as poor safety culture, and limited safety awareness drives poor management commitment to pipeline safety. This then cascades to poor pipeline maintenance culture, lack of technical capabilities at operational levels and very limited risk communication and community engagement. These are the factors that makes pipeline interdiction and product theft thrive. From the failure response perspective, it was discovered that the reason pipeline failure recorded high consequence values is that local incident response capability is lacking and the vulnerability of host communities increase due to poor knowledge of pipeline hazards and risks.

Based on the discoveries from the risk assessment of the pipeline, the chapter recommended some mitigation strategies which combined the use of social tactics – for engaging host communities in pipeline surveillance, vigilance and improve risk communication, with technical tactics to enhance the pipeline integrity.

7.2.4 Conclusion of chapter 5: achieving Objective 4

Chapter 5 addressed product road trucking as an integral part of full-circle petroleum transportation and distribution in Nigeria and the risk associated with the operation. The chapter developed a framework for risk management of road trucking of petroleum product as a holistic approach to preventing and dealing with the consequential nature of petroleum truck tanker accidents. The chapter began by reviewing relevant research on risk assessment of hazmat transportation by road and then developed a data driven risk assessment model. The model utilised tailored formulas to identify accident causal factors, accident hotspots, accident relative probabilities per trip, casualty consequence and accident financial implications. Other statistical tools were used to complement consequence analysis and analysis of yearly accident patterns.

Of the 2318 accidents analysed, 79% were caused by human factors associated to dangerous driving. 81% of the accidents resulted in either injuries, death or both. Based on the event tree produced, the most frequent initiating event (97%) is collision or failure of tanker component(s) out of which over 70% caused LOC. The LOC results in accident phenomena such as: spills, jet fire, pool fire, unconfined vapour cloud explosions and explosions. The findings revealed that regulatory effort needs to concentrate on limiting human factors associated with dangerous driving.

The model revealed Nigerian states with high accident casualty consequences. They include: Kaduna, Kwara, Ogun, Cross Rivers, Delta, Rivers, Abuja, Akwa-Ibom, Benue, Kano, Katsina, Kogi, Niger, Ondo, and Oyo, most of which are states with either import jetties and/or refineries or states that serve as key transport corridors. Ogun, Kwara, Kogi, Oyo, Benue, and Akwa-Ibom were again discovered to have high accident frequencies (between 1×10^{-5} and 1×10^{-2} accidents per trip per year throughout 2009 to 2012). The risk assessment conducted also estimated the dollar value of accidents using established cost of fatality, injury, product loss and environmental damage. On average, it was estimated that the average value of a single accident cost over 7 million USD. The cost dimension was identified as a means of motivating policy development aimed at improving the risk perception of operators.

Again, data from the risk assessment, interview analysis and road inspection was used in Rasmussen's Risk Management Framework for wider socio-technical causal factor analysis. The analysis revealed the two main regulators (FRSC and DPR) have no clear or structured approach to dealing with the regulation of road transportation of petroleum products. Accordingly, also, companies poorly adhere to safety standards. The analysis also revealed that at managerial level operating companies have low risk awareness and poor accident reporting and investigation culture. Perhaps due to these reasons, risk management and safety is not taken seriously as evident in driver behaviours such as dangerous driving and speed violation. The companies are overdriven by profits, their drivers are underpaid and, therefore, overwork themselves to make more money. It was also discovered that poor budgeting, corruption and resource limitation at government level affects regulatory staffing and staff capabilities, and the efficiency of accident response.

Based on the risk assessment and causal factor analysis, tailored risk mitigation strategies were proposed for both regulators and operators in a framework. The framework identified various control points for effective prevention and management of truck accidents and adheres to principles of commitment to change, regulatory and peer collaboration, development of risk knowledge, organisation and communication, risk management action and continues improvement.

7.2.5 Conclusion of Chapter 6: achieving Objective 5

Chapter 6 presented some relevant policy directions that can be used for implementing the risk mitigation strategies proposed in Chapters 4 and 5. Chapter 6 began by reflecting on the assurance of the proposed risk mitigation strategies to assess whether they are effectively designed to achieve their objectives if deployed as policies. Using the SUPPORT tool, the chapter designed and proposed 3 policy briefs. The briefs were designed based on the statutory responsibilities of key downstream stakeholders and the decisions that can influence the implementation of the proposed mitigation strategies for both pipeline and truck tanker operations. The role of each stakeholder was discussed within the context of each policy brief.

Policy Brief No1 leverage on the powers of the Minister of Petroleum Resources to ensure that policies are in place to guarantee that the pipeline operator (PPMC) understands the environmental and social impact of the pipeline on host communities. The brief also recommended the deployment of policies that will enhance community engagement, ROW surveillance and vigilance, CSR, royalty payment schemes and risk communication. This should be supported by a dedicated risk management fund set up as instructed by the Minister. In addition, Brief No. 1 emphases the need for effective regulation of the pipeline asset by suggesting that the Minister should ensure adequate regulatory powers are apportioned to DPR and PPMC's capacity should be enhanced from both technical and managerial perspectives.

Policy Brief No. 2 recommended a joint and collaborative approach to truck tanker regulation by DPR and FRSC in consultation with the trade unions such that while DPR formulate and deploy guidelines for risk management, FRSC will monitory compliance by focusing on the identified accident hotspots. Similarly, Brief No.3 recognised the important role that the trade unions can play in ensuring peer safety and operational improvements. Hence, policy recommendations were made to assist the union bodies in encouraging regulatory compliance amongst their members using their presence at local, state, regional and national levels. The chapter concluded by discussing the likely challenges to expect in designing and implementing the risk management policies.

7.2.6 Overall conclusion

Petroleum transportation and distribution in Nigeria has been characterised by catastrophic accidents/incidents. This thesis presented strategies which can be used to prevent and manage these accidents using the concept of risk management. The thesis focused on the two main modes of petroleum product transportation and distribution (i.e. pipeline and road trucking) in a holistic inter-nodal context.

The main finding of this study is that the current petroleum transportation practice needs to be changed and the risk management concepts provide appropriate mitigation strategies that can influence the needed change. This is the first time these concepts has been used to address the safety and environmental management problems of petroleum transportation in the downstream petroleum sub-sector in Nigeria.

This research showed the peculiar scale of the problems of pipeline and truck operations which stems from governmental and regulatory levels down to operational and work levels. In particular at government and regulatory levels, it was discovered that the poor safety performance of the downstream operations is largely influenced by lack of specific regulatory approach, conflict and overlaps of regulatory institutions and laws, lack of good governance, and inadequate funding of regulatory agencies. From risk assessment results, realities observed at operational and work levels were also complex. It was discovered that for both pipeline and truck systems failure or accidents were mostly influenced by bad or unsafe human behaviours. Specifically, for the pipeline this is mostly due to activities of vandals, while dangerous driving mostly contributed to accidents involving truck tankers. These behaviours were also found to be 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.

The research demonstrated that there is a need to go beyond the current operating context and focus on risk-based approach to accident/incident prevention and response. Effort needs to be channelled towards assessment of operational risks, communication of the risk to affected persons, development of appropriate risk mitigation strategies and adherence to good operational practices. Efforts also need to be made to enhance regulatory coverage by concentrating resources on accident/incident hot-spots, and also influencing risk management commitment at all levels.

For pipeline operations, PPMC need to develop and deploy royalty and CSR strategies that enhance community engagement. Communities need to feel that they are part of the system and also benefit from it. Communities can play a vital role in pipeline surveillance and vigilance. This research has showed that PPMC lack the capacity for surveillance of the pipeline and host communities are willing to assist as it is in their best interest that the pipeline remain safe. There is also the need to use appropriate pipeline technology for optimised pipeline integrity. The research also revealed that the Minister of Petroleum Resource can trigger the required change within DPR and PPMC and influence good pipeline risk management practices. This is a top pipeline risk management priority.

For truck operations, the research revealed risk management strategies which DPR and FRSC can use to improve their regulatory activities. This included: regulatory collaboration, identification of accident hot-spots for resource prioritisation, development and deployment of a joint safety standard and collaboration with trade unions. On the part of the trade unions, is was observed that there is an opportunity to develop risk management capabilities within peers by collaborating with regulators to set, implement, monitor and review risk management targets and policies within member companies.

Overall, the research finding supported the idea that the concept of risk management 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. The policy directions have been proposed in 3 policy briefs. However, designing and implementing these policies may come with some challenges such as the rent seeking culture of the petroleum industry in Nigeria, the need for risk management resources and the need for enacting comprehensive enforceable laws. For the resource constraints, the research has shown that in fact there problem may not be the limitation in resources but the absence of political will and limited knowledge of the existence of funds and access.

7.3 Contribution of research

This research contributes to knowledge in a number of ways, specifically to risk management of petroleum transportation and distribution in Nigeria, but also to the wider petroleum industry and the advancement of development of safety and risk management knowledge. From the specifics, it was identified, based on review of safety and environmental regulatory framework, the limitations in downstream safety and environmental laws in Nigeria, but also identified the prospects within the framework. The research also used primary data to provide empirical evidence based on exploration of risks within the complex socio-technical context of petroleum transportation in Nigeria. This provided understanding of accident/incident causal factors, upon which mitigation strategies were proposed based on identification of stakeholder interest.

On a wider petroleum industry perspective, the research exposed the problems of pipeline theft and the realities of managing these problem as published in the paper titled: "*Risk Assessment of a Petroleum Product Pipeline in Nigeria: The Realities of Managing Problems of Theft/sabotage*". This publication provided conceptual pivot for risk management studies to the global petroleum industry as countries such as Mexico, UK, Italy, China, etc., with new records of pipeline interdictions and product theft can learn from the study to find tailored risk management solution to address their contextual problems. The research also contributes to improving the regulation of petroleum transportation by road by proposing a framework for regulatory enhancement in the publication tittle: *"Risk assessment of petroleum product transportation by road: A framework for regulatory improvement"*. The published study presented a framework which can be applied to wider context of petroleum regulation especially in developing countries where the effectiveness of regulation is often constrained by limited availability of regulatory resources.

From the perspective of the contribution of the research in the development and advancement of safety and risk management knowledge, the research contributes to the domains shown in Figure 7-1 via the following ways:

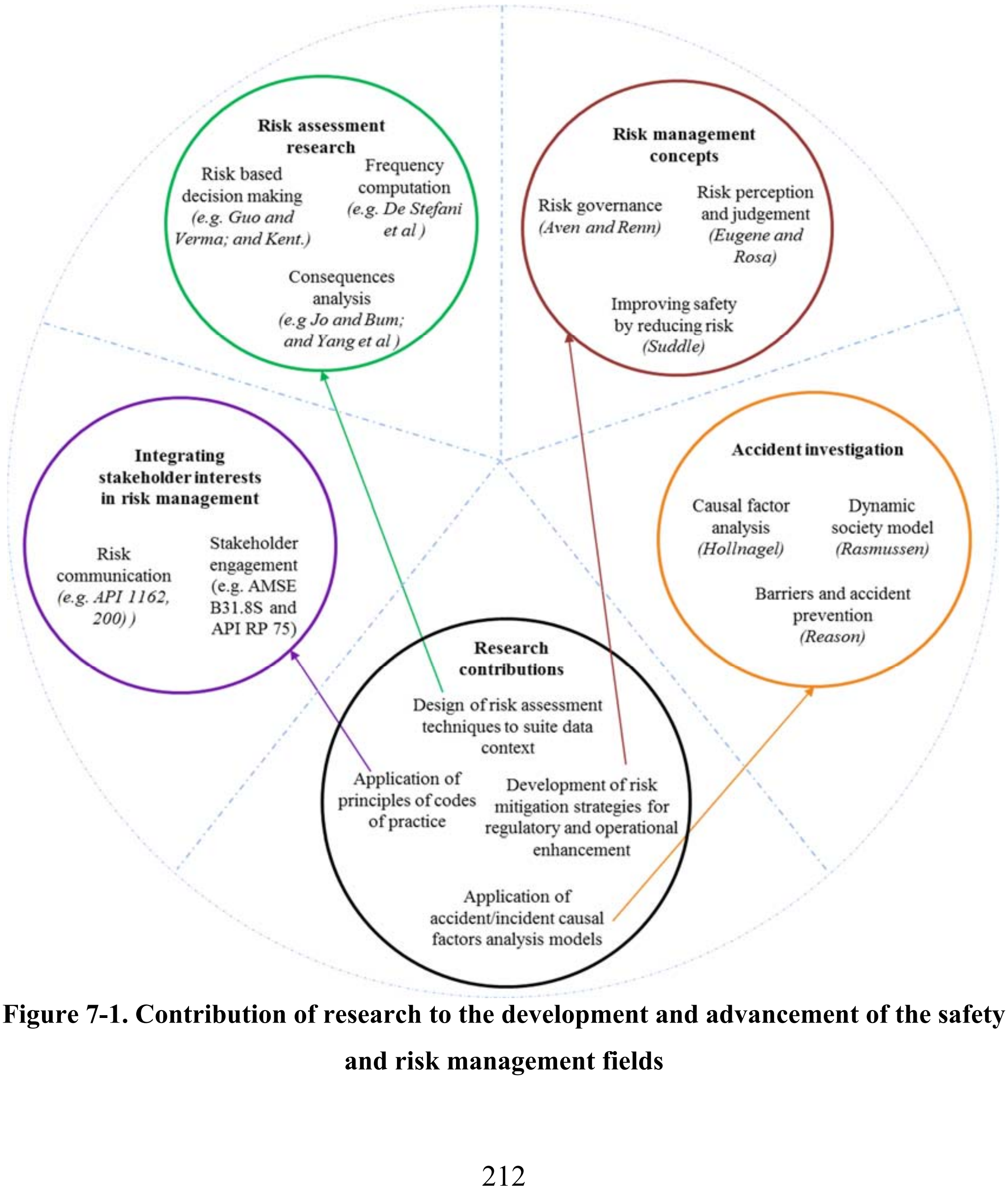

Figure 7-1. Contribution of research to the development and advancement of the safety and risk management fields

- **Risk assessment:** the research illustrates how data driven risk assessment models can be designed and utilised to overcome the limitations of data demand in risk assessment in order to develop evidence-based mitigation strategies. This contributes to other risk assessment methods used for, (e.g.,) risk-based decision making (Muhlbauer, 2004; Guo and Verma, 2010), enhancing frequency computation (De Stefani *et al.*, 2009) and consequence analysis (Jo and Bum, 2005; Yang *et al.*, 2010).
- **Risk Management:** The study showed how risk management strategies from results of risk assessment, causal factor analysis, stakeholder engagement and integration of regulatory requirements can be used to develop management initiatives to suit a particular context. This contributes to the development of the concepts of risk governance, e.g. Aven and Renn (2010), risk perception and judgement, e.g. Eugene and Rosa (2003), and improving safety by reducing risk e.g., Suddle (2009).
- **Accident investigation and causal factor analysis**: the study provided evidence-based examples of application of two models for causal factor analysis to show how faults within barriers in systems can result in accidents or system failures (Reason, 1990), as well as the interactions of faults within the complex socio-technical systems (Rasmussen, 1997).
- **Integrating stakeholder interests in risk management:** By applying the principles of risk communication e.g. (API 1162, 2003), the research illustrates how adequate communication strategies can be developed with inputs from regulators, operators, first responders and local authorities. Such communication strategy will enhance public education and provide effective information on the hazards involved in petroleum transportation to the persons that are most likely to be impacted by any adverse event and also advise them of response plans. Similarly, concepts of stakeholder engagement (API RP 75, 2004) were developed to ensure collaboration which was used to demonstrate how regulatory enhancement can be achieved, how risk management capabilities can be enhanced amongst peers and how aggrieved communities can be engagement for the optimisation of safety and integrity performance of critical energy infrastructures.

7.4 Reflection on research methods

7.4.1 Mixed method research

The research combined both qualitative and quantitative data and also made use of mixed methods for data analysis. From the initial research planning stage, it was decided that quantitative data in the form of accident/incident reports will be analysed for understanding risk factors such as accident frequencies and consequences. The researcher also envisaged that inputs from stakeholders will be critical to successful design of risk mitigation strategies. Hence, the stakeholders were engaged via focus group discussions and semi-structured interviews. Moreover, other qualitative data such as ROW inspection and road inspection records were primarily collected to give a contextual understanding of the conditions within the two downstream operations under consideration.

Notably, the researcher observed how the use of mixed method research enhanced the quality of answers to the research questions. For instance, the quantitative historic accident data used for evaluating causal factors in road trucking operation limited the depth of analysis for understanding how organizational or governmental levels deviations manifest into accidents (i.e. RQ 4.3). The map illustrated in figure 7-1 shows the results of causal factors from the available accident reports mapped into Reason’s (1990) Cheese model and Rasmussen’s (1997) Risk Management Framework. Both models show how the accident report data only produced results that cover mainly the truck driver’s road attitude, weather condition, maintenance, and road conditions. This does not represent the complete faults within the transport system because high level factors were not reported. It also does not show the interactions within the regulatory and operational strata. However, upon combining the analysed data from accident reports with interviews and road inspection data and information from the review of regulatory framework, it was possible to show and discuss causal factors from a holistic view as seen in section 5.3.6. Similar approach also made it possible to illustrate the interactions between failure causal factors within the socio-technical complexity of the pipeline system which were discussed in Section 4.5.

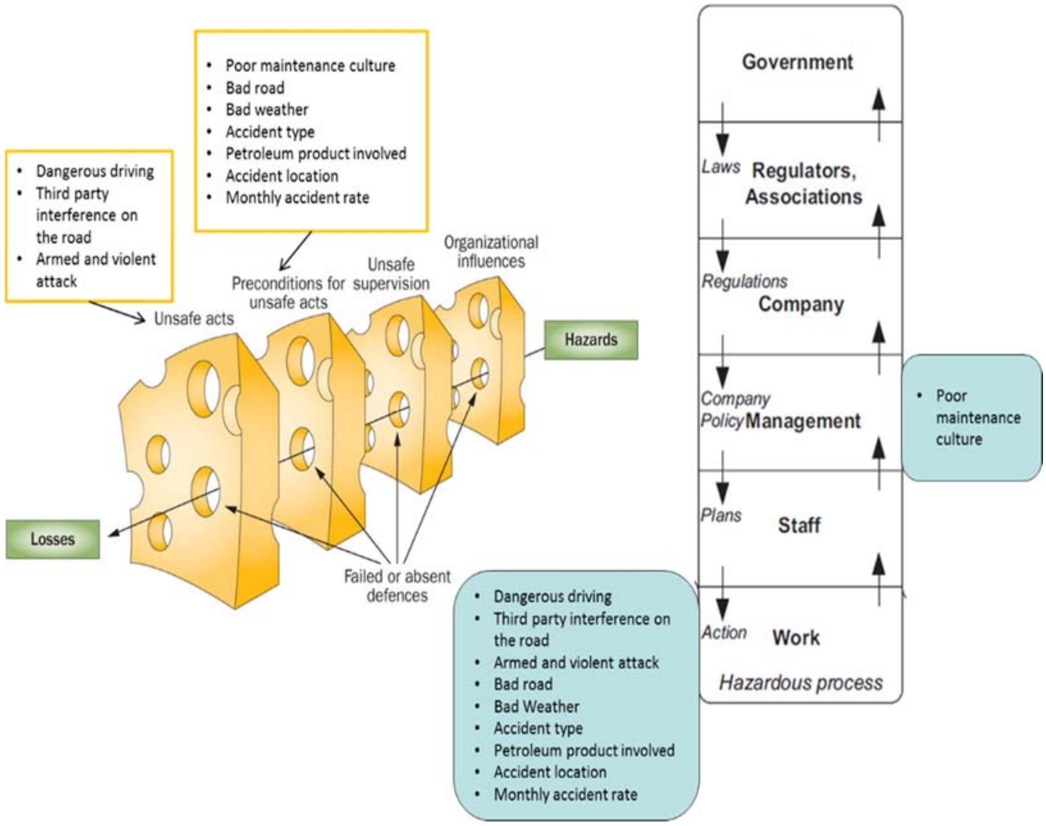

Figure 7-2. Truck accident report data mapped against accident analysis frameworks.

The stakeholder mapping in Chapter 3 was very instrumental to identifying the organisations with interests and influence in pipeline and truck operations. With this developed knowledge, the researcher was able to approach the organisations during the data collection stage and also established resource persons who were used as point of reference for research engagement. The stakeholder mapping also made it possible to discuss mitigation measures in the context of the identified organisations, their interest and their statutory responsibilities in attaining optimised risk management of petroleum transportation and distribution.

7.4.2 Interviewing and engaging research stakeholders

Conducting interviews with stakeholders was perhaps the most challenging aspect of this research. First, was the fact that face to face interviews demanded the presence of the researcher. Hence, two trips had to be taken to Nigeria. Second, was the constraints of the availability of stakeholders, especially top managers and decision makers. In one case, the research conducted the interview in the stakeholder's car as that was the only presented opportunity. Last, was the secretive nature of the Nigerian petroleum industry. Stakeholders tended to 'play safe' while being interviewed. Also access to office buildings such as the NNPC HQ was very difficult due to the presence of heavily armed securities and vigorous security protocols. This may be attributed to the security situation in the case country. However, the interviews provided valuable opportunities for the researcher to gain first-hand knowledge of various research elements, without which the research would not have been successful. The face to face contact also used opportunities for the research to establish resource persons for continuous collaboration and engagement with stakeholder throughout the study.

7.4.3 Data constraints and study limitation

Obtaining comprehensive data was especially challenging for this study. As stated earlier, this is due to the secretive nature of the petroleum industry in Nigeria (Amundsen, 2010). For example, the researcher experienced deliberate deletion of some key details from all the reports obtained from DPR due to confidentiality claims. Surprisingly, also, all the accident reports involving both pipeline and trucks only cover accidents and incidents involving PMS, HHK and AGO only. Perhaps this could be because these three products form the bulk of products used across the country. Hence, with this data, evaluating the contribution of transportation of other petroleum products to accident risk was constrained.

The limitation of data was mostly observed in the truck transport section of this study. This is mainly because unlike the pipeline system which is owned and operated by a single company, and regulated mainly by DPR, the truck system has multiple operators. This meant that truck accident data had to be collected from stakeholders with regulatory responsibility of recording, responding or investigating accidents. As a result, truck accident data were sourced from FRSC, NEMA, NNPC and DPR. Collecting truck accident reports from 4 different sources also meant that each report had to be cross-referenced using date, time, location of occurrence, and/or registration numbers of vehicles involved with all the reports so as to sieve out duplications. Therefore, where such clear distinction was not established, the report details were classified based on the only and/or best parameter(s) available. As a result, much of the data available for truck accident risk assessment were fragmented, and incomplete. Accident data for trucks had to be spatially aggregated to state levels as records of product distribution are only accessible at state level. This limits accident frequency computation to state level even though there are records of the exact place of accident occurrence. Road systems at local level would have been more valuable in identification of accident risk hotspot.

There is also the lack of homogeneity of the country source of the data used in cost estimation in developing the truck accident risk management framework. The dollar values used for estimation of accident cost impact variables was obtained from a study conducted in the US. Undoubtable, using data from the case country would have been more desirable as it would have given a specific cost analysis related to the risk-cost perception of the case country. Thus, while the study results would not be possible without the availability of these data, limitations of the study can in part be linked to the variegated nature of the risk assessment results.

7.5 Direction for further research

The initial plan of this research was to organise a workshop with the stakeholders and disseminate the final output of the research and the developed policy briefs. This was not possible due to the change in political landscape in Nigeria. With this constraint, the research output will now be communicated via the project sponsor, i.e. PTDF. A continuation of this research would be to work with the identified stakeholder organisations to deploy the risk mitigation strategies via the policy directions recommended and measure the corresponding risk reduction improvements. This would give the research a refined conclusion and improve the evidence of its wider application to optimisation of safety and risk management in the global petroleum industry context.

The research highlighted the need to conduct a detailed ESIA for the pipeline in order to define viable means of engaging host communities into pipeline surveillance and vigilance. Therefore, further contextual ESIA strategies and tools need to be researched, developed and implemented. Work needs to be done on implementing the specific community engagement strategies developed afterwards, e.g. royalty systems and CSR strategies and measuring the impact of the strategies in terms of reduction in the cases of pipeline interdiction and product theft. The research recognises the enormous security challenges associated with the pipelines. As such, further work could be undertaken to integrate the interests of relevant security authorities and develop a framework that will bring them to work together to destroy the 'organised' crime associate with the pipelines.

For the truck system, there is a need to work with the regulators and trade unions to design operations standards and set accident reduction targets, implement the standards in line with the proposed policies and measure the success based on accident reduction. Research could also be conducted by implementing the regulatory improvement strategies and measuring the impact on optimisation of regulatory resources and accident prevention and response. There is also be the need to conduct a detail risk-economic analysis of accidents within the Nigerian petroleum industry context to help reinforce the accident cost analysis conducted in this studies rather than using the life and injury values for US. This can in fact be used as a strong means of motivating policy and risk perceptions of stakeholder from both operational and regulatory perspectives.

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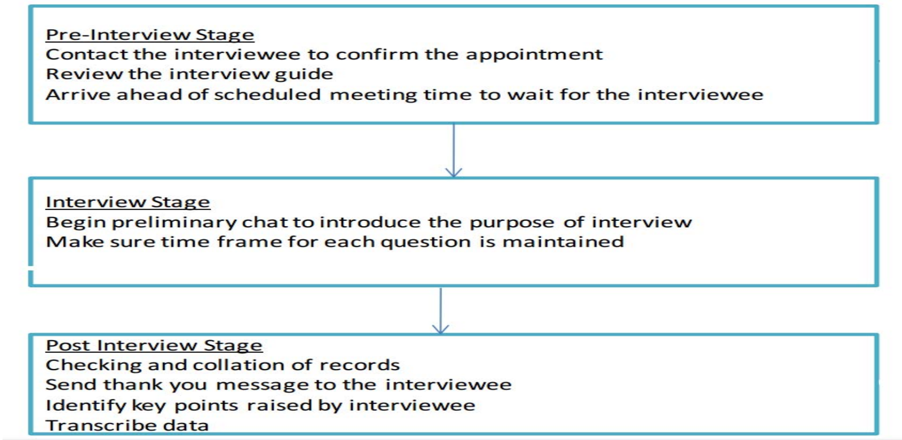
Appendix

APPENDIX 1

Interview/focus group guide



Throughout the thesis, the reference numbers in App-table 1 were used to refer to participants that had inputs into the research.

App-table 1: General reference ID number for participant

ID number	Description
INT	Reference number of participants in semi-structured interview
FG	Reference number for participant in Focus groups

Focus group participants

A pilot scoping exercise was conducted via two focus group discussions (FG1 = 4 and FG2 =6) with stakeholders in App-table 2.

App-table 2. Focus group participants

ID of participants	Affiliation
1-FG1	Fuel tanker operator/owner
2-FG1	Fuel tanker operator/owner
3-FG1	Fuel tanker operator/owner
4-FG1	Fuel tanker operator/owner
1-FG2	State fire service department-Battalion leader of NNPC refinery post
2-FG2	NNPC-Pipeline engineer
3-FG2	Major petroleum marketers association (MOMAN)
4-FG2	Independent marketers association (IPMAN)-Field engineer
5-FG2	Independent marketers association (IPMAN)- safety coordinator
6-FG2	Independent marketers association (IPMAN)-depot outpost operative

Semi-structured interview participants

App-table 3. Reference list for semi-structured interview participants who contributed to the research

Ref No.	Organisation	Classification	Role
INT1	DPR	Regulator	HSE Manager
INT2	DPR	Regulator	Field Officer
INT3	NEMA	Regulator	Director (search and Rescue)
INT4	NEMA	Regulator	Field Manager
INT5	FRSC	Regulator	HOS Fed. Operations
INT6	FRSC	Regulator	Accident response officer
INT7	FSD	Regulator	Chief of operations
INT8	NNPC	Operator	General Manager
INT9	NNPC	Operator	Manager
INT10	NNPC-Retail	Operator	Manager
INT11	IPMAN- Retailer	Operator	Director
INT12	IPMAN- Retailer	Operator	Field operative
INT13	MOMAN	Operator	Association chairperson
INT14	MOMAN	Operator	Retailer
INT15	IPMAN -Transporter	Operator	Director
INT16	IPMAN -Transporter	Operator	Driver
INT17	IPMAN -Transporter	Operator	Manager
INT18	IPMAN -Transporter	Operator	Tanker owner
INT19	IPMAN -Transporter	Operator	Tanker owner
INT20	PPMC	Operator	Manager Pipeline ROW
INT21	PPMC	Operator	Manager-fire safety
INT22	PPMC	Operator	Manager- HSE
INT23	PPMC	Operator	Field operative
INT24	PPMC	Operator	Field operative
INT25	PPMC	Operator	Field operative
INT26	NOSDRA	Regulator	Manager
INT27	NOSDRA	Regulator	Field engineer
INT28	NOSDRA	Regulator	Field engineer
INT29	NOSDRA	Regulator	Field engineer
INT30	Resident within ROW	Host communities	Resident with ROW
INT31	Resident within ROW	Host communities	Resident with ROW
INT32	Resident within ROW	Host communities	Resident with ROW
INT33	Resident within ROW	Host communities	Resident with ROW
INT34	Resident within ROW	Host communities	Resident with ROW
INT35	Resident within ROW	Host communities	Resident with ROW
INT36	Resident within ROW	Host communities	Resident with ROW
INT37	Resident within ROW	Host communities	Resident with ROW
INT38	Community leader	Host communities	Community leader
INT39	Community leader	Host communities	Community leader
INT40	Community leader	Host communities	Community leader

Semi-Structured interview templates

Interviews were conducted with an interview template which was sent to some of the participant prior to the interview. Two different templates was prepared based on stakeholder classification i.e. regulators and operators. The templates are as shown below. Participants were informed that the questioning technique will be semi-structured which allows for an initial question to be posed and further elaboration of the subject are to be considered and further discussed.

1. **Template for operators**

First Session: risk understanding. Time target- 30 mins

In this interview session, we discussed and obtain insight into the type of risks that the organisation face in its daily operations, especially as it relates to downstream operation within the context of HSE. I asked questions about the causes of these hazards and risks, and their corresponding consequences. Then we finally talk about human and technical issues that lead to accidents and disasters in the high risk activities identified.

List of initial questions for first session

Introduction and research aim. Explanation on how this interview is of importance to the research.

1. Tell me about your department, your position and how it fits into the general structure of the organisation.
2. How do you carry out your functions?
3. Over the years Nigeria is been constantly faced with issues of accidents and disasters especially from downstream subsector. Some of these issues come from your facilities and pose risk on HSE. What in your experience are the technical and human causes of these accidents?
4. What are the corresponding consequences of these accidents, and how does your department respond to them?
5. Within the downstream activities and operations which do you believe to be accident and risk prone and why?
6. Do you have risk mitigation strategies to tackle these risks?

7. Based on these consequences it is obvious that some of your objectives are not being achieved. What do you think are the reasons behind this?
8. What have been the technical and human challenges that you face in risk mitigations.

Second session: assessing the regulatory effective and involvement. Time target- 1hour

Here I asked about responsibilities of the departments, and how it is being regulated. We discussed the policies and guideline of the organisation in terms of HSE risk management, and how these policies translate to field operations. I also asked questions on who does the regulations and why. We explored the framework via which the organisation use for managing HSE and explore the effectiveness of the framework, its aims and objectives, and how the objectives are formulated based on regulatory requirements. I also enquired on how the HSE objectives are being achieved and how the objectives are updated in line with changes in the global business environment, and how.

List of initial questions for second session

1. How do you formulate your HSE policies
2. Who regulates your activities and how?
3. In your opinion, how effective is the current regulatory framework?
4. Do you have a risk management framework? Tell me about it
5. It is obvious that the global awareness on HSE is on the increase. How does your organisation meet with these global trends?
6. What are the challenges that your department face in meeting both the national regulatory and global best practice standards.

Last section: research collaboration. Time target- 5-10mins

In this session, we will explore means of research collaboration. Since my research is aimed at developing a risk management framework for the industry, it is my kind hope that I'll explore the chances of collaborating with the relevant department and perhaps hold a seminar or workshop with then.

- How can we collaborate so that your organisation can benefit from my research?

2. Template for regulators

<u>List of likely questions</u>

1. Tell me about your organisation, your department and your functions within the context of regulating HSE in transporting and distributing petroleum products.
2. From experience, within the context of transporting, distributing and retailing of products, what do you think are the causes of accidents in these sub-sectors.
3. What do are issues from pipeline operations and trucking?
4. Is there a risk management framework your organisation uses to regulate these issues? Tell me about it.
5. Let assume you are task with the responsibility of providing a solution to this problem. What will you do?
6. How do you formulate HSE policies for operators
7. How effective is the current regulatory framework?
8. Do you have a risk management framework? Tell me about it
9. It is obvious that the global awareness on HSE is on the increase. How does your organisation meet with these global trends and how do you cascade this to operators?
10. What are the challenges that your department face in meeting both the national regulatory and global best practice standards.

Appendix 2

PIPELINE SYSTEMS	SECTION		DIAMETER (INC)	WALL THICKNESS (INCH)	LENGTH (KM)	FLUID TYPE	DESIGN FLOW RATE		CURRENT FLOW RATE		PIPELINE CATEGORY	DESIGN PRESSURE(Psi)	Max ALLOWABLE OPERATING PRESSURE (Psi)	DESIGN LIFE	INTERNAL CORROSION MONITORING	PIPELINE GRADE	CATHODIC PROTECTION	SOIL COVERING (m)	INSTALLATION DATE
	Originating	Terminating					MIN	MAX	MIN	MAX									
2A	Warri	Benin	15"	See foot note	88.9	PMS/AGO/DPK	320	350	270	330	On Shore	1450	1160	>25yrs	None	API X52 Gr B (ERW)	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Benin	Ore	14"	"	109.8	PMS/AGO/DPK	300	350	270	330	On Shore	1450	1160	>25yrs	None	API X52 Gr B (ERW)	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Ore	Mosimi	12"	"	151.3	PMS/AGO/DPK	280	350	270	330	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1978/80
					350														
2B	Atlas Cove	Mosimi	16"	"	72.8	PMS/AGO/DPK	??	815	400	500	On Shore	1450	1160	>25yrs	None	API X52 Gr B (ERW)	Ground bed,Sacrificial Anode	0.9-1	1978/80
	SPM	Atlas Coce	20"	0.25"	5.6	PMS/AGO/DPK	**	1200	**	1000	Off Shore	450	360	>25yrs	None	API 5L Gr B(ERW)	Ground bed,Sacrificial Anode	0.9-1	1998
	Mosimi	Satelite(Lagos)	12" and 10"	See foot note	45.7	PMS	175	160	145	150	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Mosimi	Ibadan	12"	"	79.1	PMS/AGO/DPK	285	300	270	300	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Ibadan	Ilorin	6"	"	168.9	PMS/AGO/DPK	70	75	60	65	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1978/80
					372.1														
2C	Warri	Abudu	16"	"	89.6	CRUDE OIL	360	640	320	600	On Shore	1450	1160	>25yrs	None	API X52 Gr B (ERW)	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Abudu	Auchi	16"	"	89.5	CRUDE OIL	360	640	320	600	On Shore	1450	1160	>25yrs	None	API X52 Gr B (ERW)	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Auchi	Lokoja	16"	"	103.9	CRUDE OIL	360	640	320	600	On Shore	1450	1160	>25yrs	None	API X52 Gr B (ERW)	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Lokoja	Abaji	16"	"	100.2	CRUDE OIL	360	640	320	600	On Shore	1450	1160	>25yrs	None	API X52 Gr B (ERW)	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Abaji	Izom	16"	"	81.5	CRUDE OIL	360	640	320	600	On Shore	1450	1160	>25yrs	None	API X52 Gr B (ERW)	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Izom	Sakin Pawa	16"	"	90.8	CRUDE OIL	360	640	320	600	On Shore	1450	1160	>25yrs	None	API X52 Gr B (ERW)	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Sarkin Pawa	Kaduna	16"	"	58	CRUDE OIL	360	640	320	600	On Shore	1450	1160	>25yrs	None	API X52 Gr B (ERW)	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Escravos IBP	EscravosTerminal	26"	"	27.7	CRUDE OIL	**	1200	**	1000	Off Shore	1450	1160	>25yrs	None	API X52 Gr B (ERW)	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Escravos	Warri	24"	"	60	CRUDE OIL	3000	3250	2500	2603	On Shore	1450	1160	>25yrs	None	API X52 Gr B (ERW)	Ground bed,Sacrificial Anode	0.9-1	1978/80
					701.2														
2CX	Auchi	Suleja	12"	"	280	PMS/AGO/DPK	230	300	200	240	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1995
	Suleja	Kaduna	12"	"	150	PMS/AGO/DPK	230	300	200	240	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1995
	Suleja	Minna	8"	"	80	PMS/AGO/DPK	75	86	65	70	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1995
					510														
2D	Kaduna	Jos	10 and 12"	"	164.8	PMS/AGO/DPK	120	160	110	145	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Jos to Gombe	Gombe	6"	"	265	PMS/AGO/DPK	50	70	50	65	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Gombe	Biu Pump Station 13	6"	"	124.8	PMS/AGO/DPK	50	70	50	65	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Biu Pump Station 13	Maiduguri	6"	"	175.8	PMS/AGO/DPK	50	70	50	65	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Kaduna	Zaria	10"	"	83.7	PMS/AGO/DPK	40	50	33	45	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Zaria	Kano	10"	"	141	PMS/AGO/DPK	140	160	110	120	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Zaria	Gusau	6"	"	177.7	PMS/AGO/DPK	30	40	30	45	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1978/80
					1132.8														
2DX	jos	Gombe	8"	"	265	PMS/AGO/DPK	85	90	65	72	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1995
2E	Port Harcourt	Aba	12"	"	53.9	PMS/AGO/DPK	300	324	250	260	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Aba	Enugu	12"	"	156.4	PMS/AGO/DPK	300	324	250	260	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1978/80
	Enugu	Makurdi	6"	"	180	PMS/AGO/DPK	64	70	60	56	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1978/80
					390.3														
2EX WEST	Port Harcourt	Enugu	12"	"	210.3	PMS/AGO/DPK	317	342	300	330	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1995
	Enugu	Auchi	12"	"	169	PMS/AGO/DPK	377	394	300	315	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1995
	Auchi	Benin	12"	"	107	PMS/AGO/DPK	377	394	300	315	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1995
2EX EAST	Enugu	Makurdi	8"	"	180	PMS/AGO/DPK	95	112	80	90	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1995
	Makurdi	Yola	8"	"	470	PMS/AGO/DPK	75	86	65	70	On Shore	1450	1160	>25yrs	None	API X42 Gr B Seamless	Ground bed,Sacrificial Anode	0.9-1	1995
					1136.3														

The wall thickness vary along the routeaccording to the type of spoil and problem encouraged

a)Normal 0.25"(6.35mm)

b)Crossing:rail,road,Seasonal Swa 0.281"(7.14mm)

c)Bored Crossing river and Permar 0.375"(9.52mm)

			IR (x=0, y=0)				
step	x co-ord of center	distance to point y	Pc (indoors)	IR (indoors)	Pc (outdoors)	IR (outdoors)	IR (step)
1	-100	100.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
2	-80	80.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
3	-60	60.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
4	-40	40.0	1	2.3E-04	1	2.3E-04	2.3E-04
5	-20	20.0	1	2.3E-04	1	2.3E-04	2.3E-04
6	0	0.0	1	2.3E-04	1	2.3E-04	2.3E-04
7	20	20.0	1	2.3E-04	1	2.3E-04	2.3E-04
8	40	40.0	1	2.3E-04	1	2.3E-04	2.3E-04
9	60	60.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
10	80	80.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
11	100	100.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
							1.4E-03

			IR (x=0, y=25)				
step	x co-ord of center	distance to point y	Pc (indoors)	IR (indoors)	Pc (outdoors)	IR (outdoors)	IR (step)
1	-100	103.1	0	0.0E+00	0.25	5.7E-05	4.0E-05
2	-80	83.8	0	0.0E+00	0.25	5.7E-05	4.0E-05
3	-60	65.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
4	-40	47.2	1	2.3E-04	1	2.3E-04	2.3E-04
5	-20	32.0	1	2.3E-04	1	2.3E-04	2.3E-04
6	0	25.0	1	2.3E-04	1	2.3E-04	2.3E-04
7	20	32.0	1	2.3E-04	1	2.3E-04	2.3E-04
8	40	47.2	1	2.3E-04	1	2.3E-04	2.3E-04
9	60	65.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
10	80	83.8	0	0.0E+00	0.25	5.7E-05	4.0E-05
11	100	103.1	0	0.0E+00	0.25	5.7E-05	4.0E-05
							1.4E-03

			IR (x=0, y=50)				
step	x co-ord of center	distance to point y	Pc (indoors)	IR (indoors)	Pc (outdoors)	IR (outdoors)	IR (step)
1	-100	111.8	0	0.0E+00	0	0.0E+00	0.0E+00
2	-80	94.3	0	0.0E+00	0.25	5.7E-05	4.0E-05
3	-60	78.1	0	0.0E+00	0.25	5.7E-05	4.0E-05
4	-40	64.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
5	-20	53.9	1	2.3E-04	1	2.3E-04	2.3E-04
6	0	50.0	1	2.3E-04	1	2.3E-04	2.3E-04
7	20	53.9	1	2.3E-04	1	2.3E-04	2.3E-04
8	40	64.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
9	60	78.1	0	0.0E+00	0.25	5.7E-05	4.0E-05
10	80	94.3	0	0.0E+00	0.25	5.7E-05	4.0E-05
11	100	111.8	0	0.0E+00	0	0.0E+00	0.0E+00
							9.2E-04

			IR (x=0, y=75)				
step	x co-ord of center	distance to point y	Pc (indoors)	IR (indoors)	Pc (outdoors)	IR (outdoors)	IR (step)
1	-100	125.0	0	0.0E+00	0	0.0E+00	0.0E+00
2	-80	109.7	0	0.0E+00	0.25	5.7E-05	4.0E-05
3	-60	96.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
4	-40	85.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
5	-20	77.6	0	0.0E+00	0.25	5.7E-05	4.0E-05
6	0	75.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
7	20	77.6	0	0.0E+00	0.25	5.7E-05	4.0E-05
8	40	85.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
9	60	96.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
10	80	109.7	0	0.0E+00	0.25	5.7E-05	4.0E-05
11	100	125.0	0	0.0E+00	0	0.0E+00	0.0E+00
							3.6E-04

step	x co-ord of center	distance to point y	Pc (indoors)	IR (indoors)	Pc (outdoors)	IR (outdoors)	IR (step)
1	-100	141.4	0	0.0E+00	0	0.0E+00	0.0E+00
2	-80	128.1	0	0.0E+00	0	0.0E+00	0.0E+00
3	-60	116.6	0	0.0E+00	0	0.0E+00	0.0E+00
4	-40	107.7	0	0.0E+00	0.25	5.7E-05	4.0E-05
5	-20	102.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
6	0	100.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
7	20	102.0	0	0.0E+00	0.25	5.7E-05	4.0E-05
8	40	107.7	0	0.0E+00	0.25	5.7E-05	4.0E-05
9	60	116.6	0	0.0E+00	0	0.0E+00	0.0E+00
10	80	128.1	0	0.0E+00	0	0.0E+00	0.0E+00
11	100	141.4	0	0.0E+00	0	0.0E+00	0.0E+00
							2.0E-04

step	x co-ord of center	distance to point y	Pc (indoors)	IR (indoors)	Pc (outdoors)	IR (outdoors)	IR (step)
1	-100	160.1	0	0.0E+00	0	0.0E+00	0.0E+00
2	-80	148.4	0	0.0E+00	0	0.0E+00	0.0E+00
3	-60	138.7	0	0.0E+00	0	0.0E+00	0.0E+00
4	-40	131.2	0	0.0E+00	0	0.0E+00	0.0E+00
5	-20	126.6	0	0.0E+00	0	0.0E+00	0.0E+00
6	0	125.0	0	0.0E+00	0	0.0E+00	0.0E+00
7	20	126.6	0	0.0E+00	0	0.0E+00	0.0E+00
8	40	131.2	0	0.0E+00	0	0.0E+00	0.0E+00
9	60	138.7	0	0.0E+00	0	0.0E+00	0.0E+00
10	80	148.4	0	0.0E+00	0	0.0E+00	0.0E+00
11	100	160.1	0	0.0E+00	0	0.0E+00	0.0E+00
				0.0E+00			0.0E+00

y distance from pipeline	IR	acceptable limits	ALARP (public)	ALARP (worker)	Unacceptable
0	1.4E-03	1.0E-06	1.0E-04	1.0E-03	1.0E-03
25	1.4E-03	1.0E-06	1.0E-04	1.0E-03	1.0E-03
50	6.3E-04	1.0E-06	1.0E-04	1.0E-03	1.0E-03
75	3.6E-04	1.0E-06	1.0E-04	1.0E-03	1.0E-03
100	2.0E-04	1.0E-06	1.0E-04	1.0E-03	1.0E-03
125	0.0E+00	1.0E-06	1.0E-04	1.0E-03	1.0E-03

Appendix 3

Letters of introduction and acceptance

Newcastle University

School of Civil Engineering and Geosciences
Newcastle University
3rd Floor Devonshire Building
Newcastle upon Tyne
NE1 7RU United Kingdom

01 July, 2013.

The Director General
National Emergency Management Board (NEMA)
Plot 439, Adetokunbo Ademola Crescent, Maitama,
Abuja.
Nigeria.

Dear Sir,

Introduction: Mr Ambisisi Ambituuni

I am the head of academic supervisory team of Mr Ambituuni, who has been registered as a full time PhD student within the School of Civil Engineering and Geoscience at Newcastle University since October, 2012. His research is aimed at developing a structure risk management framework for downstream petroleum product transportation, distribution and retailing.

Against this backdrop, Mr Ambituuni will be conducting an extensive fieldwork in Nigeria to obtain his research data. This will entail conducting some semi-structured interviews with the members of your organisation. He will similarly need some industry reports to help establish the characteristics of accidents and disasters within the context of product transport systems in Nigeria.

Also, since Mr Ambituuni's research project is envisaged to offer a feasible approach to managing health, safety and environmental risks within downstream petroleum operations in Nigeria, it is our kind hope that he is able to explore and establish a collaborative partnership with your organisation so as to present his finding to you at the end of his research.

I would be very grateful if your organisation would be able to offer all the necessary assistance to facilitate his work.

If you have any queries, please do not hesitate to contact me.

Yours faithfully,

Dr. Jaime M. Amezaga
Water Theme Coordinator
Newcastle Institute for Research on Sustainability (NIReS)
Devonshire Building
Newcastle University
Newcastle upon Tyne
NE1 7RU
Direct dial: +44 (0)191 246 4876

Newcastle University

School of Civil Engineering and Geosciences
Cassie Building, Newcastle upon Tyne
NE1 7RU, United Kingdom

tel :+44 (0) 191 222 6402
fax :+44 (0) 191 246 4961

ceg@ncl.ac.uk
www.ceg.ncl.ac.uk

THE QUEEN'S ANNIVERSARY PRIZES
FOR HIGHER AND FURTHER EDUCATION
2009

THE PRESIDENCY

NATIONAL EMERGENCY MANAGEMENT AGENCY

8, Adetokunbo Ademola Crescent,
Maitama, P.M.B. 357 - Garki
Abuja - Nigeria.

NEMA/AR/397/I
5th August, 2013

Newcastle University,
School of Civil Engineering and
Geosciences,
3 rd Floor Devonshine Building,
Newcastle upon Tyne,
NE1 7RU United Kingdom

Attention: Dr. Jaime M. Amezaga .

Re: Introduction: Mr Ambisisi Ambituuni

I am directed to acknowledge the receipt of your letter dated 1st July, 2013 on the above subject matter, and to inform you that our organization is willing to accord Mr Ambisisi Ambituuni with all the interviews, reports, collaborations and partnerships he requires.

2. However, the agency is requesting for his complete contact address to enable her communicate directly with him when the need arises.

3. For further enquiries you can contact us on 08039282881 and

sundaydzupu@yahoo.com

4. Accept the Director General's warmest regards

Alhassan Nuhu
Ag. Director Planning Research & Forecasting
For: - Director General

Dcm(PRS) 15/7/13

CO..ACE OFFICE (F R S C)
Na..onal Headquarters, Abuja
Received by Uchenna 10/07/13
Sign.......Date........

Newcastle University

School of Civil Engineering and Geosciences

Newcastle University
3rd Floor Devonshire Building
Newcastle upon Tyne
NE1 7RU United Kingdom

01 July, 2013.

The Corps Marshal and Chief Executive
Federal Road Safety Corps
National Headquarters
No. 3 Maputo Street. Zone 3, Wuse,
Abuja,
Nigeria.

Dear Sir,

Introduction: Mr Ambisisi Ambituuni

I am the head of academic supervisory team of Mr Ambituuni, who has been registered as a full time PhD student within the School of Civil Engineering and Geoscience at Newcastle University since October, 2012. His research is aimed at developing a structure risk management framework for downstream petroleum product transportation, distribution and retailing.

Against this backdrop, Mr Ambituuni will be conducting an extensive fieldwork in Nigeria to obtain his research data. This will entail conducting some semi-structured interviews with the members of your organisation, and conducting a Hazard and Operability studies of transport systems with a representative of the Safety Engineering Department in your organisation. He will similarly need some industry reports to help establish the characteristics of accidents and disasters within the context of petroleum product transport systems in Nigeria.

Also, since Mr Ambituuni's research project is envisaged to offer a feasible approach to managing health, safety and environmental risks within downstream petroleum operations in Nigeria, it is our kind hope that he is able to explore and establish a collaborative partnership with your organisation so as to present his finding to you at the end of his research.

I would be very grateful if your organisation would be able to offer all the necessary assistance to facilitate his work.

If you have any queries, please do not hesitate to contact me

Yours faithfully,

Dr. Jaime Amezaga
Water Theme Coordinator
Newcastle Institute for Research on Sustainability (NIReS)
Devonshire Building
Newcastle University
Newcastle upon Tyne
NE1 7RU
Direct dial: +44 (0)191 246 4876

tel :+44 (0) 191 222 6402
fax :+44 (0) 191 246 4961

ceg@ncl.ac.uk
www.ceg.ncl.ac.uk

Newcastle University
School of Civil Engineering and Geosciences
Cassie Building, Newcastle upon Tyne
NE1 7RU, United Kingdom

COMACE OFFICE (F R S C)
National Headquarters, Abuja
Received by Uchenu
Sign........ Date 25/6/14

ACM (PRS)
25/6/14

Newcastle University

School of Civil Engineering and Geosciences

Newcastle University
3rd Floor Devonshire Building
Newcastle upon Tyne
NE1 7RU United Kingdom

25th/06/2014

The Corp Marsha and Chief Executive
Federal Road Safety Corps
National Headquarters
No. 3 Maputo Street. Zone 3 Wuse
Abuja, Nigeria.

Dear Sir,

Request for updated data for my PhD research

On 15th of July, 2013 I applied and obtained your kind permission (please see attached a copy) to collect data including accident records involving truck tankers from the Trucks and Heavy Vehicles department for the propagation of my PhD research. With the thankful assistance and cooperation of your staff, I have obtained the required data. I however need the 2013 accident record to update my research to reflect the current trend.

Kindly accord me with the permission to approach your Trucks and Heavy Vehicles department for the requested data.

Thanks for your consideration

Yours faithfully,

Ambisisi Ambituuni

tel :+44 (0) 191 222 6402
fax :+44 (0) 191 246 4961

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www.ceg.ncl.ac.uk

THE QUEEN'S ANNIVERSARY PRIZES

FRSC/HQ/PRS/598/VOL.VI/

30 Jun' 14

Ambisisi Ambituuni,
School of Civil Engineering and Geosciences,
New Castle University,
3rd Floor Devonshire building,
New Castle Upon tyre,
NEI7RU United Kingdom.

RE: REQUEST FOR UPDATED DATA FOR PhD RESEARCH

The above subject refers.

2. Find attached updated reported Road Traffic Crashes (RTC) for year 2013 and reported vehicles involved in Road Traffic Crashes (RTC) 2013 as requested.

3. Please accept the highest regard of the Corps Marshal and Chief Executive.

4. Thank you.

ACM Kayode OLAGUNJU(PhD)
Head, Policy, Research and Statistics Department
For: Corps Marshal and Chief Executive

PETROLEUM TECHNOLOGY DEVELOPMENT FUND
Plot 672, Port-Harcourt Crescent, Off Gimbiya Street, Off Ahmadu Bello Way, Garki (Area 11) Abuja
P. O. Box 9899 Garki (Area 10) Abuja. Tel: +234 9 8700532-3 (Fax) +234 80 75000561
Post Code 900247, www.ptdf.gov.ng

DEPARTMENT OF PETROLEUM RESOURCES
RECEIVED
29 JUL 2013
Director's Office

10th July 2013 PTDF/E/OSS/PHD/AA/453/12

The Director
Department of Petroleum Resources (DPR)
Lagos

Dear Sir,

LETTER OF INTRODUCTION – AMBISISI AMBITUUNI

Mr. Ambisisi Ambituuni is a PhD student at Newcastle University, United Kingdom under the sponsorship of the Petroleum Technology Development Fund commencing from October 2012.

2. The scholar is undertaking a research in Health, Safety and Environment with the topic 'Developing Risk Management Framework for Health, Safety and Environment within the Transportation, Distribution and retailing sub-sector of the Nigerian Petroleum Industry.'

3. He is currently at the level of data gathering and he has identified your organization as one of the key players in the downstream sector of the oil and gas industry. Consequently, he wishes to visit your organization in order to gather necessary data that will assist him in his research.

4. You are therefore, kindly requested to render all necessary assistance to him in this regard.

5. Please accept the assurances of the Fund's highest regards.

A.G. AMINU
General Manager (Education & Training Department)
For: Executive Secretary

Newcastle University

School of Civil Engineering and Geosciences

Newcastle University
3rd Floor Devonshire Building
Newcastle upon Tyne
NE1 7RU United Kingdom

01 July, 2013.

The Director
Department of Petroleum Resources
DPR Headquarters,
Lagos,
Nigeria.

Dear Sir,

Introduction: Mr Ambisisi Ambituuni

I am the head of academic supervisory team of Mr Ambituuni, who has been registered as a full time PhD student within the School of Civil Engineering and Geoscience at Newcastle University since October, 2012. His research is aimed at developing a structure risk management framework for downstream petroleum product transportation, distribution and retailing.

Against this backdrop, Mr Ambituuni will be conducting an extensive fieldwork in Nigeria to obtain his research data. This will entail conducting some semi-structured interviews with the members of your organisation, and conducting a Hazard and Operability studies of transport systems with a representative of your organisation. He will similarly need some industry reports to help establish the characteristics of product transport systems and their regulatory requirements in Nigeria.

Also, since Mr Ambituuni's research project is envisaged to offer a feasible approach to managing health, safety and environmental risks within downstream petroleum operations in Nigeria, it is our kind hope that he is able to explore and establish a collaborative partnership with your organisation so as to present his finding to you at the end of his research.

I would be very grateful if your organisation would be able to offer all the necessary assistance to facilitate his work.

If you have any queries, please do not hesitate to contact me.

Yours faithfully,

Dr. Jaime M. Amezaga
Water Theme Coordinator
Newcastle Institute for Research on Sustainability (NIReS)
Devonshire Building
Newcastle University
Newcastle upon Tyne
NE1 7RU
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Cassie Building, Newcastle upon Tyne
NE1 7RU, United Kingdom

The Queen's Anniversary Prizes
For Higher and Further Education
2009

Newcastle University

School of Civil Engineering and Geosciences

Newcastle University
3rd Floor Devonshire Building
Newcastle upon Tyne
NE1 7RU United Kingdom

01 July, 2013.

The Director-General
National Environmental Standards and Regulations Enforcement Agency (NESREA)
Abuja,
Nigeria.

Dear Sir,

Introduction: Mr Ambisisi Ambituuni

I am the head of academic supervisory team of Mr Ambituuni, who has been registered as a full time PhD student within the School of Civil Engineering and Geoscience at Newcastle University since October, 2012. His research is aimed at developing a structure risk management framework for downstream petroleum product transportation, distribution and retailing.

Against this backdrop, Mr Ambituuni will be conducting an extensive fieldwork in Nigeria to obtain his research data. This will entail conducting some semi-structured interviews with the members of your organisation. He will similarly need some industry reports/guidelines to help establish the characteristics of environmental issues from product transport systems and they are being regulated.

Also, since Mr Ambituuni's research project is envisaged to offer a feasible approach to managing health, safety and environmental risks within downstream petroleum operations in Nigeria, it is our kind hope that he is able to explore and establish a collaborative partnership with your organisation so as to present his finding to you at the end of his research.

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If you have any queries, please do not hesitate to contact me.

Yours faithfully,

Dr. Jaime M. Amezaga
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Newcastle University

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and Geosciences

Newcastle University
3rd Floor Devonshire Building
Newcastle upon Tyne
NE1 7RU United Kingdom

23 May, 2014.

The Director General
National Oil Spill Detection and Response Agency (NOSDRA)
Plot 590 Zone, AO,
Central Business District
P.M.B 145 Garki, Abuja.

Dear Sir,

Introduction: Mr Ambisisi Ambituuni

I am the head of academic supervisory team of Mr Ambituuni, who has been registered as a full time PhD student within the School of Civil Engineering and Geoscience at Newcastle University since October, 2012. His research is aimed at developing a structured risk management framework for downstream petroleum product transportation, distribution and retailing.

Against this backdrop, Mr Ambituuni will be conducting an extensive fieldwork in Nigeria to obtain his research data. This will entail conducting some semi-structured interviews with the management members of your organisation. He will similarly need some industry incident reports to help establish the characteristics of product transport systems and their regulatory requirements in Nigeria and also the financial consequences associated with product spills.

Also, since Mr Ambituuni's research project is envisaged to offer a feasible approach to managing health, safety and environmental risks within downstream petroleum operations in Nigeria, it is our kind hope that he is able to explore and establish a collaborative partnership with your organisation so as to present his finding to you at the end of his research.

I would be very grateful if your organisation would be able to offer all the necessary assistance to facilitate his work.

If you have any queries, please do not hesitate to contact me.

Yours faithfully,

Jaime

Dr. Jaime M. Amezaga
Senior lecturer
School of Civil Engineering and Geosciences
Devonshire Building
Newcastle University
Newcastle upon Tyne
NE1 7RU
Direct dial: +44 (0)191 246 4876
tel :+44 (0) 191 222 6402
fax :+44 (0) 191 246 4961

ceg@ncl.ac.uk
www.ceg.ncl.ac.uk

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Pipelines & Products Marketing Company Limited, Abuja
17 JUL 2013
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Pipelines & Products Marketing Company Limited Abeokuta
EDO'S OFFICE
15 JUL 2013
48

PETROLEUM TECHNOLOGY DEVELOPMENT FUND

Plot 672, Port-Harcourt Crescent, Off Gimbiya Street, Off Ahmadu Bello Way, Garki (Area 11) Abuja
P. O. Box 9899 Garki (Area 10) Abuja Tel: +234 9 8700532-3 (Fax) +234 80 75000561
Post Code 900247, www.ptdf.gov.ng

Pipelines & Products Marketing Company Limited
EDO'S OFFICE
17 JUL 2013
30

10th July 2013

PTDF/E/OSS/PHD/AA/453/12

12 JUL 2013

(3) Mgr HSE
Pls convey acceptance
17/07/13

(2) EDO
Kindly handle
15/07/13

The Managing Director
Pipeline and Product Marketing Company
NNPC Towers
Abuja

Dear Sir,

LETTER OF INTRODUCTION – AMBISISI AMBITUUNI

Mr. Ambisisi Ambituuni is a PhD student at Newcastle University, United Kingdom under the sponsorship of the Petroleum Technology Development Fund commencing from October 2012.

2. The scholar is undertaking a research in Health, Safety and Environment with the topic 'Developing Risk Management Framework for Health, Safety and Environment within the Transportation, Distribution and retailing sub-sector of the Nigerian Petroleum Industry.'

3. He is currently at the level of data gathering and he has identified your organization as one of the key players in the downstream sector of the oil and gas industry. Consequently, he wishes to visit your organization in order to gather necessary data that will assist him in his research.

4. You are therefore, kindly requested to render all necessary assistance to him in this regard.

5. Please accept the assurances of the Fund's highest regards.

A.G. AMINU
General Manager (Education & Training Department)
For: Executive Secretary

(3) Mgr HSE
Pls comment
17/07/13
EDO

(4) EDO
Management May wish to [illegible] candidate to gain approval for the needed information in [illegible] Operation

Newcastle University

School of Civil Engineering and Geosciences

Newcastle University
3rd Floor Devonshire Building
Newcastle upon Tyne
NE1 7RU United Kingdom

01 July, 2013.

The Managing Director
Pipeline Product Marketing Company
Nigerian National Petroleum Corporation,
Abuja,
Nigeria.

Dear Sir,

Introduction: Mr Ambisisi Ambituuni

I am the head of academic supervisory team of Mr Ambituuni, who has been registered as a full time PhD student within the School of Civil Engineering and Geoscience at Newcastle University since October, 2012. His research is aimed at developing a structure risk management framework for downstream petroleum product transportation, distribution and retailing.

Against this backdrop, Mr Ambituuni will be conducting an extensive fieldwork in Nigeria to obtain his research data. This will entail conducting some semi-structured interviews with the members of your organisation, and conducting a visual inspection of condition of right-of-way within his sampled location. He will likewise need some industry reports (see attached) to help him establish the characteristics of product pipeline operated by your organisation.

Also, since Mr Ambituuni's research project is envisaged to offer a feasible approach to managing health, safety and environmental risks within downstream petroleum operations in Nigeria, it is our kind hope that he is able to explore and establish a collaborative partnership with your organisation so as to present his finding to you at the end of his research.

I would be very grateful if your organisation would be able to offer all the necessary assistance to facilitate his work.

If you have any queries, please do not hesitate to contact me.

Yours faithfully,

Dr. Jaime M. Amezaga
Water Theme Coordinator
Newcastle Institute for Research on Sustainability (NIReS)
Devonshire Building
Newcastle University
Newcastle upon Tyne
NE1 7RU
Direct dial: +44 (0)191 246 4876

Newcastle University
School of Civil Engineering and Geosciences
Cassie Building, Newcastle upon Tyne
NE1 7RU, United Kingdom

tel :+44 (0) 191 222 6402

PPMC Pipeline Operating Data Request

- Piping and instrumentation diagrams (P&ID).
- Pipeline alignment drawings.
- Pipeline aerial maps.
- Facility layouts and maps.
- As-built drawings.
- Survey reports and drawings.
- Operating and maintenance procedures.
- Emergency response procedures.
- Inspection records.
- Incident and risk data.
- Repair and maintenance records.
- Test reports and records.
- Incident reports and operation history.
- Regulatory and compliance records.
- Pipeline design and engineering reports.
- Technical studies.
- Operator standards and specification.
- Equipment dossiers.
- Industry standards and specifications.

PIPELINES AND PRODUCTS MARKETING COMPANY LIMITED

(A Subsidiary of Nigerian National Petroleum Corporation) RC 121776

Block C NNPC Towers, Herberts Macaulay Way, Central Business District P.M.B 459, Garki, Abuja.

A SUBSIDIARY OF NNPC

Cablegram NAPETCOR

Ref: PPMC/HSE/005

Date: 19/07/2013

The Executive Secretary
Petroleum Technology Development Fund
Plot 672 Port-Hacourt Cresent
Off Gimbiya street
Garki Area 11
Abuja.

Dear Sir,

ACCEPTANCE OF LETTER OF INTRODUCTION – AMBISISI AMBITUUNI

The above subject refers:

Your letter with ref: PTDF/E/OSS/PHD/AA/453/12 dated 10th July, 2013 introducing Mr. Ambisisi Ambituuni.

We are pleased to convey to you the decision of the Management of the Pipelines and Products Marketing Company Limited (PPMC Ltd.) to accept Mr. Ambisisi Ambituuni a PhD student at Newcastle University, United Kingdom under your sponsorship to undertake a research in Health, Safety and Environment within the Transport and Distribution sub-sector of the Organization.

Please accept the assurances of the Company's highest regards.

Yours Faithfully,

for: PIPELINES AND PRODUCTS MARKETING CONPANY LIMITED

Ibrahim, M.
for: Managing Director

Nigerian National Petroleum Corporation
24 JUL 2013
MANAGER SECURITY
RECEIVED

PPMC

NNPC/PPMC
RECEIVED
24 JUL 2013
MGR. Security
Depo,
ABUJA

INTERNAL MEMORANDUM

To:	Manager, Security	Ref:	PPMC/MTC/30.1.1
From:	Manager, HSE	Date:	24th July, 2013

ENTRY REQUEST FOR MR. AMBITUNI AMBISISI

The above named person has an appointment with the MANAGER Health, Safety and Environment by 11:00 hours today.

This meeting is in respect of his PhD. academic research request which has gained approval from the MD, PPMC.

Kindly clear to enable him come in for the meeting as scheduled.

Regards,

OLADELE, O. T.

Mgr Security (CHQ)
Pls oblige
24/7/13

Supv. Ops
Pls oblige.
24/07/13

PETROLEUM TECHNOLOGY DEVELOPMENT FUND
Plot 672, Port-Harcourt Crescent, Off Gimbiya Street, Off Ahmadu Bello Way, Garki (Area 11) Abuja
P. O. Box 9899 Garki (Area 10) Abuja. Tel: +234 9 8700532-3 (Fax) +234 80 75000561
Post Code 900247, www.ptdf.gov.ng

10th July 2013 **PTDF/E/OSS/PHD/AA/453/12**

The Group Managing Director
Nigerian National Petroleum Corporation
NNPC Towers
Central Business District
Abuja

Dear Sir,

LETTER OF INTRODUCTION – AMBISISI AMBITUUNI

Mr. Ambisisi Ambituuni is a PhD student at Newcastle University, United Kingdom under the sponsorship of the Petroleum Technology Development Fund commencing from October 2012.

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4. You are therefore, kindly requested to render all necessary assistance to him in this regard.

5. Please accept the assurances of the Fund's highest regards.

A.G. AMINU
General Manager (Education & Training Department)
For: Executive Secretary

NNPC

INTERNAL MEMORANDUM

From:	**Manager, HSE**	**Ref:**	**RTL/015**
To:	**Under listed**	**Date:**	**06/08/2013**

<u>Introduction of Mr. Ambisisi Ambituuni of Newcastle University, UK</u>

Mr. Ambisisi Ambituuni is a PHD student of Civil Engineering studying at New Castle University, United Kingdom. He is in your station to carry out HSE research on unsafe conditions, unsafe act, near misses and other HSE related issues as it concern the best practices that will enhance productivity.

Please, accord him with all necessary information that will make his study a success.

Best regards,

Igashi, I. Sabo

Sales representatives: Abuja
Jalingo
Kaduna
Lagos

Newcastle University

School of Civil Engineering
and Geosciences

Newcastle University
3rd Floor Devonshire Building
Newcastle upon Tyne
NE1 7RU United Kingdom

01 July, 2013.

To Whom It May Concern

Dear Sir/Madam,

Introduction: Mr Ambisisi Ambituuni

I am the head of academic supervisory team of Mr Ambituuni, who has been registered as a full time PhD student within the School of Civil Engineering and Geoscience at Newcastle University since October, 2012. His research is aimed at developing a structure risk management framework for downstream petroleum product transportation, distribution and retailing.

Against this backdrop, Mr Ambituuni will be conducting an extensive fieldwork in Nigeria to obtain his research data. This will entail conducting some semi-structured interviews with the members of your organisation, and conducting a Hazard and Operability studies of transport systems with a representative of your organisation. He will similarly need some industry reports to help establish the characteristics of accidents and disasters within the context of petroleum product transport systems in Nigeria.

Also, since Mr Ambituuni's research project is envisaged to offer a feasible approach to managing health, safety and environmental risks within downstream petroleum operations in Nigeria, it is our kind hope that he is able to explore and establish a collaborative partnership with your organisation so as to present his finding to you at the end of his research.

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If you have any queries, please do not hesitate to contact me.

Yours faithfully,

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