TRANSPORTATION OF HAZARDOUS MATERIALS ON GHANA'S TRUNK ROADS: THE CASE OF TEMA – ACCRA – KUMASI HIGHWAY

By

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DECLARATION

I hereby declare that this submission is my own work towards a Master of Philosophy in Planning, and that to the best of my knowledge it contains neither material previously published by another person nor material that have already been accepted for the award of any other degree by the University or any other university except where due acknowledgement has been made in the text.

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ABSTRACT

Several hazardous material shipments are made on a daily basis on Ghana's highways; exposing humans, property and environment to risks. Though accidents involving hazardous materials are rare, when they occur their consequences can be rather severe. This notwithstanding, research on hazardous materials transportation in Ghana is virtually non-existent. This study is aimed at exploring and understanding the operations of hazardous material truckers and other stakeholders, using the Tema – Accra – Kumasi (N6) highway as a case study. Specifically, the study's objectives were: (i) to explore the characteristics of hazardous materials transportation along the Tema – Accra – Kumasi corridor; (ii) to examine risks associated with transportation of hazardous materials; and (iii) to explore risk prevention and management practices of truck operators.

Using a mixed methods research design, a sample of 170 hazardous material truck operators were randomly selected from clusters used as temporary parking places along the corridor in addition to some stakeholder institutions, which were purposively selected. The study revealed that about 2.5 million litres of petroleum products are transported on a daily basis along the corridor using Large Capacity Vehicles (LCVs). The use of LCVs reduces the potential risks that populations are exposed to while also allaying fears of terrorist attacks. It also came to light that 19.4% of truck operators did not comply with the four hour-mandatory Hours of Service (HoS), a worldwide best practice, making such operators vulnerable to accidents. Generally, accident rates involving hazardous materials on the corridor are low (0.0000770 or 7.7×10^{-5}) compared to some international road corridors. This could be as a result of the relatively smaller volumes shipped daily. Non-compliance to HoS regulations is attributed to the lack of intermediate rest facilities and inspection stations. As a means of preventing

accidents, Transport Service Providers [TSPs] provide regular professional training for truck operators; regularly maintained their trucks; and insured products together with vehicles and their truck operators.

The current operations implies that there is safety consciousness. However, some more efforts are required to consolidate the achievements thus far. Accordingly, appropriate recommendations were made including the introduction of intermediate rest facility combined with a mobile inspection station. Areas of further research were also identified.

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LIST OF ACRONYMS

APD	Accra Plains Depot
BOST	Bulk Oil Storage and Transportation Company Limited
BRRI	Building and Road Research Institute
BRVs	Bulk Road Vehicles
CERSGIS	Centre for Remote Sensing and Geographic Information Services
DVLA	Driver and Vehicle Licensing Authority
EPA	Environmental Protection Agency
EPR	Extended Product Responsibility
FMCSA	Federal Motor Carrier Safety Administration
FRA	Field Research Assistants
GAEC	Ghana Atomic Energy Commission
GCNet	Ghana Community Network Services Limited
GHA	Ghana Highway Authority
GNFS	Ghana National Fire Service
GPS	Ghana Police Service
HMCRP	Hazardous Materials Cooperative Research Program
LCVs	Larger Capacity Vehicles
LPG	Liquefied Petroleum Gas
NADMO	National Disaster Management Organization
NPA	National Petroleum Authority
NRSA	National Road Safety Authority
PPP	Public Private Partnership
PS	Product Stewardship
SDSS	Spatial Decision Support Systems
SPPs	Safe Parking Places
TOR	Tema Oil Refinery

TSPs	Transport Service Providers
VALCO	Volta Aluminium Company

CHAPTER ONE
AN OVERVIEW OF THE STUDY

1.1 Introduction

It is every nation's desire to achieve social and economic development. Several authors have shown that transportation investment has a relation with economic development (see, Gillen, 1996; Banister and Berechman, 2001; Cheteni, 2013; Alises, Vassallo and Guzmán, 2014). In this regard, there is a positive relationship between transportation investment and economic growth. Table 1.1.1 indicates how transportation impacts Gross Domestic Product (GDP) of Ghana; contributing, on average, approximately 10% to annual GDP. Transportation is essential for economic development in the sense that a well-functioning and efficient freight transportation system facilitates the economic lives of people with implications for the productivity of the nation, the costs of goods and services, and the global competitiveness in terms of trade due to reduced transportation cost. Similarly, Tseng, Yue and Taylor (2005) opined that an efficient transportation manifests in delivery speed and service quality among others. They also observed that improvements in transportation systems require both private and public efforts.

Table 1.1.1: Contribution of Transportation to Gross Domestic Product (GDP) in Ghana, 2009 – 2013.

Item	**2009**	**2010**	**2011**	**2012**	**2013**
Transport and Storage (million Gh₵)	3,758	4,578	5,997	7,883	10,183
GDP (million Gh₵)	36,598	46,042	59,816	74,959	93,461
% Contribution	**10.3**	**9.9**	**10.0**	**10.5**	**10.9**

Source: Ghana Statistical Service, 2014

The road transport sector plays a role of outstanding importance in any national economy, both through its own direct contribution to Gross Domestic Product (GDP) and employment as well as through the provision of services which are crucial for the development of all other economic sectors (Cali, Ellis and te Velde, 2008). Road sector transportation comprises intra-urban, national, regional and international import, export and transit flows of goods and passengers. It has a direct impact on poverty and growth as it offers numerous employment avenues for people while also contributing significantly to GDP. Road freight transport is vital also in resource mobilization, production and distribution of consumer products (Londoño-Kent, 2009). An aspect of such products are the hazardous materials or dangerous goods like petroleum products, gases, agro chemicals as well as waste that may contain hazardous chemicals or materials. Given the utmost importance transportation plays in an economy, the processes need to be well monitored to ensure safety, especially for hazardous materials. How hazardous materials are safely transported is the focus of this study.

Hazardous materials (hazardous materialss) also play a crucial role in the development of any nation's economy. These materials are used in industries, hospitals, mines as well as homes for industrial and domestic purposes. For example, various industries demand fuel such as diesel, petrol or gases to power their plants in the process of production. Similarly, households also demand Liquefied Petroleum Gas for domestic uses such as heating. Hazardous materials, however, are not often produced in situ or at demand centers and as such need to be transported between points, usually an origin and a destination, interlaced with intermediate stops.
Industry's demands require that some hazardous materials are transformed and converted into useful products to enhance human existence (Aini *et al.*, 2001).

Transportation of freight in Ghana, generally, is carried out using different modes including walking, pipelines, roads, air, water, rail or a combination of any of these modes. Roads account for over 90% of freight transportation in Ghana (Maunder and Pearce, 2001) and, hazardous materials, by no exception, form an integral part of freight transported on the roads. However, the movement of freight on Ghanaian roads is plagued by a myriad of challenges. These range from "bad" roads and inadequate road infrastructure, delays, harassment of truck drivers on the roads by regulatory authorities such as the Ghana Police Service and Customs, Excise and Preventive Service (CEPS), accidents on highways, pollution and congestion in city centers (Verhoef, 1994; Raballand, Kunth and Auty, 2005; Takyi, Poku and Anin, 2013; Enu, 2014). These have the effect of prolonging delivery schedules, hindering "just in time" inventory management, and impede the efficient combination of factors of production in industries. In addition to these general challenges associated with freight transportation, there is a different twist for hazardous materials. This is discussed in the subsequent section.

In Ghana, generally, it appears freight transportation is not well documented in research. Some plausible reasons for this phenomenon include the absence or lack of freight demand data since it was expensive to collect; and, data were sometimes kept confidential (Jiang, Johnson and Calzada, 1999). A few earlier studies on freight transportation in Ghana include that by Tamakloe and Adarkwa (1998) and Adarkwa, Poku-Boansi, and Obeng-Atuah (2015). However, they are concerned about specific aspects of freight transportation. Tamakloe and Adarkwa (1998) assessed the parking situation in Kumasi and concluded that there were inadequate parking spaces for freight vehicles as well as visual intrusion posed by haphazard nature of parking freight vehicles. Adarkwa, Poku-Boansi and Obeng-Atuah (2015) assessed economic impacts of overloading freight vehicles on Ghana's major transit corridors and recommended rebates on newly imported freight vehicles as well as sustained road maintenance on the transit corridors. Hazardous materials, being a 'special' class of freight requires urgent attention and that is the thrust of the current study.

1.2 Problem Statement

Hazardous materials, as the name suggests, are very toxic and can be injurious to humans and property as well as the environment. These materials include petroleum products, paints, various pressured gases, refuse, industrial chemicals, explosives (for mines and quarries), radioactive equipment and materials, industrial waste, pesticides and weedicides among others. Ordinarily, in an ideal situation, these are not to be exposed to the public unless they are under controlled circumstances; however, this is not the case at all times. In the course of transporting these materials from points where they are produced or imported (origin) to demand or consumption centers (destinations) several issues come into play to ensure they are safely transported to desired destinations. Issues about regulation of entry and exit of hazardous material freight transporters, integrity of the packaging materials, labelling, and inspection among other things need to be taken care of to ensure that hazardous materials are transported without any accidents.

In spite of this, any accident that involves hazardous materials has a dire consequence on the human population immediately around the accident site, the properties as well as the natural environment. Table 1.2.1 gives an idea of the some accidents in which hazardous materials are involved and the consequences of such accidents thereof.

Urgent attention is needed in the transportation of hazardous materials considering the staggering statistics. Shall we, as a nation, sit aloof and pretend nothing is happening when, indeed, we are losing part of our population and property as well as environment to hazardous material accidents?

Table 1.2.1: Selected Hazardous Materials Accidents during Transportation and Associated Consequences

Time of accident	Location	Materials involved	Consequences	Accident type
March 2016	Kasoa	LPG	Traffic hold up for hours	Overturned truck causing leakage
* September 2015	South Sudan	Fuel	176 deaths Several vehicles burnt	Release followed by explosion
August 2015	Ngleshie Amanfrom, near Kasoa	Gas	2 deaths on the spot Several injuries	Gas explosion
July 2015	Inchaban, Takoradi	Gas	No casualties 5 hours traffic hold up 150 homes evacuated	Leakage
April 2015	Kokode, near Kumasi	Petroleum products	3 deaths 4 vehicles destroyed Several stores burnt	Explosion
September 2014	Assin Fosu	Petrol	50 shops destroyed	Explosion
August 2014	Tema	Gas	3 deaths	Explosion
January 2014	Kwahu Fodua	Gas	9 died instantly 40 severely injured 26 houses affected Farms destroyed	Collision an leading to explosion
January 2013	Bibiani-Kumasi road	Diesel	2 deaths 4 houses destroyed 5 shops burnt	Release followed by explosion
November 2008	Techiman	Petrol	22 deaths Over 50 hospitalized	Release followed by an explosion
** Between 2007-2008	KATH	4 Petrol fire disasters	37 on the spot deaths 175 seriously injured	Fires

Source: Compiled from various Ghanaian and international news websites

* Not in Ghana, but to depict the extent of devastation caused

** Agbenorku *et al.* (2010)

A cursory look at the various accidents outlined in Table 1.2.1 suggests that hazardous material accidents are very rampant and urgent steps are needed to sensitize the public on dealing with such materials. In the case of the accident in Techiman in the year 2008, several residents were at the scene of the accident to scoop fuel that was leaking from an over turned tanker. If these people were well informed on the dangers of coming directly into contact with fuel in an uncontrolled environment they would have been better placed on how to deal with a situation and not be scooping from the site.

Considering that not much has been done in this area of research in Ghana, this study seeks to bring the attention of policy makers to bear on this menace of hazardous material accidents, and also contribute to the global discourse on transportation of hazardous materials. Hazardous materials transportation is plagued with high degree of risk and dire consequences in the event of any incident during transportation. This 'special' class of freight need to be regulated and safely transported so as to ensure public health and safety. This study is intended to to examine the regulations guiding transportation of hazardous materials in Ghana, the level of public awareness as well as emergency response preparedness to deal with any situation. Answers to these few problems are the driving force of this study. The study seeks to explore the transportation of hazardous materials on Ghana's trunk roads. When this is done accurately, policy recommendations are evolved based on findings to guide the process in a bid to safeguard environmenal and public safety in Ghana, particularly, along major highways that serve as transportation routes.

This study employs an exploratory approach to reveal the major hazardous materials being transported on the trunk road, the conditions under which drivers or truck operators operate, and the existing regulations governing transportation of hazardous materials. Other areas of interest include risk estimation, compliance of truck operators to regulations, maintenance culture as well as preventive and mitigation measures adopted by truck operators to forestall any accidents. These are embodied in the objectives of the study; which are outlined subsequently.

1.3 Research Objectives

The overarching objective of this study is to capture, describe, analyze and understand the characteristics of hazardous materials transportation through Ghana's highways with emphasis on the Tema – Accra – Kumasi (N6) corridor. However, the study is guided and driven by the following specific objectives listed seriatim:

- To explore the nature/characteristics of hazardous materials transportation along the Tema – Accra – Kumasi corridor;
- To examine risks associated with transportation of hazardous materials along the Tema – Accra – Kumasi corridor; and
- To explore risk prevention and management practices of hazardous material truck operators on the corridor.

1.4 Research Questions

In carrying out this research, the following questions are put forth to guide and shape the focus of the study.

Specifically, questions to be addressed include the following:

1. What is the nature/characteristics of hazardous materials transportation along the Tema – Accra – Kumasi corridor?
2. What are risks associated with transportation of hazardous materials along the Tema – Accra – Kumasi corridor?
3. What are the risk prevention and management practices of hazardous material truck operators on the Tema – Accra – Kumasi corridor?

1.5 Scope of the Study

The study focuses on exploring and understanding the characteristics of hazardous materials transportation on highways in Ghana with particular emphasis on Tema – Accra – Kumasi (N6) highway. Specifically, it looked at the processes involved in the transportation of hazardous materials, exploring the characteristics of goods and vehicles used, challenges associated with transportation of hazardous materials, risk estimates as well as accident prevention and management practices. The major variables studied include hazardous freight characteristics, age of truck operators, educational levels, professional training, axle configuration, weight of loads or freight, origin and destinations, number of accidents truck operators have been involved in the last ten years, preventive and mitigation measures among others. Bearing these in mind, recommendations are suggested on innovative ways of ensuring safe and efficient transportation of hazardous materials on highways, and areas for further research also outlined.

1.6 Significance and Justification for the Study

The essence of spending time, money and other resources on a particular research is best provided by its justifications; whether it is beneficial to the individual and general society at large or if it contributes to intellectual discourse or serves a practical need or purpose. Baker (1999) opined that possible reasons or justifications for studying a topic are to describe a social phenomenon, to explore a largely undefined area, or to explain a hypothesized relationship. A study may be a replication of an earlier study to see whether the findings can be verified. The rationale for a research project is a sound reason for selecting the particular subject and method for carrying out the research based on some value or purpose. Baker (1999) intimates two rationales for research – to contribute to systematic knowledge in a discipline (that is, basic research) or that it will be of some practical use (that is, applied research).

Stemming from the position of Baker (1999), this study sought to address both basic and applied research. In this sense, firstly, considering that research on the subject of hazardous material transportation in Ghana and Africa, for that matter, is limited, this study will contribute to the intellectual global discourse of ensuring safe transportation of hazardous materials, particularly on highways. This constitute the basic research aspect of the significance of the study.

Secondly, this study provides a rationale for policy direction in terms of risk estimates as well as compliance with regulations that govern transportation of hazardous materials. Although accidents involving hazardous materials are rare and their consequences very dire, research on the subject is virtually non-existent. Risk estimates from this study provide basis for policy action to deal with the situation. Recommendations, including the establishment of intermediate rest facility as well as inspection sites, are intended to influence national policy. In addition, findings of this study provide background for the government to explore Public Private Partnership in providing road infrastructure.

1.7 Limitations of the Study

In conducting the study, limitations were encountered; some of which are outlined as follows. There was a limitation with the scope of study, where all the nine classes of hazardous materials as identified by the U.S. Department of Transportation (2004) could not be captured. Three classes consisting of Class 2 materials (gases such as

LPG), Class 3 materials (flammable liquids such as petrol, diesel, and kerosene) and Class 8 materials (corrosives such as caustic soda and cyanide) were included in the study. During the surveys, it was difficult to identify and delineate truck operators that transported hazardous materials from those that were transporting non-hazardous materials. However, this shortcoming was addressed during the surveys by asking freight truck operators what goods they were transporting, and when it was realized that they fall within the classification or criteria identified they were included in the survey. In addition, because of resource constraints the study did not take into consideration the entire N6 corridor, which stretches from Accra all the way through

Kumasi, Sunyani and to the border with Cote D'Ivoire through Berekum in the Brong Ahafo region. Because some hazardous freight trucks had destinations along the N6 highway beyond Kumasi, efforts were made to capture these truck operators within the various clusters for sampling.

1.8 Organization of the study

The study is organized into six distinct but coherent chapters. Chapter One provides a general introduction, background statement, research questions, objectives and justification of the study. Review of the relevant literature in relation to the transportation of hazardous materials is captured in Chapter Two. Issues such as regulation or de-regulation of entry and exit as well as control of the process, risks involved and their estimation methods in addition to causes and effects of hazardous material accidents were reviewed. Risk prevention and management tools that are used globally are also discussed in this chapter. The methodology used in collecting data required for the study and the analytical tools employed for analysis are discussed in greater detail in Chapter Three. Following data collection, Chapter Four presents the analysis of the data gathered from the field. During this stage of the research process patterns and relationships among variables of interest were established. Chapter Five contains the summary of findings and discussion of major findings within the context of existing literature. Recommendations are put forward in Chapter Six to help minimize accidents associated with the transportation of hazardous materials on Ghana's trunk roads with particular emphasis on the Tema – Accra – Kumasi Highway. Also, areas for further research were identified.

CHAPTER TWO REVIEW OF RELEVANT LITERATURE ON TRANSPORTATION OF
HAZARDOUS MATERIALS

2.0 Introduction

This chapter highlights relevant literature on the transportation of hazardous materials. It examines in close detail classical as well as recent literature on the concepts that explain transportation of hazardous materials. Specifically, it discusses how regulations have been evolved to guide the process of transporting hazardous materials; the risks related to transportation of hazardous materials; the need for risk assessment and the various assessment methods; hazardous materials routing or route selection and factors that have been considered in route selection; as well as policy tools available for mitigating hazardous materials transportation accidents. Research direction for the next sections of the study is drawn from the conceptual framework that establishes variables identified from literature review as well as their interrelationships.

2.1 Hazardous Materials Defined

In recent years, many countries, the world over, have experienced a high rate of urbanization and this has come along with industrialization (Turok, 2012). Demands of industry require the use and conversion of harmful or hazardous substances into useful products to enhance human existence (Aini *et al.*, 2001). Also, waste forms an integral part of industrial production and some of this happens to be hazardous to humans and the environment (Misra and Pandey, 2005). In fact, as a result of industrial development, Leonelli, Bonvicini and Spadoni (2000) acknowledge that huge quantities of hazardous materials are produced yearly. It is obvious that production of hazardous materials comes along with transportation, notwithstanding the modes employed in such transportation.

To have a clear understanding of occurrences in the hazardous materials transportation sector in Ghana, a clear definition ought to be outlined. It has been noted that several definitions have been put forth to explain what constitutes and does not constitute hazardous materials. A working definition is adopted for this study following review of various works done across various geographical jurisdictions.

The various definitions used for hazardous materials are summarized in the ensuing sections.

Hazardous materials have no one accepted definition like many other concepts. In this section, an attempt is made to capture and summarize some of the various definitions and explanations that have been used to describe what constitutes hazardous materials, and a working definition for what is included as a hazardous material for purposes of this research is drawn subsequently. This working definition gives a clear and precise definition of what is included and captured in this report as constituting hazardous material or dangerous good. But before coming to this, it will be useful to outline some of the existing definitions of hazardous materials.

From the mid 1970s, a collection of legal statutes and regulatory agency declarations have come about to assess and regulate risks associated with potentially hazardous materials in society (Corn, 1993). Corn (1993) provides a detailed and exhaustive list of potentially hazardous materials including cyanide, nitrogen oxides, fungicides and herbicides among others. Indeed researchers took keen interest in the area of hazardous materials from this point following legal and regulatory declarations.

Polprasert and Liyanage (1996) defined hazardous materials in terms of waste. To them, for any material to be considered hazardous, that material ought to exhibit any one or more of the following features: corrosivity, ignitability, toxicity and reactivity (see Appendix 2a for hazards of the following features). Corrosivity refers to the property of a material that makes it capable of corroding or destroying metal containers such as barrels or storage tanks. In addition, corrosive subtances, including sulfuric and hydrochloric acids as well as caustic soda, cause damage to living tissues. Ignitability refers to the property of a material to create fire or to be combustible under certain conditions with an example being petrol or diesel. A reactive material is one that is not stable under normal conditions and could potentially cause explosions. A toxic substance is one that is harmful when absorbed into the human body with examples being lead and mercury. It stands to reason that any material that exhibits these characteristics, for example, industrial residues from pesticide, weedicide, petroleum production firms are hazardous due to their toxicity.

Oluwole (2000), similarly, defined Hazardous Materials (HM) or Dangerous Goods (DG) as a range of bulk liquid chemicals and liquefied petroleum gases with potential for spillage, fire, toxic release, and/or explosion. This definition of hazardous materials appears rather limited, because hazardous materials could also take the form of solids such as flammable plastics and asphalt shingles.

Fabiano, Curro and Pastorino (2008) suggest that hazardous materials are such substances that require special care to prevent harm from them to humans, the environment and/or property, usually, as a result of accident or an unwanted event. In effect, hazardous materials need not to be exposed to the public and, where necessary, actions are required to prevent harm from their unlikely exposure or release into the environment.

Garrido (2008) defines hazardous materials to include solids and liquids that are flammable, explosives, oxidant substances, infectious and poisonous substances, corrosive substances and radioactive materials among others. These materials in themselves may not be harmful to humans but their unguarded release into the atmosphere or environment renders them harmful and pose threats to the environment, property as well as public health and safety.

The US Department of Transportation (2004) defines hazardous materials to mean any substance or material that has the capability of causing harm to people, to property as well as to the environment. These materials have been grouped into nine classes, and they are listed seriatim:

Class 1– Explosives (dynamite, caps);
- 2– Gases (propane, anhydrous ammonia, chlorine, oxygen);
- 3– Flammable Liquids (gasoline, oil, tars, diesel, kerosene);
- 4– Flammable Solids (plastics, asphalt shingles);
- 5– Oxidizing Substances (peroxides);
- 6– Poisonous and infectious substances (herbicides, pesticide);
- 7– Radioactive materials;
- 8– Corrosives (acids); and
- 9– Miscellaneous (Polychlorinated Biphenyls [PCBs], dangerous wastes).

Waste, from households, industries or construction sites, is also considered to be hazardous when due to its chemical composition and other properties, it is capable of causing deaths, illnesses or some other negative health effect to humans and other life forms including flora and fauna as well as property when mismanaged or released into the environment unguarded.

In Ghana, for example, Amegashie (2010) coming from a legal perpsective, defined Dangerous Goods as matter or substances that pose risks to human safety, property and the environment if accidentally released during transportation in commerce. These materials include, but are not limited to, acids, fertilizers, chemical products, petroleum products, biological products, explosives, gaseous substances, various forms of industrial waste as well as radioactive substances. The transportation of these materials needs to be regulated in a bid to prevent accidents to persons, property including the vehicle being used to transport as well as the environment. It is worthy of note that in addition to risk reduction or prevention, regulating the transportation of hazardous materials also facilitates their transportation as well as processes involved.

While several defintions and explanations put forth by various authors sought to define hazardous materials, they all have key similarities that amply describe hazardous materials fundamentally. To the ordinary mind, a hazardous material is considered as that which poses threat to human safety as well as property and the environment. These threats can take several forms including, but not limited to, explosions, threat of gaseous release and inhalation, threats to property along routes used in transporting hazardous materials and threats to natural environment.

From the array of definitions, it is clear that hazardous materials or dangerous goods are either raw materials or manufacturing components for production or waste resulting from production in industrial establishments or even final products for consumption and they are usually transported between points, constituted as origins and destinations. In the course of transporting these substances, there could be unintended spills, leakages, unwanted release or explosions that put the immediate human population, the environment and/or property at risk because of sheer exposure or proximity to transporting routes.

Inherent in all the foregoing definitions is the risk of humans, property and the immediate environment as a result of being exposed to hazardous materials in the course of transportation through accidental release or any other unwanted event. These materials could cause explosions, gas clouds and air pollution when released into the atmosphere and as such need to be well protected in the process of transportation.

The operational definition for a hazardous material used for this study is as follows: *"… any material – liquid, solid or gas – that possesses any of the following properties: corrosivity; ignitability; reactivity; and toxicity, and is capable of causing some degree of harm or injury to persons, the environment or physical property through an unintended, unguarded or accidental release into the natural environment*."

Hazardous materials possess some chemical properties that render them corrosive, reactive, toxic and ignitable. Petroleum products, for example, contain compounds such as lead and benzene, toluene, ethyl benzene, xylenes (BTEX) (Heath, Koblis and Sager, 1993). These compounds are not only toxic to humans but are equally damaging to the natural environment.

For the purposes of this study, a hazardous material (hazardous materials) or dangerous good is assumed to be transported on a vehicle in some form of a holding material or container and any rupture of this holding unit results in a release of the hazardous material. Much in the same vein, this study concentrated on some specific hazardous materials types, namely: Petroleum Products; Liquefied Petroleum Gas (LPG); and Chemicals used in the mines.

Following a critical review of existing definitions and coming out with an operational definition as well as a list of hazardous material types to be included in this study, the subsequent section discusses the relationships and roles of regulators and carriers in the process of transporting hazardous materials.

2.2 Theoretical Underpinnings of the Study

This section explores the theories and constructs that have been used to explain actions or behaviour of drivers as well as the unpredictable of accidents involving hazardous materials. It also tries to explain how human behaviour (of truck operators) can be influenced to yield positive socially accepted behaviour or norm. In addition, the causes and predictability of accidents, particularly involving hazardous materials which are rare, are explained from a theoretical perspective. These are captured and discussed broadly in the ensuing sections.

2.2.1 Chaos Theory

Proposed by American mathematician Edward Lorenz in the 1960s. This theory purports to explain the relationship between events, their causes and outcome. It states that there exists non-linear and unpredictable relationship among series of events. In a sense, one would observe that accidents involving hazardous materials, for example, are accounted for by a diversity of factors including negligence on the part of drivers, equipment failure or mechanical default, prevailing weather condition and a series of events that lead to the actual incident or accident (Mahmoudabadi and Seyedhosseini, 2012). However, the chaos theory explains that these series of events cannot be predicted accurately. What is being communicated ultimately by chaos theory is that we should always expect the unexpected, largely because we cannot predict it. As such local, national and international organizations should always anticipate the unexpected and prepare to deal with them in the unlikely event that they occur.

While traditionally most science theories are hinged on supposed predictability of phenomena such as gravity and electricity, chaos theory deals with phenomena whose occurrence cannot be predicted and are impossible to control. Some of such phenomena include the stock market, turbulence, weather, stock markets and brain state. The theory explains that chaotic or complex events are outcomes of some initial conditions or antecedents. Specifically, it dwells on the principle that small changes in an initial condition will result in large variations or differences in the final output or outcome (Yuan, Yuan and Zhang, 2002).

Indeed, because of its sensitivity to initial conditions Lawrence, Lin and Huang (2003) have argued that chaos theory is preferred for short term predictions rather than longer term ones.

2.2.2 Theory of Planned Behaviour [TPB]

This theory propounded by Icek Ajzen in 1991 helps to understand how human behaviour can be changed or influenced based on some three key considerations. It attempts to predict deliberate behaviour, since human behaviour can be planned or deliberate. The theory of planned behaviour [TPB] had been put forth as a successor to the theory of reasoned action (Wallen Warner, 2006). The theory of reasoned action was created to explain human action with attitude towards the behaviour and subjective norm as important predictors (Ajzen and Fishbein, 1980; Fishbein & Ajzen, 1975). A limitation to the theory of reasoned action in dealing with behaviors over which people have incomplete volitional control. As the TPB purpots to understand and explain human behaviour, it is applicable to understanding the actions or behaviour of truck operators in terms of speeding, flouting of Hours of Service regulations among other things. Similarly, while not only understanding why people behave in certain ways, the theory could also be used to mould or champion a new behaviour. However, this can only done based on influencing attitudes and combining that with perceived controls and subjective norms to predict delibrate and planned behaviour.

According to Ajzen (1991) people's *attitude towards the behaviour, their subjective norm and their perceived behavioural control determine their behaviour (a defined action) indirectly via their intention (a willingness to try to perform the behaviour)*. Attitude towards the behaviour is determined by behavioural beliefs, which are beliefs about the likely consequences of the behaviour (behavioural belief strength), weighted by the evaluation of how good or bad these outcomes would be (outcome evaluation). Subjective norm is determined by normative beliefs, which are beliefs about what important others think of the behaviour (normative belief strength), weighted by the motivation to comply with these important others (motivation to comply). Perceived behavioural control is determined by control beliefs, which are beliefs about factors that may facilitate or impede performance of the behaviour (control belief strength), weighted by the perceived power of these factors (control belief power).

From the foregoing, it is evident that the theory of planned behaviour is rooted on three considerations: behavioural beliefs, normative beliefs and control beliefs.

Behavioural beliefs are those beliefs an individual has about the likely consequences of a behaviour. These are based on a subjective probablility that the particular behaviour will produce a given outcome which may lead to favourable or unfavourable attitude towards the behaviour.

Normative beliefs refer to an individual's perception of social normative pressures, or relevant others' beliefs that he or she should or should not perform such behaviour. In other words, the perception an individual has about the reaction (approval or disapproval) of society (parents, spouse, friends, teachers, etc) to an intended action.

They make up an individual's beliefs about the normative expectations of others and motivation to comply with these expectations.

Control beliefs are those beliefs about the presence of factors that may facilitate or impede performance of the behavior and the perceived power of these factors. These beliefs are concerned with the amount of direction or support one has from the environment, suggesting how easy or difficult it will be to accomplish a particular behaviour.

The crux of the theory is that these three beliefs come into play to influence the behavioural intention of an individual. As a general rule, the more favorable the attitude and subjective norm, and the greater the perceived control, the stronger should be the person's intention to perform the behavior in question. Finally, given a sufficient degree of actual control over the behavior, people are expected to carry out their intentions when the opportunity arises. Intention is thus assumed to be the immediate antecedent of behavior. However, because many behaviors pose difficulties of execution that may limit volitional control, it is useful to consider perceived behavioral control in addition to intention. To the extent that perceived behavioral control is veridical, it can serve as a proxy for actual control and contribute to the prediction of the behavior in question. A schematic representation of the theory is presented in Figure 2.1.

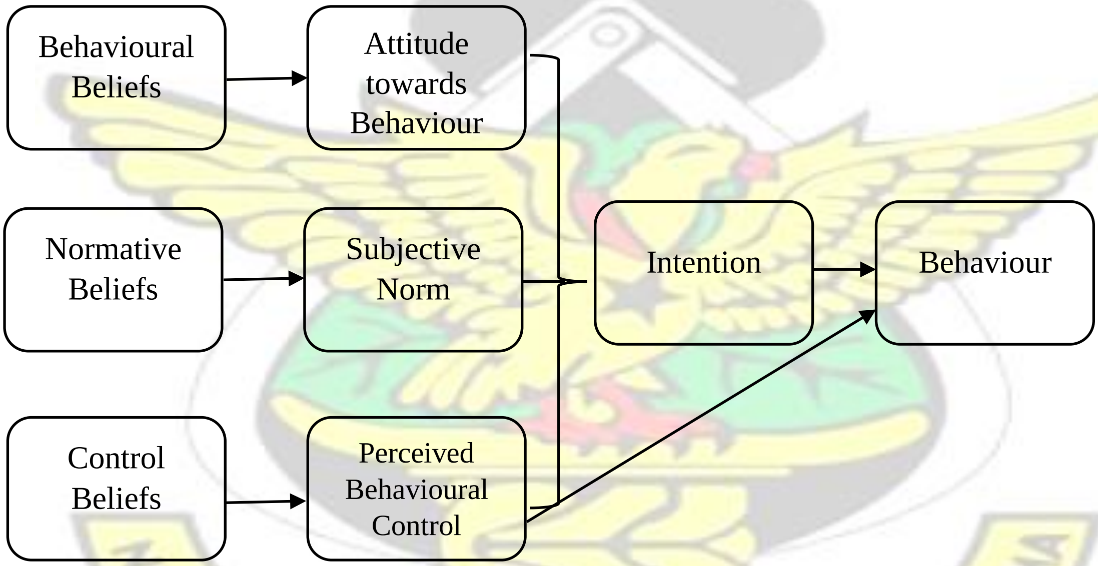


Figure 2.1: Schematic Representation of the Theory of Planned Behaviour (Adapted from Ajzen 2006)

2.3 Regulating Transportation of Hazardous Materials

Ordinarily, transportation in general, is regulated by national and local authorities as well as other mandated state institutions. In Ghana, the Driver and Vehicle Licensing Authority [DVLA], Ghana Highway Authority [GHA] and Environmental Protection Agency [EPA] are the state institutions involved in regulating the transportation of hazardous materials on roads. But for the risks involved in transporting hazardous materials and the associated consequences of incidents and accidents, hazardous materials transportation requires extra attention and regulation. Other stakeholder institutions such as the National Petroleum Authority [NPA], National Road Safety Authority [NRSA] and Ghana Atomic Energy Commission [GAEC] are equally involved in ensuring safe transportation of hazardous materials.

The transportation industry has been largely deregulated but for the safety of the public and environment, transportation of hazardous materials is regulated (Kara and Verter, 2004). It is the responsibility of governments to control and mitigate hazardous materials transportation risks in general, and particularly, in high population zones. Hazardous materials regulation is important and necessary in curbing accidents and reducing the risks involved in transporting and disposing them. There have been a number of publications on regulating transportation of hazardous materials (see, for example, Kara and Verter, 2004; Alberta Transportation, 2004; Gzara, 2013) which provide insight on whose responsibility it is to regulate the process of transporting hazardous materials in addition to the relationship structure between transporters and regulators.

Kara and Verter (2004) noted that governments were responsible for regulating some aspects of the hazardous materials transportation but the carriers ultimately also have some decisions to make with regards to route selection. Central or local governments will have the authority to designate specific roads or routes for hazardous materials transport in order to minimize the societal and environmental risks involved with their untimely release or accidents. Kara and Verter (2004) argue that ultimately, the decision of which particular route to take rests on the carriers or transporters whose primary concern may not necessarily and entirely be only on overall public safety but also to minimize cost of transportation and as such these transporters or carriers select routes that present them with minimum cost. This specific route selection, Berglund and Kwon (2014) opined, is out the control of planners, even though mechanisms such as tolls and road bans are used to regulate route choices of transporters. A bilevel approach to route selection or network design was proposed with focus on the relationships between governments and carriers (Gzara, 2013). Gzara (2013) uses the leader and follower relationship to mimic governments' and carriers' conflicting interests and concluded that governments, which make up the leaders, are supposed to account for the carriers' (followers) behaviour, actions and inactions in a network design.

In this regard, the government can account for the behaviour of carriers, to some extent, by restricting them through measures such as road tolls, bans and route selection. The use of container specification and inspection stations can be adopted to monitor and supervise the safe transportation of hazardous materials on roads in Ghana, particularly on highways.

Aldrich (2002) noted that regulating hazardous materials helped to reduce accidents in spite of a rise in the number of hazardous material shipments. It was carriers' motive to internalize and reduce social costs and as such were active participants in the regulation of hazardous material transportation. The carriers had in place private governance with federal support for the transportation of explosives and other hazardous materials. However, in order for some carriers not to 'free ride' (ignoring rules and regulations without being sanctioned where as others follow them), these regulations had been transformed into State Regulations. It is to be observed that individual carrier responses to dangers and risks in transporting hazardous materials will be undermined by competition among these carriers and as such the need for regulation cannot be over emphasized (Kara and Verter, 2004).

Concessionaires

Touching on cigarette butts as hazardous waste, Barnes (2011) proposed that quitting smoking was the best solution to dealing with the hazardous waste but in the long run this was not feasible. Barnes (2011) argued that governments and citizens must not be burdened with administrative and economic cost of cigarette butt waste. Rather, these costs, including cost of collection, transportation and safe disposal, must be borne by manufacturers. It follows that the role of the State is necessary in dealing with hazardous waste. In doing so, the State/government must evolve and enforce regulations for effective management of hazardous waste.

In managing hazardous waste, in particular, the Extended Product Responsibility (EPR) and Product Stewardship (PS) principles should be enforced by the State/government such that generators pay for managing hazardous waste and ultimately reducing risks of exposure. These principles require producers to ensure product improvement through its life cycle in addition to effective collection and reuse of products by placing responsibility on original producer and sellers of the product. A typical example will be packaging products with paper bags to enhance product safety and lifespan in addition to re-use of the bags.

From the discussions in literature, it is obvious that the State's role in managing hazardous materials, in general, and transportation, in particular, is very crucial and overarching. This implies that, central or local governments are to be tasked in ensuring that hazardous materials are safely transported through communities on highways. However, the question that arises from these is that what innovative ways are available to the government in managing the transportation of hazardous materials in order to safeguard public health, safety and minimize risks associated with hazardous materials transportation in Ghana? Some tools and policies that are available are discussed subsequently in section 2.9 of this chapter.

2.4 Risks in Transportation of Hazardous Material

2.4.1 Definition and Types of Hazardous Material Risks

The likelihood of a hazardous material accident is reportedly low, although its effects and impacts on the human population as well as environment and property can, however, be immense (Che Hassan *et al*., 2010). It is important that a clear definition of hazardous material risk is put forth by regulatory authorities so that proper steps are taken to minimize them as well as to assess and model these risks.

The accidental or untimely discharge of hazardous materials can lead to a multiplicity of events. These incidents may include, for example, a spill, fire or explosion as may be the case of flammable liquids, or a toxic cloud or plume in the case of pressured and liquefied gases. Fatalities or loss of human lives, varying degrees of injuries to humans, harm or damages to property, depreciation in value of real properties, and environmental damage and degradation are some of the adverse consequences of the different hazardous material accidents. These make up the risks associated with the event of a hazardous material accident. Erkut and Verter (1995) refer to this kind of risk as "accident risk". However, risk, according to Saat *et al*. (2014) in general terms, is defined by multiplication of the probability of the event happening and the consequences of an event if it does occur. Similarly, Erkut and Verter (1995) opined that risk refers to the probability of suffering or incurring the adverse consequences of any likely and possible release event.

Kazantzi, Kazantzis, and Gerogiannis (2011) proposed the following model as an estimation of the risk in hazardous materials transportation:

$$R = \Sigma Pi * Cs\, i$$

where: *R* is the risk estimate;

Pi represents the probability of a hazardous materials incident on road link i; and

Cs i represents the consequences of of a release event on road link i.

This model assumes that risk distribution along a road link is uniform. This is not the case in reality as some sections of a particular link are populated than others. Other researchers have attempted to define risks in similar manner (see, for example, Erkut and Ingolfsson, 2005; Cidell, 2012). Dadkar, Jones and Nozick (2008) define risk to be a combination, that is, summation of accident rates and population exposure on a particular route used for hazardous material transportation.

What is important from the literature is that varied views of risks are captured. While one school of thought examine risk in terms of the consequences of an untimely event of exposure or accident, another school of thought considers the mere likelihood of an accident occurring as the risk. Some researchers also view the risk in transporting hazardous materials as an expected or anticipated number of people likely to suffer from the adverse effects and consequences of an incident, which may be an untimely or unintended release of the hazardous material in question. A few of these are mentioned subsequently.

Abkowitz, Lepofsky and Cheng (1992); Saccomanno and Chan (1985) consider the likelihood of having a hazardous material incident(s) in the process of transportation as the risk measure. Abkowitz, Lepofsky and Cheng (1992) propose a model that estimates economic costs of transporting the hazardous materials and a risk cost of transporting a hazardous material from an origin to destination. The model, however, does not include the consequences of an incident. Because of its simplistic nature it is more suitable for the hazardous materials with relatively small danger zones.

Batta and Chiu (1988) also present risk in transporting hazardous material as the estimated number of persons that reside or live within a distance range along the routes employed in transporting hazardous materials. This model emphasizes “exposure” to hazardous materials rather than the occurrence of an incident. It is in better interest to look at risk from the point of population exposed. However, this should not be the only parameter employed as it may underestimate associated risk. It also does not take account of the severity of the exposure and other environmental conditions such as direction of wind and prevailing weather at the time of incident. In Canada, for example, persons and property that are within an 800 meter range from a spill point are considered to be at risk. Though this risk estimate measure is sound, it does not take into consideration persons that are directly impacted and those that suffer minor exposure.

Revelle, Cohon and Shobrys (1991) employ a combination of population exposed and transportation cost as a measure of risk. Alp (1995) as well as Erkut and Verter (1995) emphasize on the anticipated number of human lives that would suffer the adverse repercussions of a possible hazardous material incident. Lozano *et al.* (2011) argue strongly for including exposed travelers in risk assessment. Exposed travelers are people who are mostly commuters stuck up in traffic congestion at peak periods and pedestrians along roads. In addition, multiple exposure of inhabitants or population must not be overlooked (Lozano *et al*., 2011). This is because a particular group of persons can be exposed severally to as many hazardous materials truck trips.

Risks, in the transportation of hazardous materials, are to be viewed from all the varied angles; thus, the probabilities of accident involving hazardous materials and the consequences thereof should an incident occur. The risks involved may include the cost involved [economic cost and risk cost], the population exposed to the risk of hazardous material incident(s) [taking cognizance of direct exposure and indirect exposure; multiple exposure; travelers exposure], the probability or likelihood of the incident(s) occurring as well as the likely consequences associated with any incident or unwanted release.

2.4.2 Types of Risks

The transportation of hazardous materials is considered a key tactical and strategic decision making problem. However, the risks associated with this transportation of hazardous materials renders it planning problematic task. Although most existing analytical approaches for hazardous materials transport account for risk, there is no agreement among researchers on how to model the associated risks. A number of publications outline the different types of risks associated with hazardous material transportation. These include Saccomanno and Chan (1985); Leonelli, Bonvicini and

Spadoni (2000); Kazantzi, Kazantzis and Gerogiannis (2011); and Van Raemdonck, Macharis and Mairesse (2013).

Saccomanno and Chan (1985) emphasize an exposure risk, maning that risk should be viewed in terms of the population that will be exposed to hazardous materials during transportation. Leonelli, Bonvicini and Spadoni (2000) contended that risks include both ‘individual risks’ and ‘societal risks’. Individual risks refer to the yearly death frequency of an individual who is exposed to hazardous materials within a point of spill or impact of an accident. In other words, how many times an individual residing within a risk zone is exposed to hazardous material shipment. This also emphasizes exposure to the materials during the process of transportation.

Van Raemdonck, Macharis and Mairesse (2013) proposed that risks are estimated both at a global level and a local level. The global risks are based on probabilities of a hazardous material truck being involved in an accident based on calculations of international accident data on trucks transporting hazardous materials. At the local level, same estimation of risks are calculated based on local accident data and infrastructure parameters that exist. Following, these estimations of risks, global and local risk maps representing international and local hazardous materials risks respectively are drawn to show areas that are liable to risk. Given current circumstances in Ghana, the unavailability of data, particularly, for international accident risks renders this method of risk estimation not feasible.

From the review, it can be noted that three different types of risks have been documented, namely: accident risk; exposure risk and a combined accident and exposure risks. Accident risks are largely dependent on the likelihood of the event/accident occurring while exposure risks examine the population likely to be affected in the event of a hazardous material incident. Accident and exposure risk combines both likelihood of the incident occurring and the population to be affected. Though hazardous material accident probabilities are low, their consequences can be great and as such risks should be modelled and assessed adequately. How these risks are estimated, in other words the methods of estimating risks, is the subject of the ensuing section.

2.4.3 Risk Assessment Methods

In an ideal setting, it is the wish of transporters and other stakeholders to ensure hazardous materials are transported from origins to designated destinations devoid of any incidents. It is their desire to avoid hazards in the first place rather than to manage hazardous material risks. However, there could be some hazards that may not be entirely eliminated and as such need to be analyzed and assessed in a bid to reduce their probability of occurring or limit the consequences thereafter, if the accident does occur. Although several existing literature account for risk in the transportation of hazardous materials, there has not been any agreement on an accepted method used in assessing these risks. It is to be noted that these methods, quantitative assessment methods, are based on calculable probabilities (Ortuzar´ and Willumsen, 2011). There have been issues about which of the methods of risk assessment was most appropriate.
These have been discussed in greater detail in the sub-section ensuing.

2.4.3.1 Quantitative Risk Assessment

Quantitative risk assessment is based primarily on the probabilities of an accident occuring. Here, risks are expressed in numeric terms as a probability. Saat *et al*. (2014) describe a quantitative, environmental risk analysis of rail transportation of a group of light, non-aqueous-phase liquid chemicals frequently transported via rail in North America. They developed risk estimates based on probabilities of exposure to various spill scenarios along the rail network in North America using the Hazardous Materials Transportation Environmental Consequence Model [HMTECM] in association with a Geographic Information System [GIS] analysis of environmental characteristics. In order to estimate the nationwide annual risk of transporting each product, the risk analysis took into account the estimated clean-up cost based on the HMTECM, route-specific probability distributions of soil type and depth to groundwater, tank car safety features, railcar accident rate, and annual traffic volume.

Though this method of risk assessment is valuable, data required cannot be easily obtained in local conditions. Institutions such as the building and road research institution are not better placed to provide all the relevant data required to under such rigorous hazardous material risk assessment on Ghanaian highways.

Several authors also assessed hazardous materials risks using the quantitative methods (see, for example: Nicolet-Monnier and Gheorghe (1996); Kara, Erkut and Verter

(2003); Bonvicini, Leonelli and Spadoni (1998); Bubbico, Di Cave and Mazzarotta (2004); Shang, Dong, Wang and Wu (2008).

Nicolet-Monnier and Gheorghe (1996), Bonvicini, Leonelli and Spadoni (1998) and many others quantified hazardous materials transportation risk using shortest path and route selection methods but Kara, Erkut and Verter (2003) acknowledge that shortest path procedures can effectively remove errors in quantifying risks in hazardous materials route selection methods. This is so because the longer the length of road or rail to be travelled the higher the level of exposure and subsequently larger volumes of data required to effectively assess risks. For incident probabilities errors may occur as a result of simplication in the original model, whereas for population exposure, errors may result from the use of inadequate input data. Kara, Erkut and Verter (2003) also opined that thougherrors in risk assessment may be minimal, they should not be overlooked in any quantitative risk assessment.

Quantitiative risk assessment requires large volumes of data. Because of the relatively low probabilities of hazarodus material incidents and data requirements to estimate such risks quantitative approach is not suitable in all cases. Because of the sheer volume of data required to perform any effective quantitative risk assessment devoid of errors, this approach in risk assessment does appear not to be suitable under our local conditions. However, it is better to have a risk estimate that is close to right than not having one at all, hence, the limited data available should be used in estimating risks and appropriate interventions planned ahead. Again, because such incidents rarely occur, mandated institutions are not able to provide estimates over a long period of time.

Policy makers and transporters of hazardous materials employ routing or route selection as another effective means of dealing with the assessed or perceived risks involved in transporting such materials. Their routing decisions have been backed by the use of Geographic Information System [GIS] and Spatial Decision Support Systems [SDSS]. These are discussed briefly in the section ensuing.

2.5 Hazardous Materials Routing/Route Selection

In the quest to minimize hazardous material accidents and consequences in the unlikely event of accident, route selection is largely proposed in literature and is extensively used. Given a network of roads available for Hazardous materials transportation between on origin and destination pair, a preferred route is made available such that risk of an incident is minimal and consequences in terms of injury to persons, damage to property as well as the environment is reduced. This emphasizes the need for route selection. However, this can be done based on Geographic Information System (GIS) or Spatial Decision Support System (SDSS).

2.5.1 GIS based Solutions

To safely and effectively transport hazardous materials through highways, potential negative consequences or impacts need to be reduced or eliminated, if possible. This could be achieved through the use of safe network of roads by application of GIS. An importatnt consideration in route selection is assessing potential risk posed by hazardous material shipments along every link within a given network of roads. The use of GIS in hazardous materials transportation is considered a novelty because of its simplicity as well as large scale implementation possibility (Verter and Kara, 2001).

Using a point-source of risk or pollution and GIS map algebra techniques Zhang, Hodgson, and Erkut (2000) were able to map out areas of concentration of air pollutants released within a hazardous materials network. Based on GIS overlap and summarization procedures, the potential risk associated with unexpected accidents on each link within the network was estimated. Their approach takes into account the direction of the wind. It was recommended that on site evacuation procedures are more efficient and safer as compared to laid down procedures. This pressupposes that it is not always prudent to undertake existing predetermined measures in tackling all hazardous materials incidents. Rather, on site evacuation measures which are hazardous materials-specific and tailored for particular incident could be resorted to in dealing with incidents to reduce risk and negative consequences. For instance, in an event of a gas leakage in Ghana, emphasis should be placed on evacuating people living in the northeast of the incident site given that the wind blows towards this direction.

In Quebec and Ontario, Canada, Verter and Kara (2001) advanced a model that reduces the risks of truck shipments of hazardous materials via the highway network based on the origin and destination of each shipment. The risks related to the probability or likelihood of an accident, the popultaion exposure as well as number of people that need to be evacuated in the unlikely event of an accident in addition to routes that minimized the transport distance were evaluated. They arrived at a conclusion that the risk of transporting hazardous materials in a given geographical location is heavily dependent on variations in the type of hazardous material being carried and the topology of the road network, as well as the spatial distribution of population. Hence, the need for the development of more adequate equity measures for hazardous materials transport risk.

It is understood from the positions above that, there ought not to be a "one-fits-all" approach in dealing with hazardous material transportation in Ghana. Rather, efforts at reducing risk of accident must concentrate, firstly, on the type of hazardous material in question and then the associated consequences of any incident involving hazardous materials in a given network. In situations where the consequences could be more damaging if pre-determined risk reduction measures are adhered to then there is the need to have modifications to that measure to suit a given hazardous materials incident.

Bubbico, Di Cave and Mazzarotta (2004) proposed a risk analysis approach in transportation of hazardous materials by rail and road with the help of the Geographic Information Systems [GIS] tool. In doing this, they required information pertaining to local conditions in addition to a repository or data bank on hazardous material shipments such as information on rate of accidents, populations likely to be exposed, and weather conditions during the transportation process. The GIS tool could be easily updated with all the necessary data requirements especially prevailing weather conditions along the various routes to be used in transporting hazardous materials.

With effective application of the GIS tool, safe routes could easily be identified and transportation risks accurately assessed for single or multiple shipment of one or more hazardous substances. Considering that the probabilities of freight vehicle accidents is low and hazardous materials accidents even lower, adequate data gathering will pose a challenge to this method in Ghana. Secondary data sources, however, can be very informative and important.

The application of GIS in route selection offers a realistic and simple method in hazardous road network routing. By so doing, governments and local authorities are able to designate roads or road sections that are to be used in hazardous materials transportation bearing in mind the societal risk minimization. Considering that consequences of a hazardous material incident are dire, population exposure is reduced and cost consequences in the event of an incident are minimized using the GIS. Similarly, the GIS is used by carriers or transporters to select routes that present them with the least or minimal cost.

The GIS has become an invaluable tool in the transportation process as it offers an innovative way of assessing potential risks as well as helping to map out routes that present the least risk in the process of transporting hazardous substances or dangerous goods. In addition, it has the capability of tracking vehicles during the transportation process, and as such, can be used for monitoring purposes to ensure that truck operators stick to already selected routes and not divert.

2.5.2 Spatial Decision Support System (SDSS)

Decision making is recognized as a key function in transportation of hazardous materials. This is so because with the right decision in planning a route or journey plan risks of accidents may be minimized, potential consequences or damages reduced as well as providing services in emergency response that are not only unhindered, but also well-timed. Route selection has been used extensively as a Spatial Decision Support System and these are discussed in brief subsequently.

Beroggi and Wallace (1995) propose re-routing of vehicles as a way of dealing with hazardous materials accident consequences. In their view, the technology offered by the Spatial Decision Support System tool can be able to help a dispatcher determine all affected routes and regions in a road network following the unlikely event of a hazardous materials accident. In addition, safer and cost effective route options available are determind for vehicles that are supposed to pass or drive through the affected regions. Four decision models for re-routing hazardous material vehicles in real-time have been assessed in an experimental setting. The first model supports a dispatcher in finding alternative routes (visually), while the second model adds to the display, for each vehicle, an alternative route based on a conservative heuristic. The other two models are based on an ordinal preference and a numerical utility structure to support the dispatcher in determining the impact of the events on transportation safety and costs.

Zografos and Androutsopoulos (2008) present a system that supports decision making in terms of level of risk, minimal travel time and their implications for evacuation as well as coordination of emergency response activities along various hazardous materials routes. Their proposed system affords the following functionalities:

(i) the ability to determine alternative routes for transporting or distributing hazardous materials bearing in mind risk and cost minimization;

(ii) the abilility to identify locations that suit emergency response service providers such that their efforts are timely and help to minimize negative consequences; and

(iii) the ability to determine alternative paths for evacuation from the area impacted to safer zones within the shortest possible time.

Frank, Thill and Batta (2000) also developed a decision support system called HAZMAT PATH to help in resolving the route selection challenge that is characterized by conflict between people at risk or "exposure risk" and efficiency concerns with regards to cost and time.

It is worthy of note from the viewpoints expressed foregoing that Spatial Decision Support Systems play critical role in minimizing risks in the first place, then also they assist in providing alternative routes for evacuation and emergency response in addition to siting or location of these emergency response service providers. As part of reducing risks associated with hazardous materials during transportation appropriate efforts should be made to designate routes that minimize risks and consequences of accidents. In addition, emergency response service providers should be well distributed along routes in such a manner that sections that pose a greater tthreat or risk are well served and adequately resourced to deal with situations if need arises.

2.6 Types of Hazardous Material Accidents

The incidents/accidents that happen in the course of transporting hazardous materials take several forms. Notable among them are release; explosion; fire; and gas clouds (Linkutė, 2011; Yang *et al.*, 2010). It is to be noted, however, that in an incident of a release of the hazardous material during transportation, an explosion or fire could also occur (Darbra and Casal, 2004). For example, when petroleum products are released in the event of an accident, any contact with an exposed flame could result in fire. Therefore, this makes categorization of accidents a bit problematic. Similarly, gas clouds are formed as a result of a potential release of hazardous gases being transported. As a result, these accident or incident types should not be seen as mutually exclusive of one another but require to be treated as a whole or composite. However, the various types of hazardous material accidents are discussed independently in the section following.

2.6.1 Releases

From literature material release has been observed to be the commonest form of hazardous materials accident, especially during transportation. In a study of 322 hazardous materials accidents in China from 2000 to 2008 by Yang *et al*., (2010), it came to light that the most frequently occurring types of accidents were releases, followed by gas clouds, fires, and explosions in that order. These accidents occurred in the course of transporting hazardous materials by road. In another study, Darbra and Casal (2004) found that releases amounted to 51% of hazardous materials accidents. Fire, explosion and gas clouds accounted for 29%, 17% and 3% respectively. Releases can occur as a result of container ruptures, "rollover" of tanks or leaks. This presupposes that hazardous materials carriers have to carry out maintenance and inspections of their vehicles on regular basis so as to minimize risk of accident during transportation.

2.6.2 Explosions

Another major type of hazardous materials accident is explosion. Explosions are results of contact of hazardous materials with any open or ignited flame. Glickman and Erkut (2007) opined that explosions could be caused by a reaction between two substances. For instance, contact between sodium hydroxide and certain organic and inorganic chemicals may cause fire or explosion. They noted that if a serious accident involving two tank cars results in a release of contents from both and they come into contact, then a fire or explosion may result even if the chemicals carried in the two cars may not create a fire or explosion by themselves. An even less likely scenario might be a chain reaction including several cars, where one fire or explosion might trigger others, which would put a large impact area at risk. Clearly, such an event is extremely unlikely but the consequence would be very serious.

2.6.3 Fire

Some hazardous material accidents immediately result in fires. Such is the case when a head-on collision with vehicles carrying explosives or highly flammable materials comes into contact with an open flame. The flame could be a a result of the clash or any nearby one. Fires as a result of hazardous materials accident have been observed to be a consequence or follow up to some precedents (Linkutė, 2011). Thus, an accident involving a petrol tanker truck might result in a release that subsequently leads to a fire explosion. This fire could be sustained given that large volumes of the hazardous material are involved; and also, prevailing local conditions such as windspeed.

2.6.4 Gas Clouds Formation

As the name suggests, these are clouds formed around an incident area in the event of a hazardous materials accident. This is formed when gases are released into the atmosphere and given its concentration it tends to form a ‘small’ cloud in an area. In natural gas pipelines other causes for incidents are corrosion accidentally caused by operations. This has been observed by many authors as the least hazardous materials accident recorded. Linkutė (2011) finds that 78% of cases of accident are releases, 28% are fires, 14% are explosions and gas cloud formations account for only 6%. Darbra and Casal (2004) also found gas clouds to account for only 3% of all hazardous material accidents. Though gas glouds formation appear to be rather low, consequences could be far reaching given that harmful “gas clouds” cover large areas of land in a short space of time.

These major forms of hazardous material incidents need to be well understood to help in administering emergency response, especially by operators directly involved in the transportation process. For example, drivers of trucks transporting hazardous materials must be aware of the chemical properties of the material they are transporting and which other chemicals it reacts with. Knowing this, with a release of the material drivers will be in a better position to prevent fires or explosions as it had been observed that releases precede other accidents as the fires, gas clouds and explosions. Hence, the need for driver training and education to effectively handle hazardous material transportation.

2.7 Causes of Hazardous Materials Accidents

It is the desire of all stakeholders involved in transportation of hazardous materials to do so in a manner that ensures public and environmental safety while also minimizing cost. Be that as it may, accidents do occur and the consequences of such accidents may be dire even though such accidents are rare. Frank, Thill and Batta (2000) observed that nearly 500,000 shipments of hazardous materials are transported on a daily basis across the United States via all the various means, that is, by road, by water, by rail, by air and through pipelines. However, accidents involving these materials resulted in 15 live lost, 511 injuries of varying degrees and about $20 million worth of property damage in the year 1993 only (United States Department of Transportation, 1994). In Ghana, total number of property damage resulting from road crashes amounted to 3,877 in the year 2010 and in the same year 159 Heavy Goods Vehicle [HGV] occupants were also killed (MRH, MoT and GSS, 2012). The severity of accidents and associated consequences give a cause for worry. However, efforts that are aimed at tackling such issue need to take root from the underlying causes. Some of the major underlying causes of hazardous materials transportation accidents have been discussed in detail in subsequent sections.

Oggero *et al.* (2006) and other researchers identified the causes of Hazardous materials accidents and classified them under various failures including: impact, mechanical, instrumental, and services failure.some other causes identified include: human factor, a violent reaction, various external events and upset process conditions. (see also, Darbra and Casal, 2004; Sivaprakash, Joseph, and Satheeswaran, 2015). Zhao, Wang and Qian (2012) after a study of the causes of hazardous materials accidents in China established the following as three main factors that caused hazardous materials accidents: (i) human factors; (ii) the transporting vehicle and services; and (iii) packing and loading of materials. Bacis (2010) also acknowledges that very often errors from humans, failure of equipment, and facility or transportation related factors are the root causes of hazardous materials events or accidents.

The foregoing issues outlined by the different authors suggest that the main causes of hazardous materials accidents are human error, packaging and packing deficiencies, vehicular faults and facilities for transporting these materials. Table 2.7.1 provides a summary adapted from Oggero *et al*. (2006) and details out the general and specific causes of different hazardous material accidents.

Table 2.7.1: General and Specific Causes of HAZARDOUS MATERIALS Accidents

General Cause	**Specific/Root Cause**
External factors	External fire
	Sabotage
	External explosion
	Floods
	Temperature
	High winds
	Ground
Human	General operations
	Procedures
	Maintenance
	Design

	Communication
Impact	Road accidents
	Vehicle
	Heavy object
Mechanical	Valve
	Metallurgical
	Overheating
	Corrosion
	Brittle
	Hose
	Fatigue
	Overpressure

Source: Adapted from Oggero *et al.*, (2006)

The Hazardous Materials Cooperative Research Program [HMCRP] (2009), similarly, identified and categorized the causes of hazardous materials into five (5), namely: vehicle, driver, packaging, infrastructure, and situational. The following sections capture the possible causes of hazardous materials transportation accidents under these broad categories of the HMCRP.

Vehicle

The vehicle is the entity that is used to convey the hazardous materials between an origin and destination pair. Most vehicles used are specialised ones designed to transport particular materials. Where the vehicles are not specialised, materials are packaged in containers or palletised such that they can be easily transported. The HMCRP (2009) established that the vehicle was one parameter to be used in assessing the cause of accidents. Specifically, it noted that vehicle configuration, cargo body, Gross Vehicle Weight [GVW], a possible vehicle defect and vehicle response are the likely root causes of a hazardous material accident.

Driver

The driver of a vehicle or truck also presents another possible cause of an accident. Driver's characteristics such as age, experience, state of health, level of training as well as qualification are some of the likely causes of hazardous materials accidents (HMCRP, 2009). Actions of drivers that have resulted in hazardous materials accidents have been classified by some authors as human error. Indeed, Erkut, Tjandra and Verter (2007) observe that considering the various causes of hazardous materials accidents human error appears to be the greatest factor of all accidents (including minor and serious accidents).

Packaging

The packaging of materials is another parameter for assessing the cause of hazardous materials incidents. The type of packaging, design specification, rollover protection among other things are identified by HMCRP (2009) to be the likely causes of accidents. For instance, in transporting acids the container or packaging material must be 'strong' enough to absorb any impact. Roy (2008) also noted that packaging hazardous materials is the first line of defence in preventing hazardous materialss from being released in the process of transportation. It is possible that packaging used in transporting hazardous materials could develop rupture that might result in a release, overfilling the container, over aged packages and the design specification of the package. As part of packaging, labelling has been observed to play critical roles in emergency response and as such labels must be durable, 'easily read and understood' and also kept in plain sight for ease of access (Roy, 2008).

Infrastructure

The facilities required and used in transporting hazardous materials could potentially be another source of accidents. The HMCRP (2009) noted surface of the road, condition of the road, the type of road, traffic way, speed limit, number of lanes and access control were some of the potential causes of accidents. Road markings, signages and unavailability of emergency response mechanisms also pose threats of accidents on the roads.

Situational

This parameter looks at activities or events, actions, and conditions that preceed a hazardous materials accident. Such situations could be from the judgement of a driver, driving above speed limits, or natural phenomenon like prevailing weather condition. The HMCRP noted that such situations could arise from pre-crash conditions, a dangerous event, vehicle speed, weather condition and time of day among others.

These parameters and major causes of hazardous materials accidents have been summarised and presented in Table 2.7.2 subsequently. Thereafter some of the effects or consequences suffered in the event of a hazardous material accident are discussed in section 2.8.

Table 2.7.2: HMCRP Parameters and Causes of Hazardous Material Accidents

Vehicle	Driver	Packaging	Infrastructure	Situational
Vehicle Configuration	Age of driver	Type of Package	Surface of road	Existing Precrash condition
Cargo body	Driver's level of experience	Quanitity shipped	Condition of road	Dangerous event
Gross Vehicle Weight (GVW)	Condition/ State of the driver	Quantity lost	Type of road	Speed of vehicle
Defects with vehicle	Validity or otherwise of driver's license	Age of packaging material	Traffic way	Impact location
Vehicle responsiveness	Level of training of driver	Rollover protection	Access control	Primary reason
	Driver's response to situations	Inspection history of package	Speed limit on road section	Accident type
	Citation issued	Package design specification	Number of lanes on a given road section	Prevailing weather condition
			Location	Light condition
				Time of day
				Health consequences

Source: HMCRP (2009).

2.8 Effects of Hazardous Materials Accidents

Following the review of causes of hazardous material accidents during the transportation process, this section takes account of some of the effects we have had to suffer in terms of human lives lost, environment and property damaged or destroyed. Subsequently, examples have been drawn from cross section of regions including the United States, Australia, and Canada in addition to some African countries.

Even though hazardous materials played a very important role in the economies of most nations, its transportation does not come entirely without any accidents. It has been noted that accidents probabilities involving hazardous materials are relatively low compared to other freight trucks or vehicles. Centrone, Pesenti and Ukovich (2008) estimate a usual accident or incident rate at the value of approximately 3.0×10^{6} accidents/vehicle-km. But given the grave and enormous consequences associated with such incidents, however, it is imperative to model risks associated with these shipments to propose various techniques to minimize both risks and costs associated with such transportation or movements. Scores of researchers have pointed to this fact (see, for example, Zografos and Androutsopoulos, 2008; Frank, Thill, and Batta, 2000; Erkut, Tjandra, and Verter, 2007). To do this very well, an understanding of the effects, consequences and impacts of some hazardous materials accidents is in the right direction so as to bring home the need to efficiently prevent or reduce risk of accidents and, in the unfortunate event of any accident, be in a better position to respond to emergencies and deal with consequences.

Erkut, Tjandra and Verter (2007) argued that incidents involving hazardous materials cargo during transportation can lead to severe consequences characterized by loss of human lives, various forms of injuries, time and cost of evacuation, damage to property, loss in environmental quality, and undue disruption of traffic flow with its attendant impact on productivity and wealth creation. Chakrabarti and Parikh (2011), similarly, opined that the transporting hazardous materials on roads was a necessity of the world for the societal benefits, but at the same time the activity was inherently dangerous, particularly the transportation of class-2 materials (LPG, chlorine and ammonia) which has tendencies of resulting into loss of human lives, environmental degradation, property losses as well as injuries and additional cost in evacuation.

Frank, Thill and Batta (2000) noted that there were as much as approximately 500,000 shipment of hazardous materials across the United States only and this presented as source of worry considering the risks involved in such transportation. In ideal situations, no accidents are anticipated during transportation of hazardous materials, however, accidents have occurred. In a publication by the United States Department of Transportation in 1994, it was reported that highway accidents involving hazardous materials led to 15 lives lost, 511 varying degrees of injury and an estimated $19,800,000 worth of property damaged (US DoT, 1994).

Darbra and Casal (2004) assessed the population affected by accidents based on a classification into three categories including number of deaths, injured people and people evacuated. After analyzing historical data on 471 sample accidents, they observed a rising trend regarding the frequency of occurrence of hazardous material accidents.

Kim, Mungle and Son (2013) noted that, in the US, for instance, one person was killed with seven others sustaining injuries because of poisoning from ammonia when about 6,895 pounds of the anhydrous ammonia was released on a highway in 2009. Apart from the fatality and injuries, the anhydrous ammonia cloud led to a temporary discoloration of vegetation around the impact area. In addition to the human injuries, monetary consequences have also been incurred during hazardous materials transportation accidents. For example, in the year 2012, in the United States $59 million was lost in damages as a result of some 13,675 accidents which occurred during transportation of hazardous materials. Out of this figure, an appreciable proportion, 85.72%, occurred on highways and they account for close to $49 million worth of damages. Given the high proportion of highway accidents and the enormity of the consequences keen attention and attention is required to ensure public safety as well as protection of property and environment.

The derailment of a train carrying toxic chemiclas in 1979 in Missisauga, Ontario which lead to the release of chlorine occassioned the evacuation of nearly 200,000 people (Erkut and Verter, 1998). Similarly, an estimated 2,700 fatalities were recorded in Afghanistan owing to a tunnel explosion of a gasoline tank in 1982. In the year 1987, a major prohibition of gasoline shipments by trucks was enforced after six fatalities were recorded in an incident involving a gasoline truck that ran into an ice cream shop.

What comes out from the review is the fact that though incidents involving hazardous materials were rare, their consequences could be devastating. The consequences or effects of hazardous materials accidents can be looked at from different perspectives: the environment, humans and property. The environment is affected through the loss of vegetation, displacement of animals, and in some cases, rendering the land infertile. Property is affected in several forms including destruction to buildings, damages to other vehicles and even loss of the hazardous materials content as well as vehicles used in transporting such hazardous material themselves. Human lives are the worst affected in the event of any hazardous materials accident. Loss of lives, various degrees of injuries sustained, and evacuations are but a few of some hazardous materials accident consequences on humans.

The foregoing discussions point to the fact that preventive measures should be put in place to forestall the occurrence of accidents that involve hazardous materials. Also, in the event of any unlikely incident, emergency response mechanisms are required to help victims and to minimize the consequences in terms of casualties. Some measures that have been used in the past and those in use currently to mitigate hazardous materials accidents are discussed in the following section.

2.9 Hazardous Materials Transportation Accident Mitigating and Policy Tools

Transportation of dangerous goods or hazardous materials have always presented some form of risks to transporters and the safety of society at large. The most vulnerable are populations that live along the routes used in transporting such materials, who did not stand to immediately benefit from the process, but are exposed to the risks involved. Quite apart from transportation risks, the process of transporting hazardous materials is plagued by some infrastructural challenges. Notwithstanding these, stakeholders including regulatory institutions, resident population along routes used, emergency services providers (fire fighters, police, and ambulance service), environmental agencies and hazardous material producing industries as well as carriers have developed and used a number of innovative ways to minimize or reduce risks of transporting hazardous materials safely on highways and other roads. Several strategies and mitigating measures have been used in the process of transporting hazardous materials globally (see, for example, Frank, Thill and Batta, 2000; Kwon, 2011; Chakrabarti and Parikh, 2013). Frank, Thill and Batta (2000), for instance, propose selecting routes that reduce the probability of accidents, then judiciously selecting routes through less populated areas in a bid to reduce the population exposure to risk. Subsequently, they propose altering vehicle and container design to reduce severity in the unlikely event of an accident. A number of the well documented preventive and mitigating measures are discussed in the following sections.

2.9.1 Driver Training

Because hazardous materials transportation is a very sensitive and risky operation, special drivers are required in the process. Freight transportation has been noted to require specially trained drivers, with the expertise for hazardous materials transport even greater considering the risks at hand. Driver training is an example of a mitigating measure employed in hazardous materials transportation to reduce accidents (Erkut, Tjandra and Verter, 2007; Kara and Verter, 2004).

Countries have evolved different requirements for training of drivers. In the United States and Canada, for example, the responsibility to train hazardous material truck drivers rest on employers of these drivers. The content and duration of every training program as well as driver assessment were all responsibilities of the employers (Kuncyté *et al.*, 2003). These employers in turn resort to commercial training firms to undertake the required training programmes. Kuncyté *et al.* (2003) noted that in Sweden emphasis was placed on accreditation of training institutions whereas in the Netherlands prominence is given to the examinations used in testing drivers who have undergone the training.

Given that employers were responsible for training drivers as well as content and duration of various training programs, a national accreditation would be appropriate for the commercial training firms. Berman, Verter and Kara (2007) argue for the establishment of regulatory requirements for driver training as well as driving hours. Also, there are cases where these hazardous materials are transported across national boundaries and as such it is not enough just to have national accreditation for training drivers but these should fall within regional blocs' agreements such as European Agreement concerning the International Carriage of Dangerous Goods by Road.

Some studies have also established that age of drivers or their number of years of experience has a bearing on the accidents recorded. The U.S. Department of Transportation, Federal Motor Carrier Safety Administration [FMCSA] (2005) observed that younger drivers, especially those between 18 and 24 years, and ones with less than 3 years of experience in handling hazardous materials are more prone to spill accidents. It was also noted that about 75% of crashes were as results of driver's error during transportation. In a similar study, the HMCRP (2009) following interviews with tank drivers observed that when tanks or bulk containers were full with products, their centers of gravity were higher, rendering them more challenging to handle and therefore, were more prone to accidents such as rollover. This points to the fact that driver experience is important and needs to be given critical attention. At the time of accident, the driver's years of driving experience attained were sought consequently in establishing the cause of accidents. The results pointed out that drivers with more years of experience had lower proportion of accidents resulting in rollover as compared to drivers with fewer years (below five years).

The training of drivers as a preventive measure against hazardous materials accidents cannot be overemphasized. Regulations have to be evolved by national authorities and administered at the metropolitan, municipal and district levels. Quite apart from driver training is the issue of controlling driving hours of drivers as another strategy to mitigating hazardous material accidents. This is discussed in the next section.

2.9.2 Controlling Driving Hours

It has been theorized that driving hours is critical in combating accidents, especially for trucks and hazardous material drivers. Driving hours, also referred to as Hours of Service (HoS), have been used to promote road safety by reducing fatigue and drowsiness. In Ghana, truck drivers are not supposed to drive more than eight (8) hours within a 24-hour period. After continuous driving for 4 hours, truck drivers are expected to take rest (West Africa Trade Hub, 2010). In the United States, the Federal Motor Carrier Safety Administration (2014) permits drivers transporting products up to a maximum 11 hours of driving following 10 or more consecutive hours off the wheels.

Indeed, a great number of writers including Kara and Verter (2004); Berman, Verter and Kara (2007) as well as Jensen and Dahl (2009) have proposed the regulation of driving hours as a measure to help prevent road accidents. Heaton (2005), supports authorities regulating driving hours of truckers, but argues for the creation of environments that enable truckers abide with them. He argues that if these regulations are left to stand alone, they become ineffective. Rather, he proposed that governments and local authorities must create conditions for drivers to sleep and rest.

It is worthy of note that controlling driving hours through Hours of Service [HoS] will help prevent accidents in the trucking of hazardous materials. Emphasis must also be placed on providing rest or intermediate stop facilities for drivers that transport the hazardous materials and truckers in general to help them abide by set rules on Hours of Service.

2.9.3 Container Specifications

Hazardous materials, more often than not, have been transported in specialized containers or packages. This practice has been noted to help mitigate risk of accidents in transportation of hazardous materials. Kara and Verter (2004) and Berman, Verter and Kara (2007) have proposed this strategy as a tool in mitigating the risk of hazardous materials accidents. Containers for transporting hazardous materials have special designs that allow for safe transportation. In addition, placards are placed on vehicles to indicate which material type they were carrying and how to respond in times of any accidental release. But Milazzo *et al.* (2009) have argued that this may cause public panic, especially among those who did not benefit readily from the hazardous materials, and fears of attack by terrorists.

Rushton, Croucher and Baker (2010) accentuate the need for packaging as well as labelling of hazardous materials in their transportation process. In the United States, for example, the Pipeline and Hazardous Materials Safety Administration (PHMSA) requires that placards are placed on each material transported. The placards show a hazard of the material while also indicative of the material type and class. In Plate 2.9.1, the placard indicates that the box contains explosive material Class 1.2 and not flammable materials Class 3.

Plate 2.9.1: Placards used in hazardous materials transportation.

Source: PHMSA, Hazardous Materials Transportation Placarding Requirements.

It will be useful if containers are specially designed for hazardous materials like tank containers for pressured liquids and gases. Also, packaging can be done in such way that the hazardous material is packaged in a material separate from containers. This way, the exposure risk of humans and property in the unlikely event of an accident is reduced or contained.

2.9.4 Inspection Stations to monitor compliance

Rules and regulations are meant to guide society but if not monitored or enforced they will be flouted time and again. Kara and Verter (2004) advocate for the setting up of inspection stations along major hazardous material routes to ensure that carriers are adhering to rules and regulations. Placement of inspection stations have been an issue of concern in the process of transporting hazardous materials. Conway and Walton (2010) noted that activities to monitor and ensure compliance to rules governing hazardous materials transportation range from the traditional static stations, through mobile stations to the use of technologies like the Global Positioning Systems (GPS). Hall and Intihar (1997) have also underscored the need for inspection stations notwithstanding the complaints of burdensome paper work as well as delays imposed by them.

For these inspection stations to function effectively, their location should take account of designated routes and should be done in consultation with all relevant stakeholder institutions. In a study conducted in Norway by Elvik (2002), it was found that abolishing technical inspection stations could lead to 5-10% increase in the number of heavy vehicles involved in injury accidents. Likewise, it was found that increasing the number of inspection stations by 100% would yield between 5% - 10% decrease in injury accidents involving heavy vehicles. Elvik's finding does not only emphasize the need to have inspection station, but in addition there must be efforts to increase the number of these stations to enjoy full benefits of their existence in terms of reduction in the number of injurious accidents associated with heavy vehicles.

2.9.5 Toll Policies

As a way of regulating hazardous materials transportation on specific roads, toll policies can be used such that hazardous material transporting vehicles pay higher tolls compared to other trucks. This way, hazardous material truckers will be compelled to use alternate roads (or designated roads) with lesser tolls. This tool presents national and local authorities with an addition to routing of hazardous materials. To do so, designated roads for hazardous materials transport can have lower tolls than other roads so as to attract the hazardous materials carriers.

Marcotte *et al*. (2009) proposed the use of toll setting as a course of action to regulate the use of roads for transporting hazardous materials. They have argued that toll setting policies can yield more fruitful and effective results as compared to network design policies or routing that have been used widely. This was grounded on an analysis of mathematical models. However, Centrone, Pesenti and Ukovich (2008) observed that population or residents living along designated routes for hazardous material transportation, especially those that do not benefit directly from the activity, become agitated. These dwellers are made to assume great risks when in actual sense they do not benefit from such transportation. For this reason, stiffer opposition is expected from them if a particular route segment is selected for hazardous materials transportation. They would prefer alternate network routings that equitably spreads risks. Again, for fear of terrorist attacks public opposition to hazardous material transportation has seen some amplification lately (Milazzo *et al*., 2009). Tolling roads offers some advantages, including: expansion of revenue sources beyond traditional road levy or gas tax, effectively managing road space demand, inspiring efficient operations, levelling tax burden for both local trucks and those in transit, and reduction of CO_2 emissions (Broaddus and Gertz, 2008).

Taking views of Centrone, Pesenti and Ukovich (2008) as well as Marcotte *et al*. (2009) into consideration, it is clear that designating routes and imposing tolls creates room for public fears and opposition. Therefore, this should not be treated as a standalone mitigation tools. Instead, it can be combined with other tools such as container specifications, establishment of inspection stations as well as emergency response systems to attend to any unfortunate incident in transportation.

2.9.6 Emergency Response Systems

Emergency Response Systems, as the name suggests, are facilities and processes in place to respond in times of any accident involving hazardous materials. These activities become relevant in times of an accident. The swift interventions of emergency response service providers have tendency to reduce negative consequences in the event of accidents

Emergency response systems have been used, for some time, as mitigating measures to reduce the consequences of hazardous materials accidents. Kara and Verter (2004) proposed this method as part of policy tools to mitigate the effects of hazardous materials accidents.

Berman, Verter and Kara (2007) postulated that undesirable impacts or consequences of incidents involving hazardous materials can be reduced given that emergency response service providers are located in close proximity to accident sites since time is critical in reacting to hazardous material incidents. In effect, it comes to mind that, location of emergency response sites must be factored into network designs, especially on routes designated for transporting hazardous materials. In addition, these emergency response teams could be sited in areas with high probability of accident or higher risk zones.

Other scholars including Saccomanno and Allen (1988) as well as List *et al.* (1991) have argued for the need to have specialized response teams and equipment to react against accidents involving hazardous materials. It is imperative in doing so to take into consideration factors such as the level of risk posed, equity in terms of not exposing a particular area or road section greatly, the average response time as well as cost to be incurred. This would enhance the functionality of the emergency response service providers and decrease the level of opposition as expressed by Centrone, Pesenti and Ukovich (2008).

Chakrabarti and Parikh (2013) underscore the need to have districts prepared to handle emergencies involving hazardous materials. Their study concluded that properties of various hazardous materials transported on roads should be well noted and taken into consideration when planning for emergency response. Also, documents providing information about the materials being transported and emergency response activities are necessary to help rescuers in performing their duties expeditiously.

2.9.7 Vehicle and Container Designs

This has been noted to be one of the policies that is used to mitigate hazardous material transportation accidents. Because accident probabilities involving freight trucks and particularly hazardous materials is very low, some authors share the opinion that moving large shipments regularly helps to reduce the risk of accidents (see, HMCRP, 2009; Guo and Verma, 2010). Guo and Verma (2010) argue that larger capacity trucks be used in transporting hazardous materials so that risks and consequences are minimized. This implies that number of trucks to be used in shipments will be reduced but volumes of material will be increased. Their conclusion was that accident probabilities were low for hazardous materials truck and subsequently, decreasing the number of trucks used by using larger trucks and containers further reduces risks.

This approach is very feasible and can be used to mitigate the likelihood of accidents involving hazardous materials. Similarly, a reduced number of hazardous material trucks will allay fears of public panic as well as fears of terrorist attack as noted by Milazzo *et al.* (2009). The HMCRP (2009) propose the use of Longer Combination Vehicles (LCVs) to reduce the number of shipments being made. However, these larger containers and vehicles must take into consideration axle load limits so as not to destroy the road pavements. This policy tool will need to be combined with other tools such as driver training as well as Hours of Service (HoS) to effectively and safely transport hazardous materials on the roads.

2.9.8 Route Selection

A large chunk of literature on hazardous materials transportation is centered on route selection. These include: Abkowitz and Cheng (1988); Frank, Thill and Batta (2000); Kara and Verter (2004); Knorring, He and Kornhauser, (2005); Erkut and Alp (2007); Dadkar, Jones and Nozick (2008); Verter and Kara (2008); as well as Lozano *et al*. (2011). They all point to the fact that route selection is an appropriate tool to help minimize accidents and the consequences thereof in the process of transporting hazardous materials. Frank, Thill and Batta (2000) opined that route selection equally helps in resolving conflicts between efficiency considerations and population at risk. Indeed, when routes are carefully selected taking account of the cost to transporters, society, that is, the population exposed to risk, in addition to environment and property, hazardous materials will be transported with fewer incidents and consequences minimized, if any.

The benefit with route selection is that it provides carriers or transporters with a good number of choices of roads and reduces cost but at the same time it also increases risk exposure, that is, population and property exposed considering that several roads are designated for hazardous materials transportation (Erkut and Alp, 2007). Lozano *et al.* (2011) argue for consideration to be given to night time and day time populations likely to be exposed to hazardous materials accidents. Taking the case of gasoline and chlorine transportation in Mexico City, Lozano *et al.* (2011) concluded that these hazardous materials are best transported at night to avoid rush hour populations as well as commuters in the city. During the night when the roads are not congested and commuters return to their domiciles, exposure is reduced. This approach will be suitable for internal distributions or service stations which are dotted across cities. It is worthy of note that population exposed to hazardous materials accidents is repeated for as many times a particular truck or as many trucks that ply a particular road in a single day.

Dadkar, Jones ans Nozick (2008) contend that route selection decisions consider the cost to transporters and should be varied by time of day. This means that decision making on route selection should not necessarily be based on cost to transporters and society but also the time of day must be considered.

For route selection to work efficiently, the US Department of Transportation, (FMCSA) (2003) proposed the use of routing guides that outline Safe Parking Places (SPPs) as well as Safe Stopping Places (SSPs) on each available route. SSPs provide drivers with a place to break their journeys temporarily to rest, albeit with the vehicle where as in the case of SPPs drivers can leave the vehicle unattended to have rest or meals. Dedicated hazardous materials parking places along the road, truck stops and other commercial ventures such as filling stations' park are but a few of these locations.

Before designating routes for hazardous materials transportation, a public hearing process is argued for. (US Department of Transportation, FMCSA, 2003). It is through this public hearing process that residents and civil society as well as all other stakeholders can be informed about the designated routes, SSPs and SPPs in addition to other relevant issues. Feedback from residents are useful in the process of designating routes as hazardous material transportation routes. When this is done agreeably local residents play crucial 'watchdog' roles to ensure safety in the community. In places where technology is not used extensively to monitor hazardous material transporting trucks local residents 'supervisory/watchdog' activities can be used. In a similar vein, in areas where these technologies exist, local residents' activities can be used to complement technology monitoring systems to ensure safety during transportation.

The foregoing are some of the policy tools that are available and have been used extensively across the world to deal with the hazardous materials transportation risks. It is the responsibility of mandated institutions to select which ones are appropriate in their local circumstances to implement. When these tools are put in place, generally, risks would be reduced and consequences also minimized to ensure safe transportation of hazardous materials on highways in the country. The ensuing section summarizes the entire literature review – placing emphasis on outstanding or key issues following which a conceptual framework is constructed to guide the rest of the study.

2.10 Summary of Review

This Chapter set out to review pertinent literature regarding safe transportation of hazardous materials on roads. The issues identified include a clear cut definition for hazardous materials for the current study, regulations and regulatory bodies in hazardous materials transportation process as well as decision support systems for assigning or designating hazardous materials transportation routes. In addition to these, various types of risks and their assessment methods have also been presented. The review also outlined the various types of accidents a hazardous material transporting truck can face, their causes as well as consequences or effects taking case studies from hazardous materials incidents around the world. Policy tools available for mitigating hazardous materials transportation accidents such as toll policies, driver training, route selection have also been reviewed.

Following the reviews and establishment of inter relationships between stakeholders a conceptual framework is drawn subsequently to assist in guiding the research. Figure 2.11.1 indicates the various stakeholders involved in the process of transporting hazardous material, their interactions and inter relationships that ensure a safe and efficient transport of hazardous materials devoid of accidents and with minimum consequences, if any.

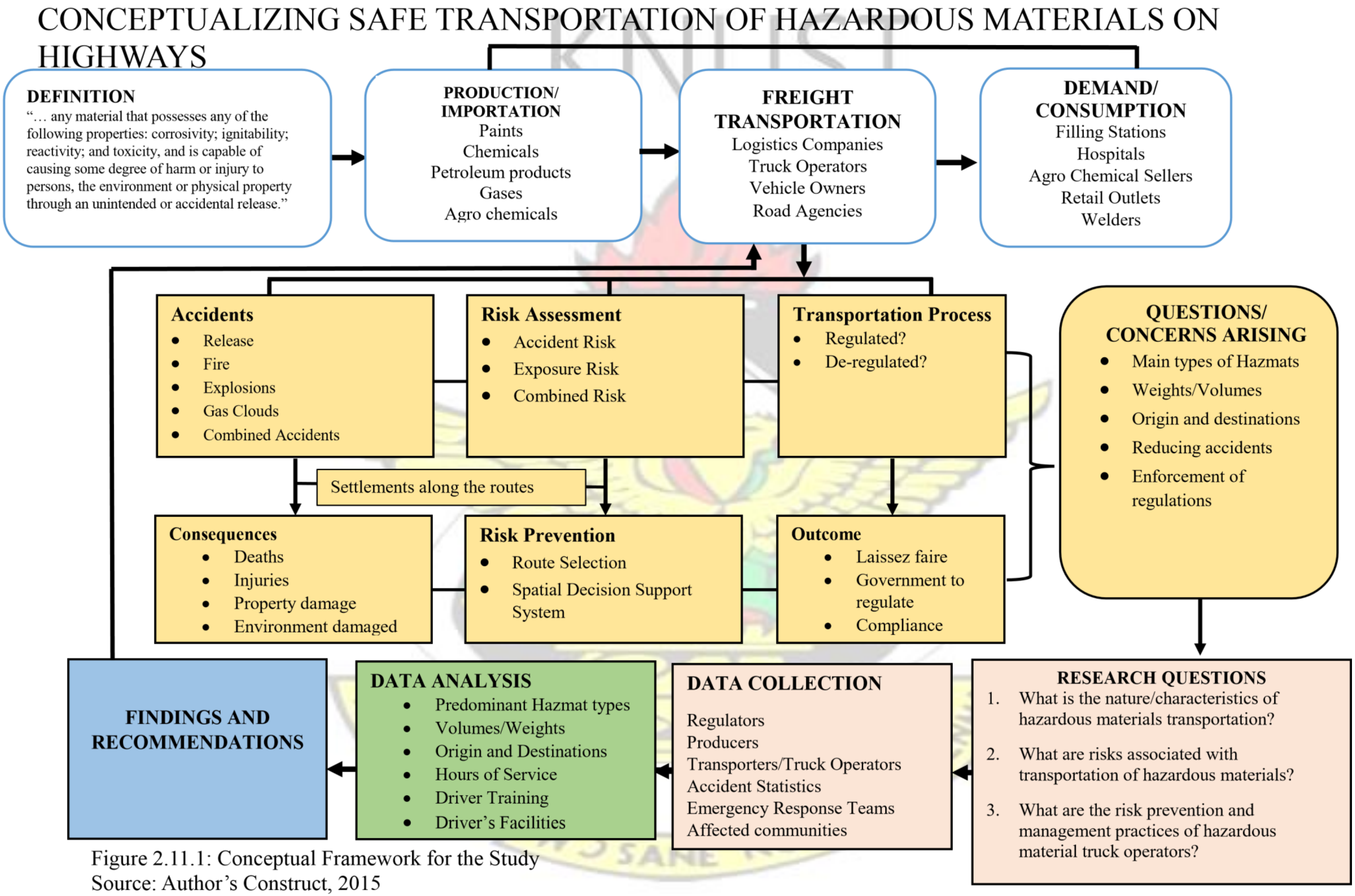


Figure 2.11.1: Conceptual Framework for the Study
Source: Author's Construct, 2015

2.11 Conceptualizing Hazardous Material Transportation in Ghana

To fully appreciate the transportation of hazardous materials on highways in Ghana, there ought to be first an understanding of the underpinning concepts, and then relationships among these concepts established. When this is done, then the research variables that need to be measured to depict the nature of transportation of hazardous materials are outlined going forward. This is the subject of discussion in this section.

The Conceptual Framework in Figure 2.11.1 provides an overview of the entire research. Essentially, it serves as a road map to guide the research process. It can be seen from the framework that, the general introduction in Chapter one, through the review of relevant literature in Chapter Two, the methodology for operationalizing the research in Chapter Three, data analysis of Chapter through to findings, discussions and recommendations of Chapter Five have been detailed out.

As can be seen from the framework, hazardous materials are produced or imported into the country and subsequently some are shipped to demand centers, including Kumasi. This interaction between production and consumption is made possible only through transportation, particularly by roads, in Ghana. The framework, consequently, suggests that for a safe transportation of hazardous materials between production/importation centers and demand centers, various aspects including risk assessment, regulations as well as consequences of accidents need to be considered. Bearing these in mind following the review of relevant literature, the study's research questions and the relevant data collection methodology are discussed. Data gathered from the field was analyses and some recommendations are made based on the study's findings.

2.12 Summary of Chapter

This Chapter sought to explore the relationship among various concepts that are intertwined in explaining the nature of transportation of hazardous materials on highways. This was achieved through review of relevant literature on the subject; which includes but not limited to: definition of what constitutes a hazardous material, regulations, types of hazardous materials accidents, risk assessment or estimation, accident prevention as well as management policies and tools. The variables necessary to analyze the situation on the study corridor and their inter relations as well as the steps followed in subsequent Chapters are summarized into the conceptual framework, as can be seen in Figure 2.11.1.

CHAPTER THREE
STUDY APPROACH AND METHODOLOGY

3.1 Introduction

Following the review of relevant literature on the transportation of hazardous materials, the next stage of the study was to evolve a detailed methodology that was employed in collecting data from the field prior to the analysis. In this Chapter, details such as the research design framework adopted, sampling strategy in terms of sample size interviewed and the selection process are discussed in addition to the data sets required and their major sources.

3.2 Research Design

The nature of any scientific enquiry has a bearing on the methodology used. Bhattacherjee (2012) asserts that the approach to be used ideally should depend on the phenomenon under study. In this study, a mixed-method approach was considered to be appropriate. This is because the study intended to collect and analyze some quantitative data as well as qualitative description of some events and processes associated with the transportation of hazardous materials on Ghana's trunk roads. Some of the quantitative data requirements include the volumes of hazardous materials that are transported on the Tema - Accra – Kumasi highway, age characteristics in terms of drivers and vehicles used, years of experience, trucks and packaging materials used, and the associated risk in terms of exposure to the general public as well as consequences of accidents. In addition to the quantitative aspects, some other components such as the journey characteristics – origins and destinations, facilities for truck operators, the regulatory requirements in terms of entry, exit and enforcement as well as challenges associated with transportation of hazardous materials on the corridor need to be documented. These make up the qualitative aspect of the research. Indeed, Creswell (2003) acknowledges that mixed methods are suitable for closed-ended measures as well as opened-ended observations. For mixed methods design, data collection also involves gathering both numeric and text information resulting in a qualitative and quantitative database.

This scientific enquiry is cast in the post positivist framework in the sense that it attempts to study a contemporary and on-going phenomenon in a real life setting. Creswell (2003) opines that post positivist studies are based on real world measures. In this regard, the study employed the use of instruments such as interviews and questionnaires to collect measurements or data from the field objectively following which findings were used in drawing generalisations for the study corridor.

3.3 Selection and Justification of Study Highway

Road transportation of freight is carried out mainly on highways especially considering the fact that demand centers are scattered all over the country and these demand centers, usually, are far from production centers. The spatial distribution and concentration of population and industries in Ghana is uneven, favouring the south as against the north (Oduro, Afrane and Braimah, 2014); hence, the need for transportation of the hazardous materials to serve the demand centres in the northern and middle belts. The hazardous materials under consideration in the current study are partly imported into the country through the Tema port and transported to demand centers such as Kumasi and areas beyond by road. Similarly, the main producers of hazardous materials are located in the Tema Industrial enclave. For example, petroleum products are loaded into tanker trucks from the Tema Oil Refinery [TOR]; agro chemicals are equally produced by Chemico Ghana Limited and Sidalco Limited; and paints are also produced by BBC Paints Ltd; all of which are situated in Tema. A substantial proportion of the various products are transported using the Tema – Accra – Kumasi highway. Again, these demand centers and production centers are connected mainly by roads; hence, the dominance of road freight transportation established in Chapter One.

The Tema – Accra – Kumasi highway was selected taking cognizance of the reasons discussed subsequently in this section. First of all, the Tema – Accra – Kumasi road accounts for the highest vehicular traffic volume in the country. Some data available from the Ghana Highway Authority (2015) puts the Average Daily Traffic (ADT) volume on this route to be 14,160 vehicles with variations along sections of the road. Out of this number, about 26% are medium and heavy vehicles that are used in transporting freight, a part of which is the hazardous materials. Light vehicles comprise taxis, saloon cars, pick-ups and cross country vehicles in addition to mini, medium and large buses. These are designed primarily for passenger movement whereas medium and heavy vehicles are designed for freight transport (see, Appendix 3a for further details on vehicle configurations). Table 3.3.1 provides details on the Average Daily Traffic volumes and their compositions. As can be observed from Table 3.3.1, on road sections close to Accra and Kumasi; that is, Accra - Ofankor, Ofankor - Nsawam, and Ejisu - Kumasi, observed

ADT volumes are higher in relation to the other sections along the stretch. This was as a result of “city effect” from Accra and Kumasi respectively.

The Tema – Accra – Kumasi highway was also selected for this study because it is heavily used as a transit route by neighbouring West African landlocked countries - Burkina Faso, Mali, and Niger – to transport imports and exports. These include mainly rice, sugar, cotton lint, livestock, liquefied petroleum gas, cars, shea nuts, and petroleum products. Petroleum products as well as chemicals used in the mines form an integral part of hazardous materials transported. Based on observation and some preliminary studies it was realized that petrol, liquefied petroleum gas and diesel demands in these countries are transported along the Tema – Accra – Kumasi road.

Table 3.3.1: Average Daily Traffic Count and Vehicle Classification by Sections of the Tema – Accra– Kumasi Highway.

Road Section	Length (km)	ADT	LIGHT %	MEDIUM %	HEAVY %
Tema - Accra	22.6	- *	-	-	-
Accra – Ofankor	15.0	30,375	87	8	5
Ofankor – Nsawam	23.0	21,475	76	17	7
Nsawam – Suhum	38.0	8,201	66	19	15
Suhum – Bunso	32.2	6,950	69	17	14
Bunso - Nkawkaw	57.2	7,963	73	15	12
Nkawkaw - Konongo	52.1	5,573	65	18	17
Konongo - Ejisu	35.0	11,120	79	12	9
Ejisu – Kumasi	18.2	21,625	83	11	6
TOTAL	**293.3**	**113,282**	**598**	**117**	**85**
Average		**14,160**	**75**	**15**	**11**

Source: Ghana Highway Authority, 2015.

***** In row 2, data for the section were not available at the time of study.

Kumasi’s geographic location offers it an advantage in terms of transportation and centrality (Adarkwa, 2011). It is the fastest and most convenient point of connecting most consumption centers in northern Ghana including Brong Ahafo region to production centers down south. In theory, there are alternative routes that link Accra/Tema to Kumasi and areas beyond which include:

a. Tema – Accra – Nsawam – Nkawkaw – Kumasi;
b. Tema – Accra – Aburi – Koforidua – Kumasi;
c. Tema - Accra – Yamoransa – Obuasi – Kumasi; and
d. Accra/Tema – Atimpoku – Hohoe – Yendi – Tamale.

The Tema – Accra – Nsawam – Nkawkaw – Kumasi route is widely used owing to some reasons to be outlined subsequently. It provides the shortest road distance between Accra/Tema area and Kumasi. The Accra/Tema – Aburi – Koforidua – Kumasi route, for example, is not widely used by freight transporters because of the difficult topography between Ayimensah and the foot hills just beyond Mamfe. The Accra/Tema – Yamoransa – Obuasi – Kumasi route is hardly used as it prolongs the journey and adds to extra cost except in situations where transported freight have destinations in Obuasi or make an intermediate stop there.

The researcher was also constrained with funding and time to carry out the research along the entire stretch from Accra/Tema to border destinations such as Paga and Hamile. Ideally, these would have presented a better understanding of the issues concerning transportation of hazardous materials on the roads. However, given that these trucks going to such destinations go through Kumasi, they were captured accordingly and as much in the sample drivers interviewed.

In view of the reasons put forth, the Tema - Accra – Kumasi Highway was chosen for the study. This provided heterogeneity in terms of hazardous materials being transported, origins and destinations as well as vehicles used in the process. The different target groups; that is, transit and local transporters were captured adequately on this route.

Based on adequate data gathered from this route and analysis of such data, useful inferences were made and generalizations drawn subsequently on the transportation of hazardous materials on Ghana’s trunk roads.

3.4 Data Requirements and Sources

By the nature of phenomenon under study, data requirements included origin and destinations of vehicles, volumes and types of hazardous materials being transported, intermediate facilities for truck operators as well as regulatory requirements for entry, exit and operation of hazardous material haulage. The data required for the research were obtained primarily from truck operators and hazardous material producing companies. National Highway Regulations as well as Environmental Protection Agency [EPA] regulations on hazardous materials transportation were also used as secondary sources of information for the study. A detailed list of data required, source and method of data collection are presented in Table 3.4.1. These data sets required were captured, as much as possible, in line with the research objectives or questions so as to adequately address them in the analysis chapter and put forth recommendations that will help reduce accidents and ensure safe transportation of hazardous materials on the trunk roads in Ghana.

Table 3.4.1: Data Requirements, Sources and Instruments for Data Collection

Research Objective	**Data Requirements**	**Source of Data**	**Instruments for Data Collection**
1. To explore the characteristics/ nature of hazardous materials transportation along the Accra – Kumasi route	• Type of hazardous materials • Volume/weight of freight • Origin and Destination • Type of vehicle used • Condition of vehicle • Hours of Service • Ages of operators • Ages of vehicles • Truck Operators' years of experience • Qualification of operators • Number of accidents or incidents, if any • Packaging used • Labels of hazardous materials	Truck Operators Producers/Importers	Questionnaires
2. To examine risks associated with hazardous materials transportation along the Tema – Accra – Kumasi Highway	• Risk levels/ Accident rates • Communities under risk of hazardous materials accidents • Risk Mapping • Population exposed • Threshold distance for risk assessment from accident site • Consequences of accidents • Accident Response readiness and adequacy of expertise and equipment for operations	• Ghana Highway Authority • Truck Operators • Ghana National Fire Service [GNFS] • Building and Road Research Institute [BRRI]	Questionnaires Interview Guides
3. To explore risk prevention and management practices of hazardous material truck operators on the corridor	• Safety road signs and markings • Intermediate rest stops • Risk prevention and management practices adopted by hazardous materials truckers • Desired facilities by truck operators • Preferred location for rest stop • Health and safety measures from producers and transporters	• Ghana Highway Authority • Truck Operators	Interview guides Questionnaires

Source: Author's Construct, 2015

3.5 Sampling and Selection Criteria

Given the scope of the phenomenon under consideration and resource constraints on the part of the researcher the study adopted sampling strategy. This sampling was done in a representative and objective manner so that the research findings can be generalized for the study area and other similar routes in Ghana. The sampling method used, sampling units from which actual samples were selected, sample size determination, criteria for inclusion and selection in the survey in addition to the units of analysis are discussed in the ensuing sections.

3.5.1 Sampling Method

The nature of the phenomenon under study warrants the use of probability sampling method. In view of this method, generalizations could be made on the subject of road transportation of hazardous materials in Ghana based on findings from the current study. This method was employed in selecting truck operators to be included in the survey. However, some institutions were also contacted purposefully by virtue of the fact that they are the only ones privy to required information on transportation of hazardous materials. These include regulators, importers and producers of hazardous materials. Others include selected communities along the corridor and end users such as hospitals, farmers, agro-chemical retail outlets and fuel filling stations. The selection processes are discussed in ensuing sections.

Considering that hazardous materials are essentially freight that are being transported, selection of truck operators for inclusion in the survey was done randomly. Kumekpor (2002) opined that when every element within the sample frame has a non-zero chance of selection, the random or probability sampling method was considered appropritae. For this study, the intent was to examine characteristics, risks associated, facilities for truck operators along the route and to examine the regulatory requirements for hazardous materials transportation on Ghana's trunk roads. As such any truck driver or operator operating along the Tema/Accra – Kumasi Highway stands a chance of being selected for the survey. In view of this, the probability sampling method is deemed fit and used accordingly for data collection. However, a multi-stage probability method is used, thus, combining cluster and simple random sampling techniques to select samples to be included in the survey.

In addition to truck operators, some institutions are involved in the process of transporting hazardous materials and as such their views needed to be captured. Because of the specific roles performed by these institutions they were selected purposively. These institutions include producers and importers of hazardous materials, emergency response service providers and regulatory institutions. Some of the producers of hazardous materials include:

i. Chemico Limited (producers of fertilizers, herbicides, insecticides, fungicides, industrial and domestic paints);
ii. Air Liquide Ghana Limited (producers of industrial gases such as oxygen, helium, nitrogen, medical supplies, etc);
iii. Sidalco Ghana Limited (producers of agro chemicals);
iv. BBC Industrial Company Ghana Limited (producers of paints); and
v. Bulk Oil Storage and Transportation (BOST) Company Limited (transporters of petroleum products)

The regulatory institutions involved in the transportation of hazardous materials are mainly the Environmental Protection Agency [EPA] and the Ghana Highway Authority [GHA]. There are other agencies that are not directly involved in regulations but are mainly emergency response service providers, and they include the Ghana Police Service [GPS], Building and Road Research Institute [BRRI], Ghana Ambulance Service and the National Disaster Management Organization [NADMO].

All the above listed organizations were purposefully contacted for their inputs to the subject of transportation of hazardous materials. This is because these institutions have expert knowledge on the transportation of hazardous materials.

3.5.2 Sampling Frame

As explained by Kumekpor (2002), a sampling frame is a list or group of elements which is resorted to in selecting samples to be included in a survey. Because of the focus of the study, which is to examine the nature and characteristics of hazardous materials transportation, freight truck operators constitute the sampling frame out of which freight truck operators transporting hazardous materials were selected for the study. From Table 3.3.1, the medium and heavy vehicle categories constitute the trucks that are used in transporting freight only and not passengers. Based on data provided by the Ghana Highway Authority (2015) on the Average Daily Traffic (ADT) volume, the sampling frame had been determined to be 26% of an average 14,160 vehicles per day; that is, 3,682 freight vehicles. This comprises various vehicle types including light, medium, heavy and extra-large trucks, light and heavy semi-trailers as well as truck trailers (see Appendix 3a for details on vehicle classifications). Out of the 3,682 freight vehicles, operators of those trucks that are transporting hazardous materials were then randomly selected for the survey. The selection or sampling scheme employed is discussed in section 3.5.4 subsequently following the sample size determination.

3.5.3 Sample Size Determination

Following the determination of the sampling frame, the next stage of the study approach was to estimate the minimum number of respondents, the sample size, to be interviewed. In theory, a sample should not be too large or too small, but rather optimum. According to Kothari (2004) an optimum sample size should be flexible, reliable and representative. However, in determining a sample size researchers must bear in mind the level of precision and an acceptable confidence interval; thus, a margin of error and an acceptable confidence level in the results or estimates. In addition to these, budgetary constraints, level of variance in the population as well as the size of the population in question are considered for this study.

To obtain the proportion of total freight vehicles that constitutes hazardous materials, petroleum tanker vehicles were used as a proxy for all hazardous materials within a given traffic stream on a section of the highway. This was because petroleum tanker vehicles, which constitute a large proportion of hazardous materials, were easily identifiable as compared to other hazardous materials in a given traffic stream such as chemicals, acids and agro chemicals that are packaged and covered during transportation. Subsequently, twelve (12)-hour classified and unclassified counts were conducted around the KNUST Police Station along the Accra – Kumasi highway. These counts helped in determining the proportion of freight vehicles that were carrying hazardous materials. The surveys indicate an Average Daily Traffic (ADT) volume of 19,872 vehicles. This comprises 18,221 light vehicles, 881 medium vehicles and 770 heavy vehicles representing 92%, 4% and 4% respectively. Table 3.5.1 provides a summary of the results from the classified ground counts conducted along the Accra – Kumasi highway (see, Appendix 3b for details of the hourly unclassified count along the Accra – Kumasi highway).

Table 3.5.1: Hourly Classified Ground Count along the Accra – Kumasi Highway

Census Point: KNUST Police Station roundabout			**Direction: Both**				**Date: 13/11/2015**				**Time: 6:00 am – 6:00 pm**		
VEHICLE TYPE	**06:00 - 07:00**	**07:00 - 08:00**	**08:00 - 09:00**	**09:00 - 10:00**	**10:00 - 11:00**	**11:00 - 12:00**	**12:00 - 13:00**	**13:00 - 14:00**	**14:00 - 15:00**	**15:00 - 16:00**	**16:00 - 17:00**	**17:00 - 18:00**	**TOTAL**
TAXIS	242	335	287	275	258	256	235	330	327	364	299	275	**3483**
PRIVATE CARS	249	458	353	333	365	358	338	403	413	404	306	357	**4337**
PICK/UPS/4WD VEHICLE	175	264	265	291	339	298	313	380	344	355	306	326	**3656**
SMALL BUS/VAN	443	513	548	503	521	502	440	510	520	573	398	463	**5934**
M.BUS/MAMMY WAGON	23	36	67	63	19	45	24	26	61	49	48	55	**516**
LARGE BUS	17	11	15	12	26	26	25	26	29	35	38	35	**295**
LIGHT TRUCK	24	23	40	78	69	56	63	61	92	66	52	40	**664**
MEDIUM TRUCK	22	12	15	3	12	23	21	31	9	24	16	29	**217**
HEAVY TRUCK	14	6	6	11	4	15	10	11	6	19	16	13	**131**
SEMI - TRAILER (LIGHT)	1	1	4	3	5	8	3	2	2	6	1	1	**37**
SEMI - TRAILER (HEAVY)	4	4	2	3	4	9	5	5	4	3	3	5	**51**
TRUCK TRAILER	4	12	10	7	7	13	7	13	18	15	5	17	**128**
EXTRA LARGE TRUCK AND OTHERS	5	19	23	22	18	27	16	23	24	14	11	20	**222**
PETROLEUM TANKER	42	18	12	27	17	8	10	9	14	11	20	13	**201**
TOTAL	**1265**	**1712**	**1647**	**1631**	**1664**	**1644**	**1510**	**1830**	**1863**	**1938**	**1519**	**1649**	**19872**
LIGHT VEHICLES	1149	1617	1535	1477	1528	1485	1375	1675	1694	1780	1395	1511	**18221**
MEDIUM VEHICLES	46	35	55	81	81	79	84	92	101	90	68	69	**881**
HEAVY VEHICLES	70	60	57	73	55	80	51	63	68	68	56	69	**770**
TOTAL FREIGHT VEHICLES	116	95	112	154	136	159	135	155	169	158	124	138	**1651**
% OF FREIGHT VEHICLE BEING HAZARDOUS MATERIALS	**0.36**	**0.19**	**0.11**	**0.18**	**0.13**	**0.05**	**0.07**	**0.06**	**0.08**	**0.07**	**0.16**	**0.09**	**0.12**

Source: Field Survey, 2015.

From Table 3.5.1, it can be observed that light vehicles comprising of taxis, private cars, pickups, four wheel drives, small bus/van, medium and large buses, make up a huge chunk (92%) of the vehicles counted. This could be attributed to the "city effect" and the predominance of 'trotro' as a means of public transport in Kumasi (Adarkwa and Poku-Boansi, 2011). Freight vehicles which comprise of light, medium and heavy trucks, semi-trailers as well as extra-large trucks, on the other hand, constitute just about 8% of the total traffic stream. Petroleum tanker vehicles constitute 201 out of the total 1,651 freight vehicles counted, representing an average of 12%. Using these petroleum tanker vehicles as proxy for hazardous materials, it was estimated, consequently, that in a typical traffic stream, trucks transporting hazardous materials constitute about 12% of total freight trucks.

The sample size for the survey has been determined to be 163 trucks transporting hazardous materials (see Appendix 3c for details) using the formula prescribed for known proportions of a universe or sample frame from which samples are to be selected (Cochran, cited in Singh and Masuku, 2014). The following section outlines how the sample units are to be selected for inclusion in the survey.

3.5.4 Sampling/Selection Scheme

Following the determination of the sampling frame and sample size, the next stage of the study is to select samples for inclusion in the survey. Based on initial observations on the Tema - Accra – Kumasi highway, it was noted that truck operators usually stop or park their vehicles at virtually any location along the stretch. However, there are locations where the practice is predominant as freight trucks are parked in clusters in these locations (see, Figure 3.5.1 for the locations along the Tema – Accra – Kumasi Highway). Truck operators either break their journeys to refresh themselves and continue later or are waiting to be loaded with products. At other locations such as the BOST Tank Farm situated at the Kaase Industrial area in Kumasi, these trucks are in designated parks waiting to discharge the petroleum products they have brought from Tema. These predominant parking points or clusters for freight truck operators along the Tema - Accra – Kumasi Highway (N6) include:

a) The Tema Industrial Area, especially, around the Tema Oil Refinery [TOR] along the road stretch to Aluworks and Volta Aluminium Company [VALCO];

b) Nsawam Adoagyiri area- along the new by-pass;
c) Apedwa, around Kibi Junction;
d) Bunso Junction, after the Toll Booth;
e) Anyinam- just before Joefel Restaurant and Kwabeng junction;
f) Nkawkaw, along the new by-pass and junction to Nkawkaw;
g) Kubease, near the Toll Booth; and
h) Kumasi, at the BOST Tank Farm at Kaase.

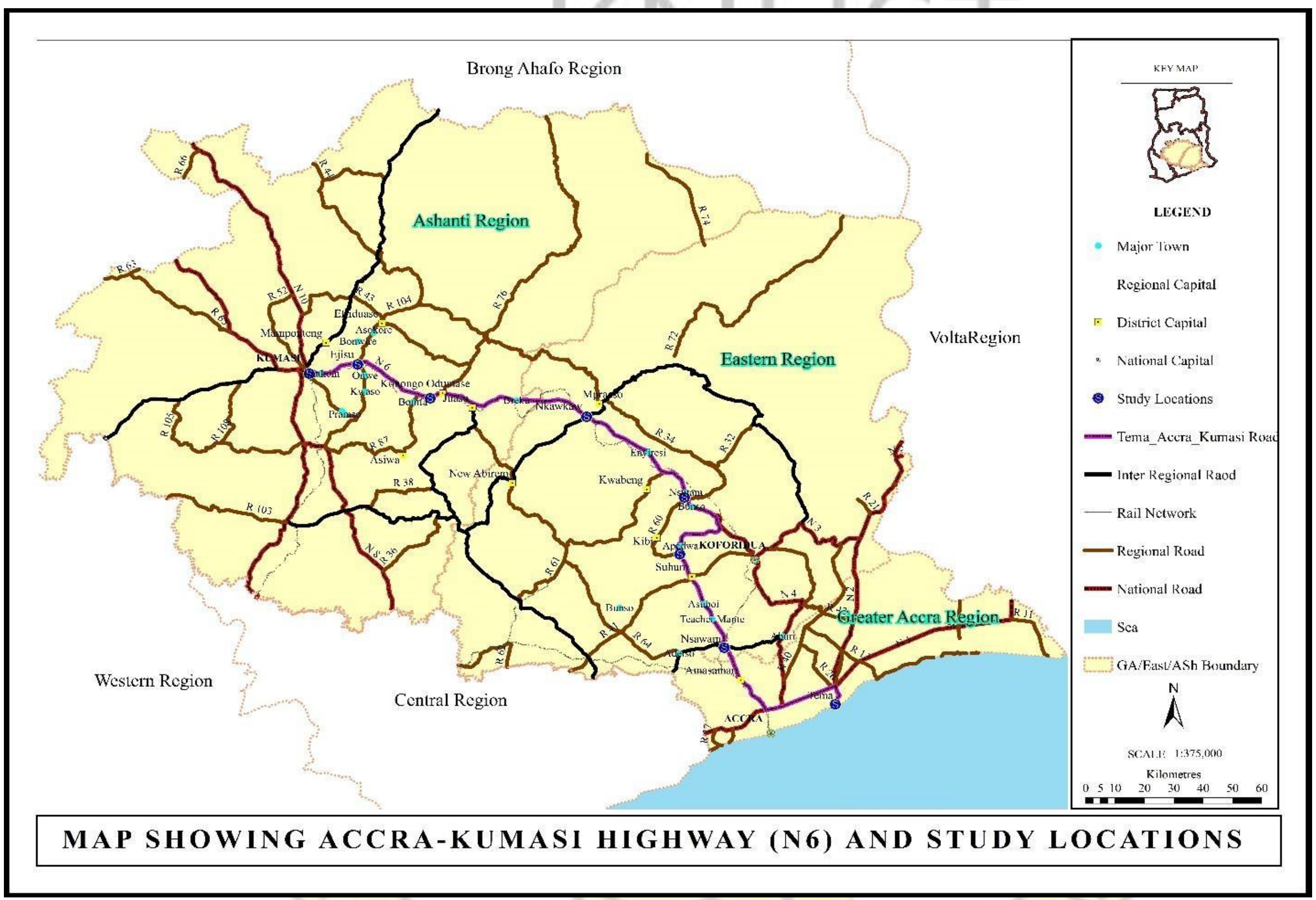


Figure 3.5.1: Strip Map of the Tema/Accra – Kumasi Highway showing study locations/clusters Source: Author’s Construct, 2015.

Figure 3.5.1 is a strip map of the Tema/Accra – Kumasi Highway which stretches approximately 282 km from Tema through major towns such as Accra, Nsawam, Suhum, Nkawkaw, Konongo and Ejisu to Kumasi. It indicates the clusters where freight transporting trucks are usually parked and constitute the points from which questionnaires were administered to truck operators. However, owing to time and resource constraints some clusters were selected for inclusion in the survey.

In determining which clusters to include in the survey, the researcher used three (3) clusters. These clusters were chosen such that they cover the administrative regions through which the highway traverses. These regions are the Greater Accra, Eastern and Ashanti regions respectively. The clusters chosen from each region include Tema Oil Refinery area, Nkawkaw – along the new by-pass and BOST Tank Farm at Kaase in Kumasi respectively.

In addition, these clusters were selected because they had higher numbers of trucks parked compared to other locations. At the BOST Tank Farm, for example, the petroleum tanker trucks were parked waiting to discharge.

After locating the sampling points, the next stage was the actual selection of sampling units. At the various clusters, operators of trucks transporting hazardous materials were selected using the simple random sampling technique to respond to the questions posed for the survey. This way, each truck operator transporting hazardous materials has an equal chance of being selected for the study. Operationally, at each cluster the truck operators were first asked the materials they were carrying, if it was not clear for the researcher to establish a hazardous materials transporting truck. For example, petroleum tankers are easily identifiable whereas other hazardous materials such as agro-chemicals and paints, which are packaged in smaller units and not transported in bulk like petroleum products, may not be easily recognized. Hence, if a truck operator acknowledges he is transporting any hazardous material, that truck operator is then selected for inclusion in the survey. When it was ascertained that a truck operator was transporting any of the materials classified hazardous then that truck operator was selected for inclusion. The questionnaires were self-administered to all selected truck operators.

3.5.5 Units of Analysis

To gain an in-depth understanding of the transportation of hazardous materials, data were collected and analyzed from two major groups. These are truck operators, on one hand, and the producers and importers, on the other hand. Findings from the truck operators were then triangulated with those from the producers and importers of hazardous materials.

In addition to the truck operators, other relevant stakeholder institutions were interviewed for their views on the road transportation of hazardous materials. These included the Ghana Highway Authority [GHA], Environmental Protection Agency [EPA], Building and Road Research Institute [BRRI], Ghana Police Service [GPS], National Disaster Management Organization [NADMO], and the Ghana Ambulance Service. These institutions were purposively selected for inclusion in this study because they have stakes and are the only ones privy to information on road transportation of hazardous materials in Ghana. (See Appendix 3d for the list of stakeholders interviewed).

3.6 Data Collection, Processing and Analysis

3.6.1 Data Collection

The researcher used the assistance of Field Research Assistants [FRAs] in addition to himself because of the large area of coverage for the study spanning 282km from Tema through Accra to Kumasi and the limited time within which the research had to be completed. As such, the FRAs were trained and educated on how to interpret and put questions across to respondents as well as how to elicit accurate responses from respondents. Where appropriate, the use of local language was resorted to but in such instances during the course of training the FRAs, the researcher made sure that the questions are accurately interpreted. Following the training sections, a pretest of the field instruments was conducted at Kubease, just before the toll booth on the highway to ensure that questions are well sequenced, clear, non-ambiguous, potential errors detected and corrected as well as to have an idea of how long it will take to administer one questionnaire. This gave the researcher ideas as to how many questionnaires were expected to be completed at the end of each day. This provided useful inputs into planning the field surveys.

The data collection spanned mid-October, 2015 to December 2015. Questionnaire administration and stakeholder interviews spanned the whole period. Traffic counts were carried out on the 13th of November, 2015. Within the selected clusters, the hazardous material truck operators were selected at random. In operationalizing this, all drivers that were at the park/cluster were asked which materials they were transporting.

3.6.2 Data Processing

Prior to data analysis, field results were coded, edited and cleaned of any errors and non-responses. This was done to ensure that outputs are representative of respondents and errors with data entry are corrected. This served as a check on the internal validity of results obtained from the analysis of data. For example, in order not to have a case where a truck operator was interviewed more than once, the vehicle registration numbers were captured and used to guide in data collection and processing. However, it was possible that some may not be detected during data collection stage. These repeated responses were deleted from the database accordingly.

3.6.3 Data Analysis

When questionnaires had been administered and responses gathered, the data were entered into the SPSS [version 16] software which was used for the analysis. The SPSS was used because of its ability to cross-tabulate variables in addition to other statistics such as the mean, mode, standard deviation and percentages among others. The analysis consisted of uni-variate and bi-variate analysis. Uni-variate analysis employed the use of simple statistics such as the mean, mode and standard deviation for variables that need to be analyzed on a stand-alone basis. For the bi-variate analysis cross-tabulations were used to present relationships among variables of interest. In addition to the SPSS package, use was made of Microsoft Excel software to carry out quantitative analysis. The age of truck operators and number of years of experience, for example, were regressed on the number of accidents/incidents using the Microsoft Excel package. In view of risk analysis conducted, the researcher had a risk map to show areas that are liable to hazardous material risks. In this case, the ArcMap 10.2 GIS computer software was used to produce the necessary maps to illustrate the phenomenon. This revealed populations that are at risk of a potential hazardous material incident and this was used to estimate costs of accidents. In addition, black spots along the highway stretch were located and recommendations put forth to reduce incidence of accidents at such locations. This was carried out based on incidences of hazardous material accidents.

3.7 Summary of Chapter

This Chapter has reviewed the study approach in terms of data requirements, sources of such data, methods of collection as well as the sampling techniques employed. In addition to these are data processing and the various analysis used to analyze data following their collection so as to bring to bear the characteristics/nature of hazardous materials transportation on Ghana's Trunk roads, particularly the Tema/Accra – Kumasi Highway (N6). The next stage of this research is the analysis of data from the field surveys presented subsequently in Chapter Four.

CHAPTER FOUR DATA ANALYSIS ON TRANSPORTATION OF HAZARDOUS MATERIALS

ALONG THE TEMA – ACCRA – KUMASI HIGHWAY

4.1 Introduction

The earlier chapters of this study contained a general background to the study, review of relevant literature as well as a detailed methodology for data collection and analysis. In the current chapter, results from the surveys are presented and analyzed to give a picture of the current situation of the transportation of hazardous materials on the Tema – Accra – Kumasi highway. Where applicable, results from the current study are compared with practices from elsewhere based on the literature reviewed. Data were collected from truck operators, a limited number of hazardous material producers as well as some key stakeholder institutions in the sector.

Data from the truck operators include background information such as age characteristics, educational attainment and level of experience; among others which are presented in Section 4.2. In addition to the foregoing, other data collected from truck operators include hazardous material types and corresponding volumes being transported, origins and destinations of products, the level of professional training truck operators have had, the designated routes they used as well as safety measures they have in place to forestall the occurrence of accidents as well as their preparedness to deal with any accident in the unfortunate event that it occurs.

Following the general background information on truck operators, the next sections have been presented in line with the objectives of the research such that each one is treated under a separate section. However, where there is need to analyze some data across sections, cross tabulations are used to give a clear elucidation on the situation. The logic behind presentation of study results is to get to know the truck operators, the vehicles they use and then products they transport as well as their operational characteristics. In line with this, Section 4.3 contains presentation and analysis of data on the characteristics of vehicles being used to transport hazardous materials, Section 4.4 considers the products transported while risks and attendant causes and effects associated with transportation of hazardous materials are captured in Section 4.5. Operational characteristics of truck operators relating to trucks and packaging materials used, the condition of trucks, labelling of vehicles, speed levels, location of intermediate stops and facilities for rest, known black spots as well as regulations and compliance are captured in Section 4.6.

Following the foregoing, a summary is presented in Section 4.7 to depict pertinent issues that hinder safe transportation of hazardous materials and how truck operators and institutions have put in efforts aimed at dealing with such hindrances.

4.2 Background Information on Truck Operators

4.2.1 Age Characteristics

Under the current circumstances in Ghana, transportation of freight in general is seen as a male dominated occupation unlike the use of private cars and some passenger buses like the Metro Mass Transit where some females are engaged as drivers. It is important to know the age characteristics of truck operators as it has been a determining factor in establishing the cause of some hazardous material accidents (Federal Motor Carrier Safety Administration [FMCSA], 2005).

The results from the survey indicate that a wide age range of truck operators are engaged in transporting hazardous materials. This ranges from age 21 to more than 60 years as summarized in Table 4.2.1.

Table 4.2.1: Age Distribution of Truck Operators Transporting Hazardous Materials on the Tema – Accra – Kumasi (N6) Highway.

Age Range (Years)	Frequency	Percentage	Cumulative Percentage
21-25	7	4.1	4.1
26-30	22	12.9	17.1
31-35	37	21.8	38.8
36-40	25	14.7	53.5
41-45	31	18.2	71.8
46-50	28	16.5	88.2
51-55	13	7.6	95.9
56-60	6	3.5	99.4
60+	1	0.6	100.0
Total	**170**	**100.0**	

Source: Field Survey, November 2015.

There appears to be a wide representation from all age ranges, with the highest being 31- 35 years while the lowest is those aged 60 and over. Putting this in line with

Driver and Vehicle Licensing Authority's [DVLA] minimum requirement of 18 years for eligibility to acquire a driver's license, it will be noted that all drivers meet minimum requirements to hold and use a driver's license. Although the truck operators meet minimum requirements to hold and use a driver's license, a sizable proportion, that is 17%, falls below 30 years and this will have implications on the level of experience and the ability to handle freight vehicles transporting hazardous materials. These variables, age and level of experience, have been found to be major causes of accidents by Hazardous Materials Cooperative Research Program [HMCRP] (2009). This will be analyzed in a subsequent section of this study.

From Table 4.2.1, three clearly discernible patterns can be identified. These include truck operators aged between 21 – 25 years, 26 – 55 years, and those aged between 56 years and above. The pattern suggests that only few truck operators (8.2%) are aged less than 25 and beyond 56. This has implications for the general operations. For example, truck operators who are relatively old, by virtue of their old age may have problems with reflexes such as poor vision at night. In general, 5.3% of truck operators interviewed transported products at night, nonetheless, with variations in the ages of such operators. Relatively younger drivers aged less than 50 years were involved in night transportation. The 4.1% of truck operators aged 56 years and beyond do not operate at night giving a relief of some sort as accidents associated with poor visibility at night, especially for the older drivers, will be reduced, if not eliminated.

In Table 4.2.2, it can be seen that a large proportion (80%) of truck operators travel during the day with a minimal 5.3% travelling at night while 14.7% operate both day and night. Considering that more drivers operate during the day, population at risk is expected to be high compared to night populations. As Lozano *et al.* (2011) have argued, night time population exposure to risk is reduced and as such they recommended night time as suitable for transportation of hazardous materials. In the not too distant past in Ghana, the practice was to have freight trucks, in general, transport products at night in a bid to reduce road accidents. This was, however, found not to have achieved the desired impact of reducing road accidents and was subsequently abolished. The practice in Ghana at the moment is that freight transporters move freight at convenience irrespective of the time of day. The consequences of accidents involving hazardous materials are very dire and emergency response service providers may not be at hand to save situations. To some extent, it will be easy to side with arguments by Lozano *et al.* (2011) since night time passengers and commuters are lower compared to day time but the situation is not same in Ghana. In addition, traffic congestion in cities and town centres which tend to slow down speeds resulting in inability of some truckers to meet just in time delivery periods.

Table 4.2.2: Distribution of Truck Operators Time of Operation by Age

Age of Truck Operator (Years)	Time of Operation						Total	%
	Day and Night	%	Night	%	Day	%		
21-25	0	0.0%	1	0.6%	6	3.5%	7	4.1%
25-30	3	1.8%	3	1.8%	16	9.4%	22	12.9%
31-35	4	2.4%	0	0.0%	33	19.4%	37	21.8%
36-40	6	3.5%	3	1.8%	16	9.4%	25	14.7%
41-45	7	4.1%	1	0.6%	23	13.5%	31	18.2%
46-50	2	1.2%	1	0.6%	25	14.7%	28	16.5%
51-55	3	1.8%	0	0.0%	10	5.9%	13	7.6%
56-60	0	0.0%	0	0.0%	6	3.5%	6	3.5%
60+	0	0.0%	0	0.0%	1	0.6%	1	0.6%
Total	**25**	**14.7%**	**9**	**5.3%**	**136**	**80.0%**	**170**	**100.0%**

Source: Field Survey, November 2015.

4.2.2 Level of Experience

As the good old adage says "practice makes perfect", having a lot of experience in doing a particular thing results in higher efficiency and reduced risks as well as ability to deal with any incident. With several years of experience in transporting hazardous materials, drivers become better placed to handle both the products and the vehicles used in transportation. In addition, they also become very familiar with the roadway, which in this case is the Tema – Accra – Kumasi Highway. The number of years of experience of a driver is key in determining his ability to safely transport hazardous materials with minimal incidents. On the Tema – Accra – Kumasi highway, results from the survey indicate that approximately one out of every four drivers interviewed has attained less than five years of experience. Considering that about 74% of drivers have been operating hazardous material trucks for more than five years a low level of incidents are expected, all other things being equal (see, Table 4.2.3).

Table 4.2.3: Truck Operators' Number of Years of Experience in Handling Hazardous Material Trucks.

Level Of Experience (Years)	Frequency	Percent	Cumulative Percentage
Below 5	44	25.9	25.9
6-10	47	27.6	53.5
11-15	25	14.7	68.2
16-20	26	15.3	83.5
21-25	15	8.8	92.4
26-30	7	4.1	96.5
31-35	5	2.9	99.4
36-40	1	0.6	100.0
Total	**170**	**100**	

Source: Field Survey, November 2015.

It is observed from Table 4.2.3 that close to 8% of drivers have been operating such trucks for between 26 to 40 years with another 66.5% having between 6 to 25 years of experience and a sizable 25.9% having less than five years of experience. The number of years of experience has been observed to vary inversely with number of drivers such that as the number of years of experience increases then frequency of drivers that have attained such level of experience reduces (see Figure 4.2.1). A plausible reason could be that truck operators retire from active service early given the stressful nature of the job. During the interviews with truck operators one hazardous material truck operator mentioned that:

> "… this job when you do it for long time, you will have problem because all the time you are seated and driving this truck, it can affect your back (spinal cord). That is why some people quit early ..."

This gives an indication of the health problems associated with such transportation activity. Benstowe (2008) found that sitting for prolonged hours, vibration in the body and physical fatigue associated with truck driving were the risk factors related to occupational health problems for truck operators. Some illnesses such as obesity, musculoskeletal disorders, hypertension, cardiovascular disease, stroke, psychological distress and sleep disorders were noted to be the risk factors truck operators were exposed to.

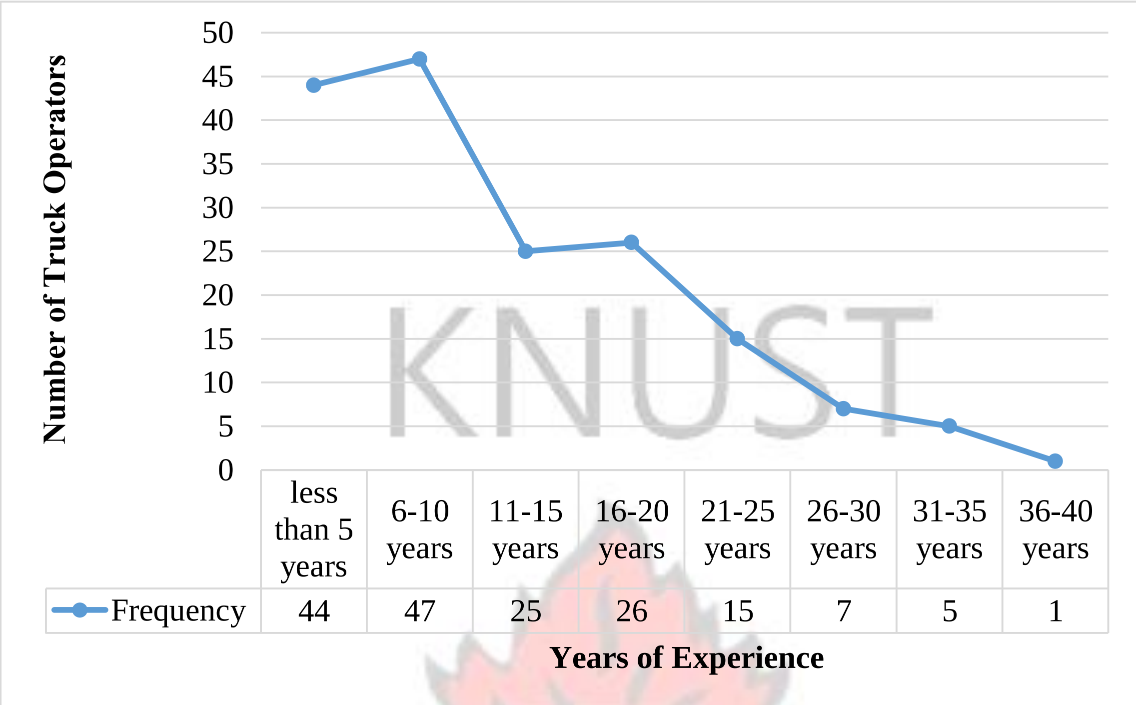


Figure 4.2.1: Graph showing Truck Operators' Years of Experience. Source: Field Survey, November 2015.

Given that a high proportion (66.5%) of truck operators have a lot of experience in handling such hazardous material trucks, it is a good indication that they will be able to safely transport the materials between production points and demand centers. However, it is equally noteworthy that 25.9% of truck operators have less than five years of experience in handling hazardous material trucks. This proportion appears alarming given that one in every four drivers has attained less than five years of experience. Comparable to the age of drivers, the US Department of Transportation, Federal Motor Carrier Safety Administration [FMCSA], (2005) has noted that truck operators with less than five years of experience are more prone to hazardous material accidents, especially spills. Subsequently in this study an attempt is made to relate hazardous material accident with the number of years of experience of truck operators who might be involved to ascertain the veracity or otherwise of this finding under the Ghanaian circumstances.

4.2.3 Educational Attainment

Education is important in all aspects of life simply because it has a bearing on the individual in question, his/her immediate community and the nation at large. It is in this regard that information of truck operators' educational attainment is collected and analyzed. For all drivers, minimum level of formal education is key considering that in recent times in Ghana, tests conducted before awarding driver's licenses are conducted in the English language and also because most road signs, where applicable, are communicated in English. It had been proposed by the Driver and Vehicle Licensing Authority to conduct the theory examinations in some selected local Ghanaian languages for drivers that are not literate. However, this has remained a proposal even though some driver unions have called for its implementation. In view of the fact that hazardous products are toxic, easily ignitable, corrosive and reactive with other agents or substances, some level of formal education and professional training of truck operators is of utmost importance. This would help prevent accidents and also reduce consequences and casualties, if any accidents do happen in the process of transporting hazardous materials.

Results of the survey conducted are summarized in Table 4.2.4. It can be observed that majority of truck operators (93.5%) have attained up to a minimum level of primary education whereas 6.5% have never been to school. According to the Ghana Statistical Service (2014) in the Ghana Living Standards Survey [GLSS] Round 6, adult population that has never been to school amounted to 19.7% but in the current study only 6.5% of truck operators have never been to school. This gives a good indication for safe transportation of hazardous materials. The relatively low proportion of illiterate truck operators could be attributed to the level of education and professional training required to transport hazardous materials.

Again, it would be observed that approximately 51% of truck operators have attained basic education, a figure that is lower than 86% of drivers who hold a Basic Education certificate according to findings by Appiah (2012). This suggests that truck operators have lower level of education compared to all drivers in the country. On the surface, it would appear as though their inability to attain higher levels of formal education will inhibit their ability to operate trucks in general, let alone those used for transporting hazardous materials. However, these drivers have been trained informally as apprentices or assistants to other established and experienced truck operators. This apprenticeship training is conducted for up to a minimum of three years before a trainee is allowed to drive a truck albeit subject to the trainee holding a valid driver's license.

Table 4.2.4: Level of Education attained by Hazardous Material Truck Operators on the Tema – Accra – Kumasi Highway.

Educational attainment	Frequency	Percentage	Cumulative Percentage
Never	11	6.5	6.5
Primary	38	22.4	28.8
Junior High School	87	51.2	80.0
Senior High School	30	17.6	97.6
O/A Level	3	1.8	99.4
Middle School	1	0.6	100.0
Total	**170**	**100.0**	

Source: Field Survey, November 2015.

In addition to the foregoing, these shortcomings on the side of truck operators who have never been to school are made good with some professional training provided by their various Transport Service Providers [TSPs]. TSPs are the companies that own the vehicles being used in transporting the materials and employ drivers to carry out duties for them. As can be observed from Table 4.2.4, some 11 out of the 170 truck operators interviewed had never had any formal education. However, for them to also operate hazardous material trucks they have had to undergo some professional training in order to transport such materials. The professional training provided is not limited to only the truck operators who have never had a formal education but instead it is for all truck operators and is conducted on regular bases.

Table 4.2.5: Period when Truck Operators have had Professional Training

Last Period of Training	Frequency	Percentage
Less than 1 year	97	57.1
2-5 years	19	11.2
6-10 years	12	7.1
11-15 years	7	4.1
16-20 years	8	4.7
21-25 years	5	2.9
26-30 years	4	2.4
more than 30 years	2	1.2
No Professional Training	16	9.4
TOTAL	**170**	**100.0**

Source: Field Survey, November 2015.

Professional training has been noted to be an important risk mitigation measure in the transportation of hazardous materials (Kara and Verter, 2004; Erkut, Tjandra and Verter, 2007). Consequently, this method has been used extensively in Ghana as a risk reduction measure as evident in Table 4.2.5. Truck operators who have had professional training less than a year formed 57.1% while 9.4% have never had any professional training. The remaining 33.5% have had some form of professional training in periods varying between the last 2 and 30 years. The implications from this are that there is likely to be minimal accidents associated with hazardous material trucks, if at all because of the training provided to truck operators by their respective Transport Service Providers [TSPs], The TSPs are large or medium sized firms that own the trucks being used and employ drivers or truck operators to transport products on their behalf.

Interviews with truck operators and the Bulk Oil Storage and Transportation [BOST] Company Limited revealed that the professional training organized for truck operators was provided by Transport Service Providers [TSPs], and these were centered largely on road safety as well as product safety. These findings are consistent with those by Kuncyté *et al.* (2003) who contended that professional training of truck operators should be the responsibility of their employers, thus the TSPs. Some key issues that are usually considered during training sessions include accident management, defensive driving, how to safely discharge products, dress codes or appropriate gear to use, controlling driving hours, speed limits as well as road sign interpretation. Interviews with the truck operators revealed that although professional training was necessary some TSPs did not offer them such training opportunities, especially the small scale individually owned ones. In spite of this, it was maintained that the larger TSPs, including Total and Goil, provided some professional training for truck operators on a regular basis, at least every quarter. Other medium scale TSPs such as TT Brothers, JK Horgle, Ahiadome, Kodson, Legacy and Okodatt also provide some professional training for their truck operators albeit at irregular intervals.

The truck operators affirmed that during training sessions, experts such as safety officers from the Ghana National Fire Service [GNFS], Bulk Oil Storage and Transportation [BOST] Company Limited, The National Petroleum Authority [NPA] as well as health practitioners such as neurosurgeons are invited to educate them. They are educated on appropriate gear (boots) to use during transportation and discharge (the use of nose masks, goggles, helmets and hand gloves). In addition, truck operators are educated on planning their journeys and driving habits, especially mandatory rest after every four hours of continuous driving with or without products. The Hours of Service or mandatory rest period of 4 hours is a worldwide best practice (Berman, Verter and Kara, 2007; Jensen and Dahl, 2009). The benefits of this mandatory rest can be maximized more when there is appropriate infrastructure such as truck parks in place for truckers in general, and hazardous material truck operators in particular. Heaton (2005) has argued that necessary conditions must be in place for truckers to break their journeys to sleep and rest.

Table 4.2.6: Educational Attainment and Professional Training of Hazardous Material Truck Operators along the Tema – Accra – Kumasi Highway

Level of education attained	**Professional Training in Handling Hazardous materialss**					**Column %**
	"Yes"	**Column %**	**"No"**	**Column %**	**Total**	
Never	9	5.8%	2	12.5%	11	6.5%
Primary	35	22.7%	3	18.8%	38	22.4%
Junior High School	81	52.6%	6	37.5%	87	51.2%
Senior High School	25	16.2%	5	31.3%	30	17.6%
O/A Level	3	1.9%	0	0.0%	3	1.8%
Middle School	1	0.6%	0	0.0%	1	0.6%
Total	**154**	**100.0%**	**16**	**100.0%**	**170**	**100.0%**

Source: Field Survey, November 2015.

From Table 4.2.6, it can be seen that contrary to popular perceptions held about some truck operators being illiterate, majority (51.2%) of truck operators have attained, at least, Junior High School with only 6.5% not having had any formal education. This gives an indication that they will be able to read, write and communicate effectively in Basic English language and arithmetic, hence, they can provide safe and efficient haulage services for Transport Service Providers in the hazardous materials industry. This notwithstanding, (2 out of 16, representing 12.5%), truck operators who have not had any professional training were also found not to have had any formal education and this provides a course for worry. According to studies by Kara and Verter (2004) and Erkut, Tjandra and Verter (2007), these truck operators who have had neither formal education nor professional training stand higher risks of accidents compared with those that have attained either formal education or professional training.

Following an introductory background information on truck operators, it will be useful to ascertain the characteristics of products transported and then follow that with operational characteristics. However, the next section looks at the vehicles used in the process of transporting hazardous materials in greater detail following which the product and operational characteristics are discussed.

4.2.4 Education, Professional Training and Level of Involvement in Accidents

Common knowledge suggests that accidents involving vehicles, particularly those used in transporting freight are linked to level of education of truck operators as well as their professional training. Indeed, Kara and Verter (2004) and Erkut, Tjandra and Verter (2007) have found that truck operators with relatively lower or neither formal education nor professional training are more likely to suffer accidents as compared to educated counterparts. Findings from the study indicate that on Tema – Accra – Kumasi corridor accidents involving hazardous materials do not occur only for those without professional training. Rather, what is observed is that though truck operators who had professional training were involved in many accidents compared to those who had professioanl training, these operators with professional training were involved in fewer number of accidents in the last ten years as is shown in Table 4.27. About 50% of the truck operators who have not had any professional training were involved in 3 accidents as against 0% for those truck operators that have had professional training.

Table 4.2.7: Professional Training and Accidents Involvement Among Hazardous Material Truck Operators

Professional Training	**Number of times involved in hazardous material accident in the last 10 years**				**Total**
	None	1	2	3	
Had professional training	132	17	5	0	**154**
Did not have professional training	12	2	1	1	**16**
Total	**144**	**19**	**6**	**1**	**170**

Source: Field Survey, November 2015.

4.3 Characteristics of Vehicles Used in Transporting Hazardous Materials

In order to assess whether truck operators use vehicles in accordance with national regulations on axle loads and suitability of vehicle to transport a particular product, this section of the study presents results and discussions on the characteristics of vehicles used in transporting hazardous materials on highways in Ghana, particularly the Tema – Accra – Kumasi highway. These are treated in the ensuing sections of the study.

4.3.1 Type of Vehicles Used

Results from the survey show that various freight transportation vehicles were used on the Tema – Accra – Kumasi highway. However, light trucks did not feature in the sample. This may be due to the relatively small capacity in terms of size and volume of goods they can carry. Results are summarized in Table 4.3.1.

Table 4.3.1: Major Truck Types used in Transporting Hazardous Materials

Truck Type	**Frequency**	**Percentage**
Medium Trucks	8	4.7
Heavy Trucks	6	3.5
3-Axle S/Trailers	6	3.5
4-Axle S/Trailers	7	4.1
5-Axle Trucks	14	8.2
6-Axle Trucks	129	75.9
Total	**170**	**100.0**

Source: Field Survey, November 2015.

From Table 4.3.1, it is observed that 5-axle and 6-axle trucks were the main types or configuration of vehicles used in transporting hazardous materials along the Tema – Accra – Kumasi highway. Medium and heavy trucks were not predominantly used, possibly because of their smaller capacity and designed use, which is mostly for internal distribution and shipment of consumable commercial products. The dominance of the 5-axle and 6-axle trucks, 8.2% and 75.9% respectively, could be as a result of the fact that transporters shipped in larger quantities as either a cost effectiveness or as a risk reduction measure (Hazardous Materials Cooperative Research Program [HMCRP], 2009; Guo and Verma, 2010). Guo and Verma (2010) have maintained that using Larger Capacity Vehicles [LCVs] has a tendency to reduce the number of shipments and the likely risks people, environment and property are exposed to.

In line with the stance of BOST Company Limited to transport using approximately 60 trucks daily, it is the Larger Capacity Vehicles [LCVs] that were most appropriate to do so. However, because some trucks were feeding fuel filling stations directly with relatively smaller volumes of petroleum products a few smaller capacity vehicles were also used in transportation of the hazardous materials. Damnatory

Some studies, including Darbra and Casal (2004), have shown that almost half (51%) of hazardous material accidents were releases caused by either container ruptures or rollover of trucks. The susceptibility of trucks to rollover is linked with the configuration of truck because roll over is less likely for trucks with more axles compared to trucks with fewer number of axles. For example, in the early hours of Wednesday March 9, 2016, an LPG gas tanker was involved in a rollover at Tetegu

Junction of the Kasoa-Mallam road. A cursory look at the scene and the vehicle involved showed it was a medium truck (see Plate 4.3.1). Given that in the current study, approximately 83% of trucks used in transporting hazardous materials are 5axle and 6-axle trucks, implications are that there will potentially be a reduced number of release accidents. This notwithstanding, the number of axles or vehicle configuration in itself alone may not be a sure determinant of susceptibility to accidents but may be related to some other factors such as age and level of experience of truck operators.

It has also been established that truck operators ability to handle LCVs is related to their age and level of experience (US Department of Transportation, FMCSA, 2005). The following section examines the relationship between age and level of experience of truck operators and the type of vehicle they operated.

Plate 4.3.1: LPG tanker overturns on the Kasoa road.

Source: myjoyonline.com

4.3.2 Configuration of Trucks, Age and Level of Experience of Truck Operators

As has been noted by the US Department of Transportation, FMCSA (2005), age and level of experience of truck operators could be linked with accidents recorded as well as the type of vehicle used. This section of the study examines in close detail the relationship between these variables as they apply to truck operators plying the Tema – Accra – Kumasi highway. Results of the survey are presented in tables.

Table 4.3.2: Distribution of Truck Operators' Ages and Configuration of Vehicles they Operated

Age of Truck Operators (years)	Configuration of Vehicle						Total
	Medium Trucks	Heavy Truck	3-Axle S/Trailer	4-Axle S/Trailer	5-Axle Truck	6-Axle Truck	
21-25	0	1	1	0	0	5	7
25-30	1	0	0	1	2	18	22
31-35	3	1	0	0	4	29	37
36-40	0	3	3	1	0	18	25
41-45	2	1	2	3	5	18	31
46-50	1	0	0	1	2	24	28
51-55	1	0	0	1	0	11	13
56-60	0	0	0	0	1	5	6
more than 60	0	0	0	0	0	1	1
Total	**8**	**6**	**6**	**7**	**14**	**129**	**170**

Source: Field Survey, November 2015.

It is expected that the older a truck operator is the higher his level of experience and consequently his ability to handle Larger Capacity Vehicles [LCVs]. This was assessed on the Tema – Accra – Kumasi corridor. From Table 4.3.2, it can be seen that there exists no clearly distinguishing pattern in the age of truck operators and the configuration of vehicle they operated. Rather it came out that irrespective of the age of a truck operator they handle any type of vehicle configuration contrary to the position of the US Department of Transportation, FMCSA (2005). This may be associated partly with the professional training provided for the truck operators before they are licensed to operate such trucks.

4.3.3 Age and Condition of Trucks

In this section of the study, attention is paid to the ages of vehicles used and their condition. The age of a vehicle as well as condition have been noted to be important features in assessing suitability of trucks used in transporting hazardous materials especially on highways. With older trucks, there are likely to be more mechanical defects such as leakage at the valves, corrosion, overheating and a general fatigue associated with wear and tear of some parts. This may not be the case for newer trucks as they might have fewer mechanical defects compared to older ones. In addition, these defects with vehicles may be corrected through frequent maintenance of the vehicles and replacement of worn out parts. These characteristics are the subject of this section of the study.

On the Tema – Accra – Kumasi corridor, it is observed that the ages of trucks used in transporting hazardous materials range from less than five (5) years to between 26 and 30 years. Results from the field study are presented in Table 4.3.3. It can be seen that a clear pattern is presented where 78.2% and 17.1% of trucks representing those aged less than six years and between 6 – 10 years respectively were predominantly used on the corridor. Those trucks that are aged between 11 and 30 years represent a combined proportion of 4.7%. On the surface of these results, a good impression is created about the safety implications on the roads as more than 95% of trucks used in transporting hazardous materials are less than 10 years old.

From the interviews with the Bulk Oil Storage and Transportation [BOST] Company Limited, key stakeholders in the transportation of petroleum products across the country, they revealed that it was their policy to use only vehicles that are not older than 10 years of age. The results in Table 4.3.4 give a good indication that the Transport Service Providers [TSPs] are complying largely with policy objective of BOST. However, in view of the fact that some trucks were not transporting petroleum products for BOST to the strategic storage depots in Kumasi and Buipe but were actually serving fuel filling stations both within and outside Kumasi directly with products, it would have been expected that those trucks aged more than 10 years were those being used for other hazardous materials (see, Table 4.3.3). On the contrary, the trucks aged more than 10 years were all being used to transport petroleum products. This poses threats or risks of leakage and potential release of hazardous materials into the populace and the environment. In the unfortunate release of these petroleum products there is likely to be fire and damage to the road pavements resulting in pressure on already scarce road maintenance resources.

Table 4.3.3: Age of Truck and Type of Products Transported.

Age of Truck (years)	Type of Product							Total
	Petrol	Diesel	Kerosene	LPG	Chem-icals	Petrol and Diesel	Petrol, Diesel and Kerosene	
Below 6	45	21	4	1	7	53	2	133
6-10	7	5	2	0	2	13	0	29
11-15	1	1	0	0	0	1	1	4
16-20	2	0	0	0	0	0	0	2
21-25	1	0	0	0	0	0	0	1

26-30	0	0	0	0	0	1	0	1
Total	**56**	**27**	**6**	**1**	**9**	**68**	**3**	**170**

Source: Field Survey, November 2015.

For a fact that these old trucks are being used to transport petroleum products suggests the existence of some level of non-compliance to BOST directives among truck operators. This may be due to a rather relaxed system of ensuring compliance with policy directives and poor attitude from truck operators. The truck operators indicated that before they were given clearance by the National Petroleum Authority to operate; their trucks are assessed through a number of checks to ensure that the trucks were deemed “fit” to be used in transporting hazardous materials. The level of compliance is 100% for petroleum tanker operators as a result of strict regulations by the NPA and BOST.

Notwithstanding the ages of trucks used in transporting the hazardous products on highways there is the need to take a look at the condition of these trucks. Study results in Table 4.3.4 indicate that 81.2% of trucks are in “good” condition whereas the remaining 18.8% are in “fair” condition. Also worthy of note is that 8.8% and 8.2%, representing trucks aged less than 6 years and those between 6 to 10 years respectively, of total trucks involved in the survey were in fair condition. Considering that these trucks are relatively newer (aged less than 10 years), one would expect that they will be in good condition, however, this is not the case. This may be attributed to lack of proper maintenance on the part of operators considering that they are relatively newer trucks and are expected to be in good condition. There needs to be effective maintenance to ensure that trucks are kept in good shape to safely transport products on the roads in Ghana.

Table 4.3.4: Ages and Condition of Hazardous materials Trucks along the Tema – Accra – Kumasi Corridor

Age of Truck (years)	**Condition of Truck**				**Total**	**Percentage**
	“Good”	**%**	**“Fair”**	**%**		
less than 6	118	69.4%	15	8.8%	133	78.2%
6-10	15	8.8%	14	8.2%	29	17.1%
11-15	4	2.4%	0	0.0%	4	2.4%
16-20	1	0.6%	1	0.6%	2	1.2%
21-25	0	0.0%	1	0.6%	1	0.6%

26-30	0	0.0%	1	0.6%	1	0.6%
Total	**138**	**81.2%**	**32**	**18.8%**	**170**	**100.0%**

Source: Field Survey, November 2015.

Having a high proportion (81.2%) of the hazardous freight vehicles in a good condition implies lower likelihood of accidents resulting from the vehicle. Studies by Zhao, Wang and Qian (2012) and Sivaprakash, Joseph and Satheeswaran (2015) have shown that mechanical failures on the part of vehicles were a root cause of accidents. However, in this current study, the proportion of vehicles that are in good condition far outweighs those in fair condition. This presupposes that accidents involving hazardous material trucks may not come about as a result of mechanical failures; all else being equal. But there must be some little level of apprehension given that close to a fifth (18.8%) of all trucks are in fair condition which may deteriorate if not well maintained. The condition of trucks and maintenance activities as they pertain to trucks on the Tema – Accra – Kumasi corridor are discussed in the subsequent section of the study.

The HMCRP (2009) has shown that vehicle configuration plays a critical role when it comes to accidents involving freight vehicles particularly hazardous freight. On the Tema – Accra – Kumasi corridor it was found that accidents occurred across all vehicle configurations. However, it was observed that the phenomenon was rampant among the 6 – axle trucks as can be seen in Table 4.3.5. This could be because of the sheer numbers of these 6- axle trucks compared to the other vehicle configurations as was indicated earlier

Table 4.3.5: Number of Hazardous Material Accidents by Vehicle Configuration on the Tema – Accra – Kumasi Corridor

Vehicle Configuration	**Number of accidents in the last 10 years**				**Total**
	None	1	2	3	
Medium Trucks	7	0	1	0	**8**
Heavy Trucks	5	1	0	0	**6**
3-Axle S/Trailers	5	0	1	0	**6**
4-Axle S/Trailers	4	3	0	0	**7**
5-Axle Trucks	9	5	0	0	**14**
6-Axle Trucks	114	10	4	1	**129**
Total	**144**	**19**	**6**	**1**	**170**

Source: Field Survey, November 2015.

4.3.4 Condition of Trucks and Maintenance

Trucks are mere machines used in transporting products from origins to desired destinations. The trucks are composed of metal and rubber parts that are constantly affected negatively due to wear and tear during operation. For this and other reasons, trucks need to be maintained to ensure that they are in good condition to be used in transporting products safely. Maintenance activities include inspection, cleaning, adjusting, testing, lubrication and replacing worn out parts of the truck. The condition of a truck is affected by the frequency of truck maintenance. A truck that is in good condition might not undertake frequent maintenance as a frequently maintained truck is expected to be in good condition. When a truck is not in good condition it poses threat to public safety because it is likely to be involved in accident with the effect of severe consequences. The Hazardous Materials Cooperative Research Program (2009) has argued that vehicular defects were a root cause of hazardous materials accidents. This phenomenon is related to the condition of truck and maintenance culture adopted by truck operators. The condition and frequency of maintenance of trucks transporting hazardous materials along the Tema – Accra – Kumasi highway are presented in Table 4.3.6 subsequently.

Table 4.3.6: Distribution of Truck Ages and Frequency of Mainatenance

Age of Truck (years)	**Frequency of Maintenance**						**Total**
	After every trip	**Every month**	**Every quarter**	**Every 6 months**	**Yearly**	**Other**	
Less than 6	54	33	19	13	0	14	133
6-10	8	11	4	4	1	1	29
11-15	1	1	1	0	0	1	4
16-20	1	0	1	0	0	0	2
21-25	0	0	0	1	0	0	1
26-30	0	0	0	1	0	0	1
Total	**64**	**45**	**25**	**19**	**1**	**16**	**170**
Percentage	**37.6%**	**26.5%**	**14.7%**	**11.2%**	**0.6%**	**9.4%**	**100.0%**

Source: Field Survey, November 2015.

It is evident from Table 4.3.6 that all trucks are maintained on regular bases. The maintenance of trucks is carried out on monthly (26.5%), quarterly (14.7%), biannually (11.2%) or annually (0.6%). In addition, other truck operators reported to undertake maintenance after every trip (37.6%) and after every 10,000km travelled. Some 9.4%

of truck operators reported they carried out maintenance after every 10,000km travelled and this distance was usually covered in a period of three months. These findings are contrary to that by Maunder and Pearce (2001) who reported that few truck operators followed scheduled maintenance in Ghana. Maunder and Pearce (2001) also found that most truck operators in Ghana resorted to private wayside garages and only a few had their own garages. However, in this study virtually all truck operators undertook maintenance of their trucks and have their own garages, referred to as "yards" provided by their respective Transport Service Providers.

The results show that relatively newer trucks, those less than 10 years, are maintained after every trip or monthly. This frequency of maintenance indicates that those trucks will be in good condition to safely transport hazardous materials without any accidents associated with the vehicles.

4.3.5 Packaging and Labelling of Trucks

In ensuring public safety during the transportation of hazardous products trucks are supposed to be packaged and labelled appropriately. In Ghana, the Road Traffic Act - 2004 (Act 683) prohibits any person from transporting hazardous materials by road without ensuring that the outermost package of the products is labelled appropriately with the composition of the goods. This is done to safeguard public safety and emergency response in times of accident. Packaging has been observed to be a cause of accidents involving hazardous materials (Oggero *et al.*, 2006; Hazardous Materials Cooperative Research Program, 2009) and needs to assessed.

Table 4.3.7: Distributuion of Type of Packaging Material Used by Product Type

Type of Product	**Type of Packaging Material**				**TOTAL**
	Carton/Boxes	**Tanker**	**Container**	**Other**	
Petrol	3	53	0	0	56
Diesel	0	27	0	0	27
Kerosene	0	6	0	0	6
LPG	0	1	0	0	1
Chemicals	0	0	6	3	9
Petrol and Diesel	0	68	0	0	68
Petrol, Diesel and Kerosene	0	3	0	0	3
TOTAL	3	158	6	3	170
Percentage	**1.8%**	**92.9%**	**3.5%**	**1.8%**	**100.0%**

Source: Field Survey, November 2015.

From the surveys, it was realized that the main type of packaging materials used were tankers or bulk container, twenty-footer containers, boxes and others. Others refer to sacks that are used to transport sodium hydroxide flakes (caustic soda). The cartons/boxes were used in packaging lubricants. The findings show that appropriate packaging are used by truck operators and this has the tendency of preventing hazardous materials accidents as was found by Roy (2008). Considering that tankers form the largest proportion of packaging materials used in transporting hazardous materials, there are implications on the safety of trucks. The truck operators maintained that before a truck is loaded with petroleum products, the tanks or bulk containers are inspected by safety officers to ensure they are devoid of any ruptures and hence can be used to safely transport materials from loading points or origins to the destination or points of discharge. Where there are any defects with the packaging material, operators are not allowed to load products. Indications are that any accident involving hazardous materials is not likely to result from ruptures or any other defects from packaging materials.

Packaging materials used in transporting hazardous materials need a lot of attention. The safety of products as well as human populations depends to some extent on the integrity of packaging materials. When packaging materials are worn out or have any defects there is high tendency that products may be released into the environment or exposed to human population putting them at high risk levels. In this study, as can be seen from Table 4.3.7, a large chunk (92.9%) of packaging materials are tankers or bulk containers used to transport petroleum products. Considering that these bulk containers or tankers are used to transport petroleum products, it is expected that these packaging materials are aged less than 10 years as is the policy of the Bulk Oil Storage and Transportation [BOST] Company Limited. As depicted in Table 4.3.7, majority (96.5%) of packaging materials are aged less than 10 years and therefore expected to be of good integrity. This compliance with BOST policy is enhanced by the operations of the National Petroleum Authority in which vehicles are inspected on a regular basis following which those deemed fit are issued with NPA stickers displayed on the windshield.

Table 4.3.8: Age of Packaging Materials used in Transporting Hazardous Materials

Age of Packaging Material	**Frequency**	**Percentage**
Less than 1 year	32	18.8%
1-2 years	37	21.8%

2-5 years	68	40.0%
5-10 years	27	15.9%
10+ years	6	3.5%
Total	**170**	**100**

Source: Field Survey, November 2015.

With regards to labelling of trucks, it was realized that 2.9% of trucks transporting hazardous materials were not labelled whereas the remaining 97.1% were labelled with appropriate labels. However, the location of labels on trucks varied according to the type of product being transported as is captured in Table 4.3.9. The Road Traffic Act - 2004 (Act 683) proposes that trucks transporting hazardous materials are labelled on three sides; rear, left and right sides.

Table 4.3.9: Distribution of Location of Labels on Trucks by the Type of Product

Type of Product	**Location of Label**					**TOTAL**
	None	**Rear**	**Right**	**Left**	**Rear, Left and Right**	
Petrol	2	23	1	0	30	56
Diesel	0	8	0	0	19	27
Kerosene	0	3	0	0	3	6
LPG	0	0	0	0	1	1
Chemicals	2	3	0	1	3	9
Petrol and Diesel	1	5	0	0	62	68
Petrol, Diesel and Kerosene	0	0	0	0	3	3
TOTAL	**5**	**42**	**1**	**1**	**121**	**170**
Percentage	**2.9%**	**24.7%**	**0.6%**	**0.6%**	**71.2%**	**100.0%**

Source: Field Survey, November 2015.

From Table 4.3.9 it is evident that 97.1% of trucks had some form of label displayed on at least one side of the truck (see, Plate 4.3.1). This gives a good impression and presents a scenario where impacted population may be cautioned by the labels displayed on such trucks. This notwithstanding, 2.9% of trucks used in transporting hazardous materials were not labelled amounting to a contravention of Section 85 of the Road Traffic Act - 2004 (Act 683). Without these labels people will not be better placed to deal with any accidents involving such products since the labels provide a source of useful information on the products being transported. It would be observed that hazardous materials trucks which were not labelled were used in transporting petroleum products as well as caustic soda (sodium hydroxide). Because of the harmful nature of these products, actions to be taken by impacted population in the event of release or exposure need to be displayed on labels. However, in the absense of these labels the impacted population become very vulnerable and may be affected adversely and gravely.

Labels displayed on the trucks showed the particular type of hazardous material that is being transported in addition to the internationally accepted UN hazardous material classification. In addition to the foregoing, petroleum transporting trucks had the following inscriptions on the packaging material “highly flammable” , “no smoking” as well as some emergency phone numbers to call in the event of any accident involving hazardous material. It was also found that 6.5% of trucks were fitted with labels that were considered as not durable. The labels on these trucks were faded and could not be easily detected and read. Having labels that are faded is akin to not having them at all and these trucks pose the same level of risks as those that did not have any labels as have been discussed foregoing.

Plate 4.3.2: Hazarous material trucks displaying labels Source:

Field Survey, November 2015.

4.4 Characteristics of Products Transported

The preceding section dealt with a general background information on truck drivers. Specifically, it examined the ages of truck operators, their levels of experience as well as educational attainment. In addition, characteristics of vehicles used were presented in Section 4.3. Following this background information, it is time now to delve into the products that are being transported and characteristics of vehicles used in the process.

To understand the state of transporting hazardous materials on highways in Ghana, it is relevant to know which particular types of hazardous materials are transported, the volumes that are shipped on daily, weekly or monthly bases as well as origins and destinations among other things. This section of the study is, therefore, dedicated to these characteristics.

4.4.1 Main Hazardous Materials Transported

There are a great number of materials treated as being hazardous. These have been classified under the following broad classes with examples by the US Department of Transport (2004) as follows:

1– Explosives (dynamite, caps);

2– Gases (propane, anhydrous ammonia, chlorine, oxygen);

3– Flammable Liquids (gasoline, oil, tars, diesel, kerosene);

4– Flammable Solids (plastics, asphalt shingles);

5– Oxidizing Substances (peroxides);

6– Poisonous and infectious substances (herbicides, pesticide);

7– Radioactive materials;

8– Corrosives (acids); and

9– Miscellaneous (Polychlorinated Biphenyls [PCBs], dangerous wastes).

In the current study some specific hazardous materials have been selected including agro-chemicals (Hazardous materials Class 6), chemicals used in the mines (Hazardous materials Class 1) and petroleum products (Hazardous materials Class 3). The results of the surveys show that petroleum products are the main hazardous materials transported on a daily basis using the Tema – Accra – Kumasi highway. While other materials such as chemicals are also being transported to the mines, they are in smaller quantities compared to petroleum products. The various materials transported are summarized in Table 4.4.1.

Table 4.4.1: Hazardous Materials Transported on the Tema – Accra – Kumasi highway.

Product	**Number of Vehicles**	**Percentage**
Petrol	56	32.9
Diesel	27	15.9
Kerosene	6	3.5
LPG	1	0.6
Chemicals	9	5.3

Petrol and Diesel**	68	40.0
Petrol, Diesel and Kerosene**	3	1.8
Total	**170**	**100.0**

Source: Field Survey, November 2015.

** These are not combinations in a single shipment but different products transported on different trips using the same vehicle

It will be observed from Table 4.4.1 that, with the exception of chemicals and to some extent LPG, all other materials are essentially petroleum products which could have been treated as one component but for purposes of clarity they have been separated. It was realized from the surveys that some truck operators transported only one specific or dedicated petroleum product such as diesel, petrol or kerosene. Other truck operators transport any of the petroleum products depending on the availability and demand for such products. For example, a truck operator may transport diesel on one trip and petrol on another trip depending upon demand for such product. However, there was no incidence of two different products being transported by the same truck at the same time.

From the surveys, it was realized that Liquefied Petroleum Gas [LPG], did not feature much along the corridor. Though there were a number of LPG transporting trucks, they were mostly from neighbouring Sahelian countries: Burkina Faso, Mali and Niger, and had French speaking operators who could not understand English language. Due to language barrier, data from these drivers were not captured. In view of this shortcoming, an attempt was made to speak to one LPG Filling Station to enquire about how their products were transported to the station. The LPG Filling Station attendants maintained that the LPG was brought in with specialized and dedicated trucks.

As can be seen from Table 4.4.1, petroleum products, consisting of mainly petrol, diesel and kerosene, are the main hazardous materials that are transported along the Tema – Accra – Kumasi highway. This was expected because of daily shipments made by BOST to store fuel at the Strategic Storage Depot at Kaase, in Kumasi. Another category that featured in the study was chemicals, mostly cyanide, which is transported to the mines both locally, to Obuasi mines, and internationally across the border to mines in the Sahelian neighbouring countries, especially Burkina Faso. As Aini *et al.* (2001) have argued, hazardous materials are not in themselves finished products but are required for production of other products, the current survey also found that the main hazardous materials being transported are actually to be used in the production of other goods. For example, the cyanide is used in the mines to separate gold from other particles and petroleum products are also transported either directly to service stations or to the strategic storage tank farm at Kaase in Kumasi for further distribution to the northern and middle zones of the country for industrial, commercial and domestic use.

Given that petroleum products constitute the main hazardous materials transported between Tema/Accra and Kumasi, it appears that using other modes such as the railway, pipelines or water transport would have been more cost effective and environmentally friendly. Interestingly, the case in Ghana is different. Similar studies, such as that by Elaldi (2011), have also shown that road transport or truck shipments constitute the most widely used mode of transport. In spite of the dominance of road transportation of freight studies including those by Berkeley (2005); Bauer, Bektaş and Crainic (2010); Janic and Vleugel (2012); as well as Hanssen, Mathisen and Jørgensen (2012) have demonstrated the use of rail reduces greenhouse gas emissions into the environment, thus, reducing the undesirable consequence of global warming. In addition, other externalities including energy consumption, noise, congestion and traffic incidents/accidents are reduced. Data from the Bulk Oil Storage and Transportation [BOST] Company Limited indicated that about 2.5 million litres of petroleum products are shipped to Kumasi and Buipe depots on a daily basis by road. This amounts to about 60 Bulk Road Vehicles [BRVs] or tanker trucks transporting an average of between 45,000 litres to 50,000 litres daily.

The use of pipelines in transporting petroleum products is not predominant in Ghana. In the past, pipelines were used to transport petroleum products between Accra Plains Depot (APD), in Tema and Maame Water Depot at Akosombo. However, the service is defunct at the moment and only the newly re-commissioned Buipe to Bolgatanga pipelines are functioning (Ghana News Agency, 2015). In addition, BOST transports petroleum products on the Volta Lake using barges that travel between Akosombo and Buipe Ports. Figure 4.4.1 shows the various modes of transport currently adopted by BOST to transport petroleum products as well as their respective storage capacities.

In addition, interviews with Sidalco Ghana Limited, producers of agro chemicals, suggest that approximately 200,000 tonnes of agro chemicals are transported by road from the production center in Tema to Kumasi and areas beyond it annually. Similarly, Air Liquide Ghana Ltd, whose products range from medical to industrial gases including oxygen, hydrogen, carbon dioxide, ammonia, helium, nitrogen, acetylene and other gases also transport all their products by road from the production center in Tema. Considering that major hazardous materials transported in Ghana are liquid petroleum products and LPG the use of pipeline appears more economical or cost effective and environmentally friendly.

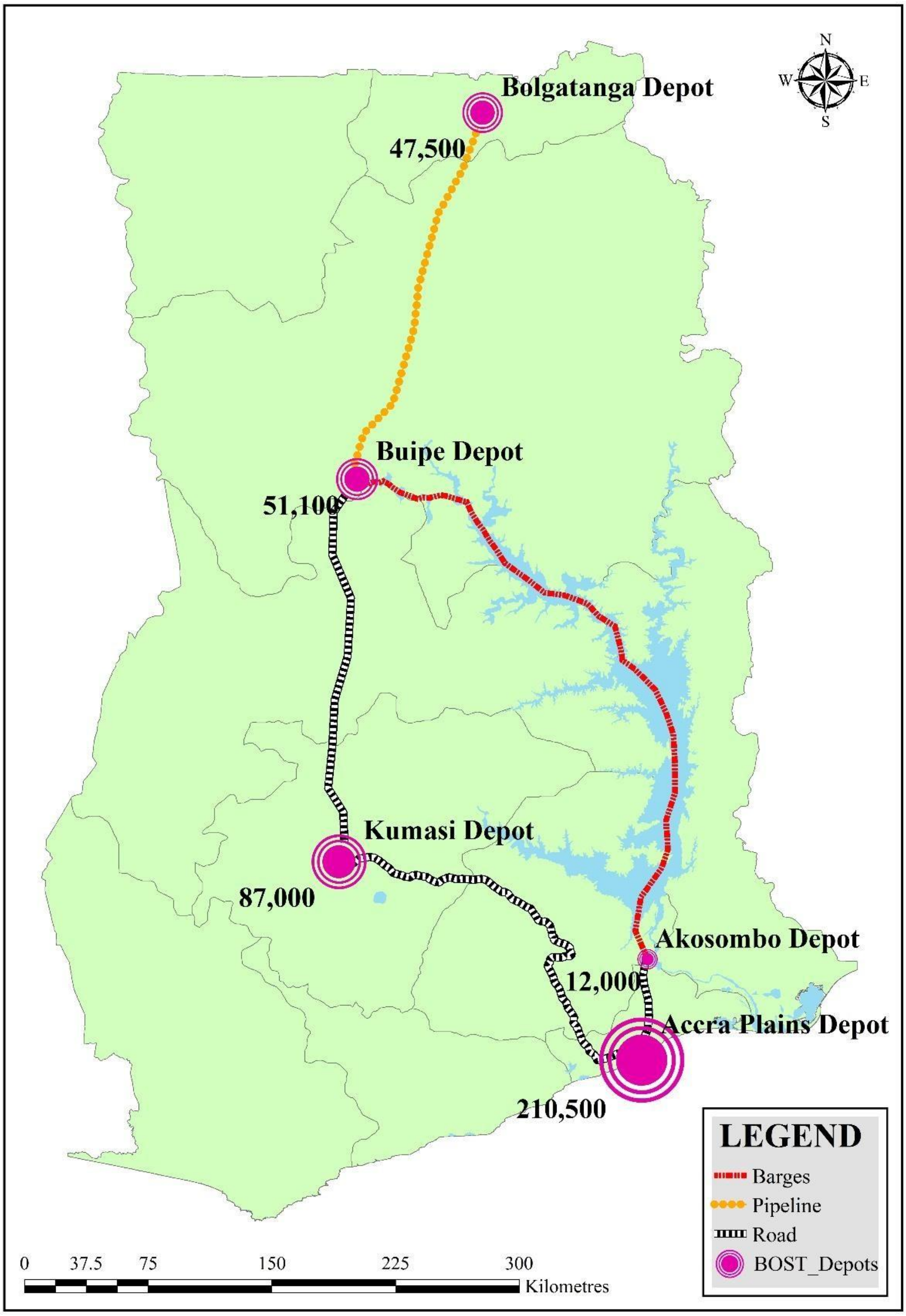


Figure 4.4.1: BOST Strategic Storage Depots and Capacities.
Source: Author’s Construct.

4.4.2 Volumes/Quantities of Hazardous Materials Transported

The volumes of hazardous materials transported along a particular route on a daily or weekly bases has a bearing on the risk levels of populations living within risk zones on such route hence the need to assess these volumes. The results are presented in Table 4.4.2 along the major product lines for ease of interpretation because all of them are not measured in a common unit. However, these volumes have been converted to standardized weights (in tonnes) for comparison with axle load regulations in Ghana.

Table 4.4.2: Distribution of Hazardous materials type by Volumes transported on the Tema – Accra – Kumasi Highway.

Product Type	Volume	Weight (tonnes)	Frequency	Percentage
Chemicals	20 Sacks*	1	1	0.6
	16 Tonnes	16	1	0.6
	20 Tonnes	20	1	0.6
	22.5 Tonnes	22.5	3	1.8
	40 Tonnes	40	2	1.2
	90 Sacks*	4.5	1	0.6
LPG	13,500 litres	6.9	1	0.6
Petroleum Products	13,500 litres	10.0	13	8.2
	18,000 litres	13.3	2	1.2
	27,000 litres	19.9	6	3.5
	36,000 litres	26.5	11	6.5
	40,500 litres	29.9	3	1.8
	45,000 litres	33	68	40.0
	50,000 litres	36.9	42	24.7
	55,000 litres	40.5	14	8.2
Total			170	100.0

Source: Field Survey, November 2015.

* 50 kg per bag

Table 4.4.2 shows the volumes of hazardous materials transported by the type of product. It can be seen from this table that the volume of petroleum products, transported in Bulk Road Vehicles [BRVs], range from 13,500 litres to 55,000 litres whereas LPG was 13,500 litres. Chemicals, as captured in Table 4.4.2, comprise cyanide which was transported to the mines in Obuasi and Burkina Faso.

Discussions with the National Petroleum Authority [NPA] revealed that Bulk Road Vehicles [BRVs] have been calibrated to transport up to a maximum of 60,000 litres. However, the truck operators maintained that due to operational inefficiencies such as difficulty in handling vehicles and challenges during discharge of oil, they do not load products to maximum capacity and this is reflected in average volumes of petroleum products transported (see, Table 4.4.2).

The maximum volume of petroleum products transported, 55,000 litres is equivalent to 40.5 tonnes which is lower than permissible total axle load limit of 41.5 tonnes excluding the vehicle itself (Ghana Highway Authority, 2015). These volume of petroleum products are transported using mainly 6-axle trucks and current axle load regulations permit a maximum of 10 tonnes per axle including the weight of the truck itself; suggesting that there is no overloading on the part of hazardous material transporting trucks. Recent data from the MRH, MoT and GSS (2012) reveal that between 2009 and 2010, number of overloaded vehicles intercepted were 14,538 out of a total 71,148 weighed, representing 20%. This shows a 5% increase in proportion of overloaded vehicles from 15% in the year 2009. There appeared to be an increase in proportion of overloaded vehicles implying that the challenge of overloading could have been institutionalised or that axle load regulations were not yielding desired results. From the current survey, there were no overloaded hazardous material trucks. To a large extent, this phenomenon could be as a result of volume calibrations as well as the regulated nature of their operations.

In addition to the foregoing, it is noteworthy that, though other Bulk Road Vehicles can transport products in smaller quantities, the truck operators on the Tema – Accra – Kumasi route are largely transporters of Bulk Oil Storage and Transportation [BOST] Company Limited, who transport in larger volumes (see Table 4.4.2). They transport products from the discharge or entry point, Accra Plains Depot [APD] at Kpone, near Tema either by road, water (in barges) and pipelines to other depots located at Kaase in Kumasi, Akosombo, Bolgatanga and Buipe in the Northern region. Following this, smaller tanker trucks are used to service fuel filling stations in the metropolis and areas beyond it. From the surveys, however, a few low capacity trucks were identified.

About 73% of all hazardous materials are being transported in large volumes; that is, between 45,000 litres and 55,000 litres. This finding is consistent with the Hazardous Materials Cooperative Research Program [HMCRP] (2009) and Guo and Verma's (2010) findings when they argued that shipment of larger quantities in fewer trips reduces risk of hazardous materials accidents. In a sense, when large capacity trucks are used in transporting hazardous materials there are fewer shipments and given that hazardous materials incidents are generally low, these relatively fewer shipments will imply a reduced probability of accidents. The use of larger capacity vehicles do not imply overloading as these volumes are within permissible axle load limits. Table 4.4.3 summarizes potential number of daily shipments that could be made using the various vehicle capacities, revealing an inverse relationship between the vehicle capacity and the number of daily shipments, where it is observed that as vehicle capacity increases the number of likely trips to be made in a day reduces. As stated earlier, using larger vehicles in fewer shipments does not connote overloading on the part of hazardous material transporters.

Table 4.4.3: Number of Truck Shipments Required to meet Daily Demand

Vehicle Capacity (Litres)	**Total Daily Demand (Litres)**	**Number of Daily Shipments**
13,500	2,500,000	185
18,500	2,500,000	135
27,000	2,500,000	93
40,500	2,500,000	62
45,000	2,500,000	56
50,000	2,500,000	50

Source: Author's Construct, 2015.

As seen from Table 4.4.3, it will be noted that there is a clear discernible pattern in which the number of trucks required to transport the products reduces as vehicle capacity is increased and vice versa. When smaller vehicles with a capacity of 13,500 litres are used there are 185 shipments of petroleum products a day between Tema and Kumasi, potentially resulting in risks of hazardous materials in that same magnitude. Again, if larger capacity vehicles, say 50,000 litres, are used a minimum number of truck shipments are required, translating into a lower level of risk involving hazardous material trucks. Consequently, in order to reduce the risk of hazardous material accidents the use of Larger Capacity Vehicles [LCVs], resulting in fewer shipments will appear to be in the right direction (Guo and Verma, 2010).

Further to these discussions, in the wake of terrorism in West Africa, with recent attacks on a hotel in Ouagadougou, Burkina Faso (Hunter and Wyke, 2016) and a series of suicide bombings in Nigeria by Boko Haram (Abubakar and Duggan, 2015), public panic and fear could be easily instigated through potential bombing of hazardous material transporting trucks. Considering that these materials are potentially harmful any threat of public peace and security can be perpetrated through these trucks that transport hazardous materials. When the public becomes agitated for this reason, any movement of such trucks transporting hazardous materials possess an immense threat to their safety. However, fears of potential terrorist attacks are allayed because the public is exposed to fewer shipments by virtue of the fact that transporters are using larger capacity vehicles, especially on highways such as the Tema – Accra – Kumasi [N6] highway. Milazzo *et al.* (2009) maintained that a reduced number of hazardous material shipments helps to assuage public fear and panic. At the moment in Ghana, because Larger Capacity Vehicles are used in transporting hazardous materials such fears of potential terrorist attacks that could be targetted at trucks used in transporting hazardous materials are allayed. This notwithstanding, there exists a broader spectrum of smaller capacity vehicles used for internal distribution of petroleum products to service stations in the major towns and cities across the country that potentially serve as a source of worry given that they transport smaller volumes of hazardous materials in a rather frequent manner.

4.4.3 Origin and Destination of Hazardous materials Shipments

Having a clue to the major flow patterns helps to understand the characteristics of movement of hazardous materials. In this sub-section, the objective is to present the flow patterns of hazardous materials transported on the Tema – Accra – Kumasi highway. With this information, the location of intermediate stops can be assessed to see if they actually help the truck operators to meet their requirements of breaking their journey after every four hours of continuous driving. The various origins and destinations of truck shipments are presented in Table 4.4.4.

In between these major origin and destinations, there are a number of intermediate stops, particularly for passenger buses. These include Linda Dor rest stop located at Bunso Junction, Jofel Restaurant, Paradise Resort Rest stop and a host of other facilities. There is no formal intermediate stop designated to freight trucks. Over time, truck operators have parked their trucks at some locations along the corridor, and these have become well established resting points for them. Some of such places include Asiakwa Junction at Apedwa, Nyame Akwan Chop bar, on the outskirts of Anyinam, Nkawkaw and Nsawam bypasses. All these informal intermediate rest stops are characterized by lack of decent wash rooms as well as places to sleep. The state of these facilities are not capable of aiding drivers abide by Hours of Service regulations as outlined by (Heinitz and Hesse, 2009).

Table 4.4.4: Distribution of Major Hazardous Materials Transported along the Tema-Accra - Kumasi Highway by Origin and Destination of Freight

MAJOR TOWNS	**PRODUCTS**							
	Petrol	Diesel	Kerosene	LPG	Chemi -cals	Petrol and Diesel	Petrol, Diesel and Kerosene	**TOTAL**
ORIGIN								
Accra	4	0	0	0	0	0	0	4
Tema	52	27	6	1	9	68	3	166
TOTAL	**56**	**27**	**6**	**1**	**9**	**68**	**3**	**170**
DESTINATION								
Kumasi	47	23	4	1	1	58	3	137
Buipe	3	2	0	0	0	10	0	15
Nkwanta	1	0	0	0	0	0	0	1
Techiman	3	0	1	0	0	0	0	4
Obuasi	0	0	0	0	1	0	0	1
Sunyani	1	0	0	0	0	0	0	1
Bolgatanga	0	1	0	0	0	0	0	1
Transit	0	0	0	0	5	0	0	5
Wa	0	0	0	0	2	0	0	2
Goaso	1	1	1	0	0	0	0	3
TOTAL	**56**	**27**	**6**	**1**	**9**	**68**	**3**	**170**

Source: Field Survey, November 2015.

As seen from Table 4.4.4, the major origin of hazardous materials are Tema and Accra whereas there are a number of destinations for these freight coming from Tema and Accra. These destinations are mainly Kumasi and Buipe and a host of others including Nkwanta, Techiman, Obuasi, Sunyani, Bolgatanga, Goaso and Wa. There were also some transit trucks (5 out of 170) that happened to be transporting products (chemicals) to destinations in neighbouring landlocked countries, especially Burkina Faso, representing 2.9% of total truck operators interviewed. The findings emphasize the north - south divide in the country where more population and production centers are located in the south compared to the north (Oduro, Afrane and Braimah, 2014). As a result, there are more destinations as compared to the number of origins of hazardous material shipments that use the Tema – Accra – Kumasi highway. The dominance of Kumasi as a destination point goes to accentuate the strategic role it plays as a central distribution point or bulk breaking point across the country and within the West African sub-region (Adarkwa, 2011). These advantages are offered by its central location where one can traverse to any part of the country within a day.

It is interesting to note that more than half (that is, five out of nine) of chemicals being transported using the Tema – Accra – Kumasi highway have destinations outside Ghana. Bearing in mind that there are major mines in Obuasi and Kenyasi and other small scale mining towns in Ghana, one would have expected more chemical shipments to be going to these destinations from Tema. However, it does appear that some of these products are not transported using the Tema – Accra – Kumasi route. Some other studies have established that freight trucks used in transporting products to destinations in Obuasi preferred the Tema – Accra –Yamoranza – Obuasi route and findings from the current study seem to support those of an earlier study. Another probable explanation could be that the mines in Obuasi, Kenyasi and Tarkwa take delivery of their chemicals through the Takoradi Port and as such may not use the Tema – Accra – Kumasi highway.

Again, the dominance of Kumasi and Buipe as destination towns is explained by the location of strategic petroleum storage tanks in these towns. These are corroborated by assertions of the Bulk Oil Storage and Transportation [BOST] Company Limited that indicate various depots spread across the country. In contrast, Bolgatanga, which also serves as a BOST depot has minimal number of road shipments going there. This was as a result of the use of pipelines that connect the Bolgatanga storage depot to the Buipe Port as was confirmed by the Bulk Oil Storage and Transportation Company Limited and Ghana News Agency (2015). For this reason petroleum products are rarely transported using Bulk Road Vehicles [BRVs] from the Accra Plains Depot [APD] around Tema to the Bolgatanga Depot. In spite of the higher proportions of petroleum products having destinations in Kumasi and Buipe, there were a few truck operators moving products to other destinations such as Wa, Techiman, Goaso and Sunyani. Indications are that these products are meant for direct supply to fuel service stations in these towns. Figure 4.4.2 further illustrates the flow of products between origin and destinations.

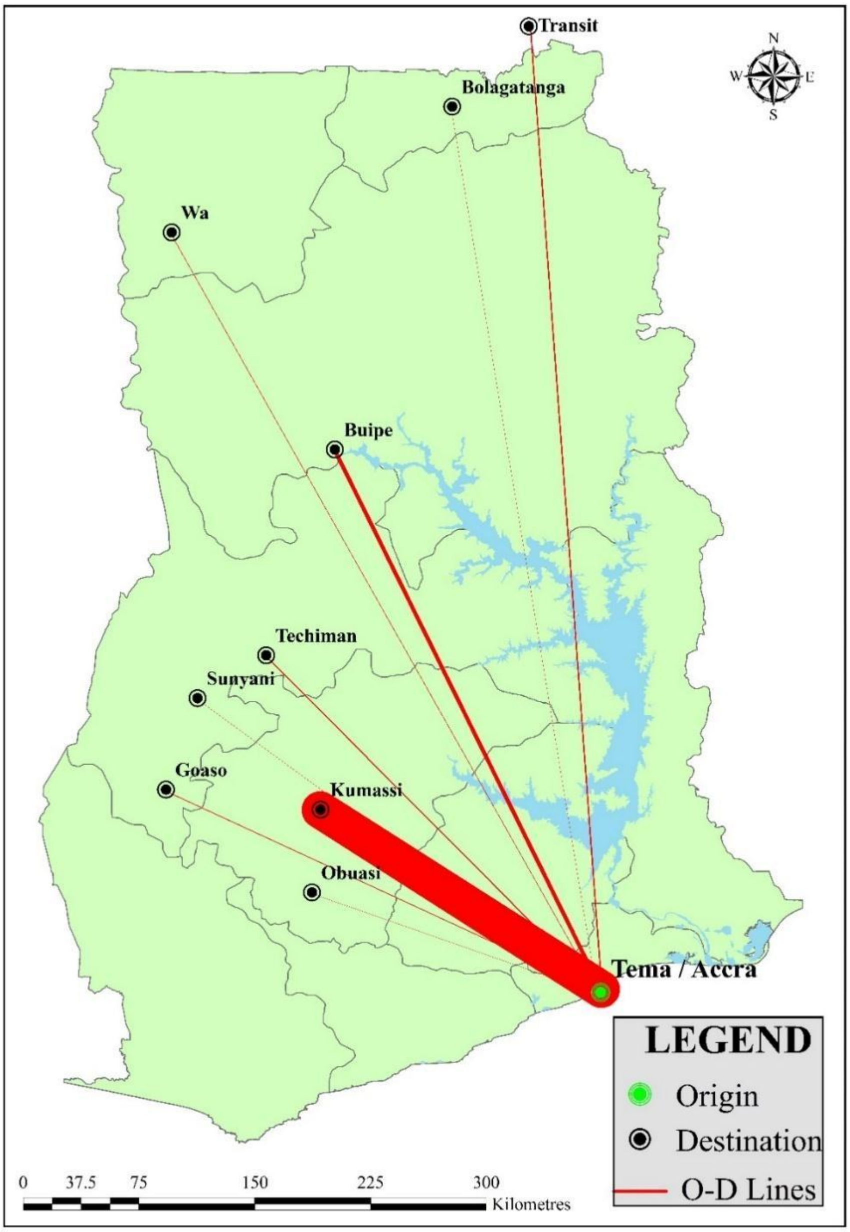


Figure 4.4.2: Map showing the Major Flow of Hazardous Materials along the Tema – Accra– Kumasi Highway.
Source: Author's Construct, 2016.

Given that major origin and destination of hazardous materials transported along the route are Tema and Kumasi respectively, there could be implications on the location or siting of intermediate rest stops for truck operators. This, however, must be guided by average speed limits and advantages offered by some road sections such as availability of land on the outskirts of town, availability of water and electricity.

Accordingly, these are discussed in subsequent sections of this study. Nonetheless speed levels of truck operators are captured in Table 4.4.5.

Table 4.4.5: Speed Levels of Truck Operators using the Tema – Accra – Kumasi Highway

Average Speed (km/h)	Frequency	Percentage	Cumulative Percentage
Non-response	7	4.1	4.1
55	3	1.8	5.9
60	14	8.2	14.1
65	81	47.6	61.7
70	38	22.4	84.1
75	18	10.6	94.7
80	9	5.3	100
Total	**170**	**100.0**	

Source: Field Survey, November 2015.

Speed of trucks have been identified by the HMCRP (2009) to be a contributory cause of accidents involving trucks. Results from the survey indicate an average speed of about 65 km per hour, modal and median speeds of 65 km per hour and a standard deviation of 14.5 km per hour. The average speed of truck operators is above the permissible 60 km per hour speed limit for commercial freight vehicles. A standard deviation of about 15 km per hour presupposes that more drivers are flouting speed limits prescribed for loaded trucks. This "over speeding" is likely to occur on the bypasses located on the corridor, including the Nsawam bypass as well as Nkawkaw bypass located on the Nsawam-Suhum and Nkawkaw-Konongo sections respectively. These sections happen to coincide with areas where truck operators have earmarked as dangerous or black spots, including the Konongo trial lane and Breku Forest area which are both situated along the Nkawkaw-Konongo section of the N6 highway. The next sub-section takes a closer look at risks associated with transporting hazardous materials on the N6 highway.

4.5 Risks of Hazardous materials Transportation on the Tema – Accra – Kumasi Highway

4.5.1 Accident Statistics of Hazardous materials Truck Operators on the N6 Highway

Road safety interventions are aimed reducing the risk of a person using the road network - either as a vehicle occupant, operator, cyclist or pedestrian - from getting seriously injured or killed. To ensure that lives are protected, measures are put in place to prevent such actions that endear road users to risks. The Ghana Highway Authority [GHA] revealed that as part of safety measures, it used the road design in itself as a mechanism to safeguard against accidents. The GHA noted that permissible lengths of up to 18m for the long vehicles, for example, was factored into road design, particularly, in curves or bends on the horizontal alignment to make sure such vehicles are not adversely affected. In addition to the GHA, efforts made by the National Road Safety Authority [NRSA], Driver and Vehicle Licensing Authority [DVLA], Motor Traffic and Transport Department [MTTD] of the Ghana Police Service as well as the National Ambulance Service have been targeted at reducing road crashes in the country. Notwithstanding these efforts road accidents in the country are very high and estimated to amount to 1.6% of Gross Domestic Product [GDP] (MRH, MoT and GSS, 2012).

From the sampled truck operators interviewed, 26 out of 170, representing 15.3% (see Figure 4.5.1), reported to have been involved in either a collision or leakage/spill within the last ten years. This implies an annual rate of accident of 1.53%. This figure is lower than fatality rates recorded nationally for Heavy Goods Vehicles over the period 2006 and 2010 (see Table 4.5.1). Out of total accidents/incidents reported 38.5% resulted in release/spills while 61.5% were collisions.

Table 4.5.1: Percentage Fatality by Type of Vehicle and Year, 2006 – 2010.

Vehicle Type	**Percentage Fatality**				
	2006	**2007**	**2008**	**2009**	**2010**
Pick-ups	11.5	11.4	13.4	14.6	12.1
Heavy Goods Vehicles	1.9	1.9	2.2	2.7	2.5
Motor Cycles	15.1	11.5	9.0	10.0	7.1
Bicycles	5.3	9.8	8.3	9.9	9.4
Other road users	4.7	4.6	5.4	4.7	4.1

Source: MRH, MoT and GSS, 2012.

As can be seen from Table 4.5.1, more motor cyclists and pick-up occupants are killed in road crashes than other categories. These two categories account for 23.1% of fatal road accidents every year, meaning that almost 1 out of 4 persons killed in road crash is either a cyclist or pick-up occupant. Again, results emphasize the rarity of accidents involving Heavy Goods Vehicles, a component of which are hazardous material trucks.

Table 4.5.2: Distribution of Truck Operators by Age and Number of Accidents involved in the Last Ten Years.

Age of Truck Operator	Number of accidents in last 10 years			Total
	1	2	3	
21-25 years	0	0	0	0
25-30 years	3	1	1	5
31-35 years	3	1	0	4
36-40 years	0	1	0	1
41-45 years	6	2	0	8
46-50 years	3	1	0	4
51-55 years	3	0	0	3
56-60 years	1	0	0	1
more than 60 years	0	0	0	0
Total	19	6	1	26
Percentage	**73.1%**	**23.1%**	**3.8%**	

Source: Field Survey, November 2015.

From Table 4.5.2, it is seen that out of all hazardous materials truck operators involved in accidents or incidents in the last 10 years a greater proportion (73.1%) had 1 accident/incident while 3.8% have been involved in 3 incidents/accidents. This emphasizes the relatively low number of accidents associated with hazardous materials. Duke, Guest and Boggess (2010) in Australia, found that accidents were rampant among younger truck operators (below 27 years) and older truck operators (above 60 years), however, findings from this study indicate otherwise, especially among older truck operators. This could be attributed to the level of experience these truck operators would have obtained in their profession over the years (Borowsky, Shinar and Oron-Gilad, 2010).

Having examined the accidents that hazardous materials truck operators have been involved in, the next sub-section attempts to establish a relationship between the number of accidents and plausible causes of accidents on highways.

4.5.2 Causes of Hazardous Material Accidents

Road accidents are rampant in Ghana; for example, the National Road Safety Commission (2016) reports that in the year 2015 a total of 10,852 crashes were recorded involving 16,958 casulaties leading to 1,634 deaths and 9,186 injuries, and when these accidents do happen leave a lot of devastating or grave consequences. The case is even worse when hazardous materials are involved simply because of the nature of such products. Some of the established or known causes of accidents include: inadequate experience, unnecessary over speeding, lack of proper judgment of drivers, carelessness on the part of drivers and pedestrians, wrong overtaking, recklessness, intoxication, over loading, machine failure, dazzling and defective light, skid and road surface defect, level crossing and obstruction. Others include inadequate enforcement of road laws and traffic regulations, use of mobile phones when driving, failure to buckle the seat belt and corruption (National Road Safety Commision, 2007). The Ghana Police Service also outlines lack of maintenance, carelessness and negligence, inconsiderate driving and failure to observe traffic rules on the part of truck operators as major causes of accidents involving freight trucks. These are related to the following factors: age of driver, years of experience, Hours of Service, level of maintenance of the vehicle, condition of the vehicle, road conditions as well as a situational factors such as prevailing weather and judgment of the driver. Some of these parameters are not easily quantifiable and as such have not been used in the current study to establish the relationship between number of accidents a hazardous material truck operator has been involved in the last ten years and the aforementioned factors. Accordingly, the predictor variables or causes of accidents involving hazardous materials truck operators are related with the factors as follows:

- Age of truck operator (inadequate experience);
- Years of experience of truck operator (inadequate experience);
- Hours of service (failure to observe traffic rules);
- Age of truck (lack of maintenance, machine failure);
- Age of packaging material (machine failure, lack of maintenance); and
- Speed levels (over speeding, inconsiderate driving).

To establish the relationship between number of accidents a hazardous material truck driver on the Tema – Accra – Kumasi highway and the predictors aforementioned, the number of accidents or incidents a truck operator had been involved was used as the dependent variable and these predictor factors, which are related to the causes of accidents (age of truck operator, years of experience, hours of service, age of truck, age of packaging material, and speed level) were used as explanatory variables. Results of correlation between these variables are summarized in Table 4.5.3; where it can be seen that, although there exists correlations amongst all variables, only 2 pairs are significant at confidence level of 0.05**.** In effect, there is a strong correlation between years of experience and age of truck operator; as well as age of truck and age of packaging material. This shows a strong and positive correlation among these 2 pairs of variables where the older a truck operator is, the higher his level of experience. These relationships are so because, for example, the packaging materials are an integral part of the trucks, especially for petroleum tanker trucks. However, there are instances where truck operators reported Transport Service Provides [TSPs] have imported just the "head" or cabin of the truck and fixed an old bulk container or tanker on them accounting for the non-unity in correlation between these two variables.

In addition, it could be seen that other variables, though, related are not very significant. In the exception of age of truck operator and their years of experience, all other predictor variables vary inversely with number of accidents (explained or dependent variable). All the explanatory variable were not significant enough in determining variations in the dependent variable.

Table 4.5.3: Results of the Correlation between Dependent and Independent Variables.

	No. of Accidents	*Age*	*YoE*	*HoS*	*Truck Age*	*PM Age*	*Speed*
No. of Accidents	1.000						
Age	0.019	1.000					
YoE	0.082	0.817**	1.000				
HoS	-0.034	0.074	0.030	1.000			
Truck Age	-0.022	0.037	0.044	-0.054	1.000		
PM Age	-0.013	0.029	0.095	0.000	0.745**	1.000	
Speed	-0.043	-0.038	-0.018	0.055	0.051	0.037	1.000

Source: Field Survey, November 2015. ** Correlation is significant at the 0.05 level (2-tailed).
N = 170

Following the correlation, a regression analysis was carried out to ascertain the extent to which these predictor variables explain variations in the dependent variable. Results are summarized in Table 4.5.4 (for further details, see Appendix 4a).

Table 4.5.4: Summary Regression Output

Regression Statistics	
Multiple R	0.13045551
R Square	0.01701864
Adjusted R Square	-0.019164723
Standard Error	0.522093224
Observations	170

Source: Field Survey, November 2015.

The results in Table 4.5.4 imply there is a weak correlation between dependent and independent variables; that is, the number of accidents a truck operator is involved in, on one hand, and the factors such as the age of truck operator, years of experience, age of truck, age of packaging material, speed levels and hours of service, on the other hand, is weakly correlated. In other words, these factors alone cannot entirely explain the variations in the number of accidents a truck operator is involved in. To a large extent, these independent variables account for less than 2% (R^2 of 0. 017) of variations in the dependent variable. This suggests that accidents are as a result of multiplicity of factors, and are not amply explained by the preceding factors. This phenomenon is attributable partly to the chaos theory which is hinged on unpredictability of events.

To sum it all, accidents involving trucks, and for that matter, hazardous material transporting trucks are as a result of a multiplicity of factors. These ones which have been assessed and used in the current study do not amply explain variations in the number of accidents. This presupposes that other factors, such as prevailing weather, level of maintenance, a human factor such as drunk driving, poor vision or eyesight, violent reaction of hazardous materials among others, may account for accidents.

4.5.3 Risks Associated with Transportation of Hazardous Materials

Transportation of hazardous materials exposes humans, property and the environment to some level of likely exposure termed as risks. These risks are in the form of mere exposure, an accident or a combination of exposure and accidents. To estimate risk of hazardous materials accident in the current study, the formula proposed by Kazantzi, Kazantzis and Gerogiannis (2011) was adopted. The formula is as follows:

$$R = \Sigma P_i * Cs_i$$

where: *R* is the risk estimate; $P_i$represents the probability of a hazardous materials incident on road link i; and Cs_i represents the consequences of a release event on road link i.

Further, $P_i = AR_i * Pi\ (RL|\ A) * d_i$; where AR_i is accident rate (probability on link *i* per vehicle kilometer, *Pi (RL| A)* is the release probability given an accident and d_i is the length of the link.

$Cs_i = Pd_i * \pi r^2$; where Pd_i is population density in the neighbourhood and *r* the impact radius.

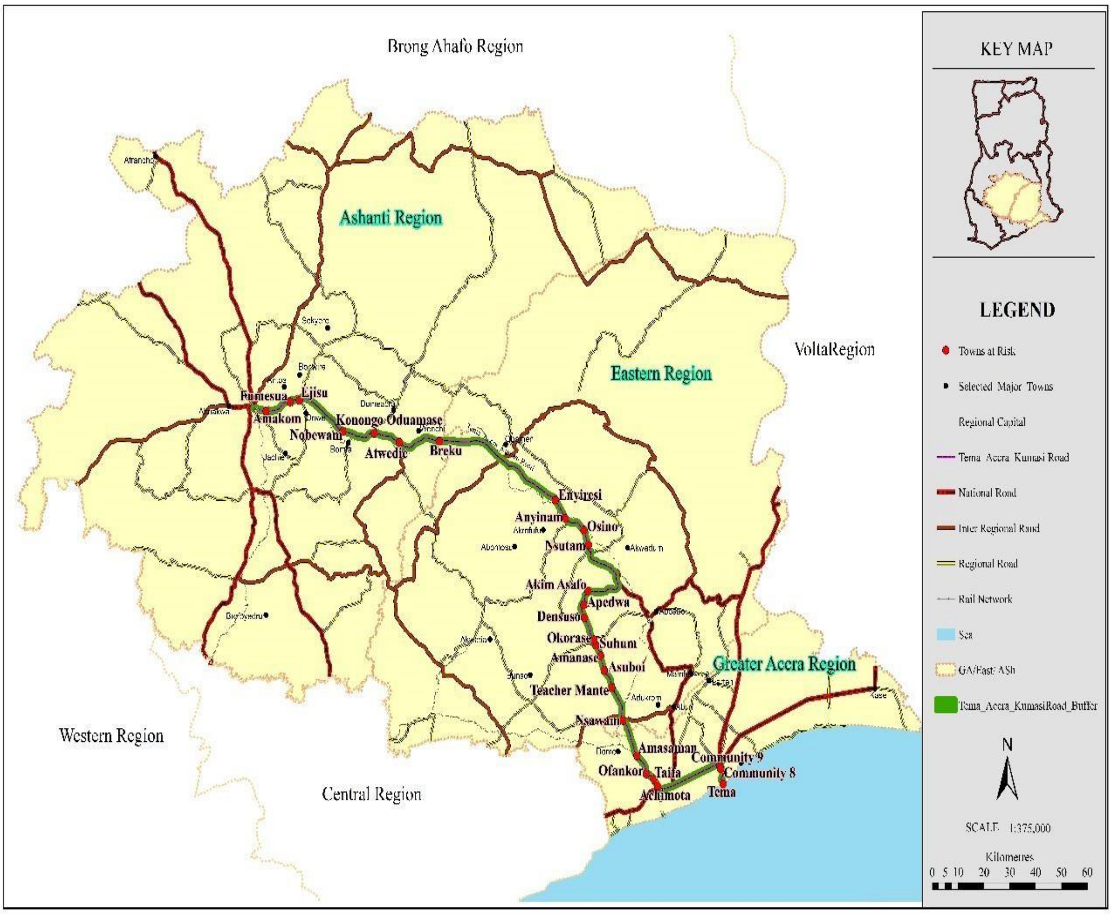
This method was selected because of its simplistic nature and availability of required data, though with some form of limitation. In estimating consequences only the affected population was used. Property and environment affected could not be assessed and used as part of the consequences. With the help of a Road Network map obtained from Centre for Remote Sensing and Geographic Information Services [CERSGIS], a list of affected towns was derived (see, Table 4.5.5) and population densities were derived accordingly. In spite of challenges in delineating or carving out boundaries of affected towns, district population densities were adopted and used consequently. The consequences or population at risk here represents risk of a single shipment and there are numerous shipments on a daily basis.

Table 4.5.5: Population at Risk of a Release Accident

No.	Affected Community	Population Density ** (inhabitants per sq. km)	Constant (π)	Impact radius (in km ^{2})	Population at Risk/ Consequence (Cs *i*)
1	Amakom	9,855	3.143	0.16	4,956
2	Fumesua	282	3.143	0.16	142
3	Ejisu	282	3.143	0.16	142
4	Nobewam	525	3.143	0.16	264
5	Konongo Odumase	525	3.143	0.16	264
6	Atwedie	114	3.143	0.16	57
7	Breku	525	3.143	0.16	264
8	Enyiresi	105	3.143	0.16	53
9	Anyinam	105	3.143	0.16	53
10	Osino	105	3.143	0.16	53
11	Nsutam	105	3.143	0.16	53
12	Akim Asafo	383	3.143	0.16	193
13	Apedwa	383	3.143	0.16	193
14	Densuso	449	3.143	0.16	226
15	Okorase	336	3.143	0.16	169
16	Suhum	449	3.143	0.16	226
17	Amanase	449	3.143	0.16	226
18	Asuboi	449	3.143	0.16	226
18	Teacher Mante	449	3.143	0.16	226
20	Nsawam	591	3.143	0.16	297
21	Amasaman	1,037	3.143	0.16	521
22	Ofankor	1,149	3.143	0.16	578
23	Taifa	1,149	3.143	0.16	578
24	Achimota	13,226	3.143	0.16	6,651
25	Tema	5,214	3.143	0.16	2,622
	TOTAL	**38,241**	**3.143**	**0.16**	**19,231**

Source: Author's Construct, 2016.

** District Population Density



MAP SHOWING AFFECTED COMMUNITIES ALONG THE TEMA - ACCRA - KUMASI HIGHWAY

Figure 4.5.1: Communities at Risk of Hazardous Material Accidents along the Tema - Accra – Kumasi (N6) Highway. Source: Author's Construct.

To estimate the probability of hazardous materials accidents, data from the surveys indicating the proportion of truck operators involved in accidents were used. It was realized that 1.53% of hazardous materials truck operators had been involved in accidents in the last 10 years. Subsequently, release probabilities were estimated to be 38.5% of all hazardous materials accidents. Results of accident probabilities on the various road sections are summarized in Table 4.5.6.

Table 4.5.6: Estimation of Probabilities of Release Accident

ID	Name	Accident Probability / Rate (AR *i*)	Release Probability (RP *i*)	Length (in km) (d *i*)	Probability of a release event (AR *i* * RP *i* * d *i*)
S1	Tema-Accra	0.0006770	0.0002606	22.6	0.0000040
S2	Accra-Ofankor	0.0010200	0.0003927	15.00	0.0000060

S3	Ofankor-Nsawam	0.0006652	0.0002561	23.00	0.0000039
S4	Nsawam-Suhum	0.0004026	0.0001550	38.00	0.0000024
S5	Suhum-Bunso	0.0004752	0.0001829	32.20	0.0000028
S6	Bunso-Nkawkaw	0.0002675	0.0001030	57.20	0.0000016
S7	Nkawkaw-Konongo	0.0002937	0.0001131	52.10	0.0000017
S8	Konongo-Ejisu	0.0004371	0.0001683	35.00	0.0000026
S9	Ejisu-Kumasi	0.0008407	0.0003237	18.20	0.0000050

Source: Author's Construct.

Results of the analysis, as can be seen from Table 4.5.6, indicate that accident probabilities are very low, ranging from 0.0000016 to 0.0000060 accidents per vehicle-km (1.6×10^{-6} and 6.0×10^{-6}). Similar studies by Centrone, Pesenti and Ukovich (2008) estimate a usual accident or incident rate at the value of approximately 3.0×10^{-6} accidents/vehicle-km. this suggests that accident rates on the corridor compare favourably with international rates from elsewhere. In fact, about five road sections have accident rates even lower. This emphasizes how rare accidents involving hazardous materials are albeit with very high consequences.

Following the estimation of probability of hazardous material accidents and associated estimate of population at risk, the risk estimate of a single shipment per vehicle-km is presented in Table 4.5.7. This was carried out using the approach of Kazantzi, Kazantzis and Gerogiannis (2011) where the risk estimate is seen as the product of the release probaility and the population at risk.

Table 4.5.7: Summary of Risk Estimate Per Vehicle-km of Hazardous Material Shipment

No.	Communities at Risk	Population at Risk	Release Probability ($x 10^{-6}$)	Risk Estimate, R ($x 10^{-4}$)
1	Amakom	4,956	5.0	245.4
2	Fumesua	142	5.0	7.0
3	Ejisu	142	5.0	7.0
4	Nobewam	264	2.6	6.8
5	Konongo Odumase	264	2.6	6.8
6	Atwedie	57	1.7	1.0
7	Breku	264	1.7	4.6
8	Enyiresi	53	1.7	0.9
9	Anyinam	53	1.7	0.9
10	Osino	53	1.6	0.8
11	Nsutam	53	1.6	0.8

12	Akim Asafo	193	2.8	5.4
13	Apedwa	193	2.8	5.4
14	Densuso	226	2.8	6.3
15	Okorase	169	2.8	4.7
16	Suhum	226	2.4	5.4
17	Amanase	226	2.4	5.4
18	Asuboi	226	2.4	5.4
18	Teacher Mante	226	2.4	5.4
20	Nsawam	297	2.4	7.0
21	Amasaman	521	3.9	20.4
22	Ofankor	578	3.9	22.6
23	Taifa	578	6.0	34.7
24	Achimota	6,651	6.0	399.6
25	Tema	2,622	4.0	104.6
	Total	**19,233**	**77.0 ***	**914.4 ****

Source: Field Survey, November 2015; Results of the Analysis.

* Release probability on the entire corridor

** Risk estimate on the entire corridor

From Table 4.5.7, it can be seen that the risk estimate involving a single hazardous material shipment is 0.09144 inhabitants per vehicle-km. In other words, within one kilometer of travel, nine (9) inhabitants are at the risk of being involved in every 100 shipments of hazardous materials. This means that, within one kilometer of travel everyday, about 5 persons stand a chance of being killed or injured from a single hazardous material accident considering there are approximately 60 daily shipments. Considering that the Tema – Accra – Kumasi Highway is 293.3km, it implies that approximately 1,467 inhabitants stand a risk of being killed or injured from a single hazardous material accident.

4.6 Operational Characteristics of Truck Operators along the N6 Corridor

This section of the study assesses the operational characteristics of truck operators, particularly, their regulations and compliance, location of intermediate rest facilities, road infrastructure and risk prevention as well as emergency preparedness. The operational characteristics of truck operators are assessed in line with these regulations to know the level of compliance and what actions are taken against those operators that are not compliant.

4.6.1 Regulations and Compliance on Hazardous materials Transportation

To have a safe and effective transportation of hazardous materials on highways and other modes of transport there ought to be regulations to guide the process. In the absence of such regulation, at any stage of the transportation process, there is bound to be some level of inefficiencies and laissez faire attitude by stakeholders. There is therefore the need to have some agencies of state or private establishments that regulate activities of transporters or carriers of hazardous materials. The transportation of hazardous materials in Ghana, which is the focus of this study, is regulated by some state institutions. These institutions are mandated to ensure safe and accident free movement of products on highways across the country. These institutions include the National Petroleum Authority, Environmental Protection Agency and Ghana Highway Authority. In Ghana, road transportation is regulated with the Road Traffic Act - 2004 (Act 683) and the Road Traffic Regulations, 2012 L.I. 2180. In addition to these institutions, Transport Service Providers [TSPs] are also involved in regulating the activities of truck operators on the highways.

From the surveys with truck operators, it was revealed that transporters of cyanide, for example, has strict regulations and inspection guidelines from the TSP, Vehrad Transport and Haulage Company Limited, which have to be followed by truck operators. For petroleum transporters, the truck operators maintained that National Petroleum Authority [NPA] has oversight over their operations, especially the vehicles they used in transporting products. They held that for a truck operator to be given license to transport products, his vehicle is inspected and given clearance, verified by NPA stickers displayed on the vehicles, from the NPA before he is allowed to transport products.

Ghana Highway Authority's mandate with regards to hazardous materials transportation is restricted to axle load controls. It was their position that any transporter who has to transport products, particularly bulk products in excess of axle load limits, had to obtain permission from the Authority and clearance given before such transportation is carried out. In this regard, truck operators were questioned on whether they overloaded their trucks and, if so, whether they sought permission from the GHA to do so. The results from the survey of truck operators are presented in Table 4.6.1 on overloading of trucks and whether or not truck operators sought permission to do so.

Table 4.6.1: Distribution of Responses on Overloading and Permission Sought by Product Type

Product Type	Overloading of Truck				With Permission			
	"Yes"	%	"No"	%	"Yes"	%	"No"	%
Petrol	1	0.6	55	32.4	1	0.6	0	0
Diesel	0	0	27	15.9	0	0	0	0
Kerosene	0	0	6	3.5	0	0	0	0
LPG	0	0	1	0.6	0	0	0	0
Chemicals	3	1.8	6	3.5	0	0	3	1.8
Petrol and Diesel	0	0	68	40	0	0	0	0
Petrol, Diesel and Kerosene	0	0	3	1.8	0	0	0	0
Total	**4**	**2.4**	**166**	**97.6**	**1**	**25**	**3**	**100**

Source: Field Survey, November 2015.

From the surveys, it was realized that 2.4% of all truck operators were reported to overload their trucks while the remaining 97.6% did not overload trucks with products. Of all truck operators who attested to overloading their trucks, 75% did not obtain permission from the Ghana Highway Authority to transport products in excess of permitted axle load limits.

Overloading trucks does not only endear the road pavement to destruction but also pose a source of risk or threat to products' safety as well as safety of the public and environment. It can be seen that overloading of trucks without permission is carried out by transporters of chemicals (in particular cyanide). However, the operators of these chemical transporting trucks maintained that their transportation is regulated by their Transport Service Provider, Vehrad Transport and Haulage Company Limited, who put in place preventive measures to forestall any accidents as well as responsive measures in the unlikely event of any accident.

In a bid to prevent accidents and associated consequences during transportation of cyanide, large shipments are made at a go using large capacity vehicles in a convoy. Large shipments at a go of hazardous materials have been shown to reduce risks and allay fears of terrorist attacks (HMCRP, 2009; Guo and Verma (2010). In the convoy, product safety officers, police officers as well as road safety officers move in pick-up vehicles in the front and at the rear of trucks being used to transport products. They warn the truck drivers of any impending hazards such as sharp curves, speed rumps, intersections, broken down or stationary trucks and pedestrian crossings by use of communication gadgets fixed on each truck during transportation. These measures are put in place to prevent the occurrence of any accidents which might result in grave consequences.

The transportation of hazardous materials on highways in Ghana appears largely regulated and there is compliance from truck operations though a few operators are not compliant with regulations. These findings are consistent with findings by Gzara (2013) and Kara and Verter (2004). Both authors argue that transportation of hazardous materials needs to be regulated by the state through mandated institutions. However, from this study, regulation appears to be limited only to vehicles used in transporting freight to the detriment of other important aspects. The age of truck operators, level of experience required and the truck operators state of health during transportation are equally importatnt and need to be regulated.

The bi-level approach which mimicks a leader and follower relationship proposed by Gzara (2013) is the approach used in Ghana. The transportation of hazardous materials is regulated at the leadership level by the State through institutions such as the Environmental Protection Agency, National Petroleum Authority and the Ghana Highway Authority. Notwithstanding the State institutions' mandate of regulating hazardous materials transportation, the additional role of route selection/designation is virtually non-existent. Between Tema/Accra and Kumasi there are a few alternative routes for transportation of freight. However, these routes have longer distances and present some operational challenges. Consequently, all truck operators are held captive to the Tema – Accra – Kumasi (N6) corridor. Therefore, the State is unable to usurp powers of restricting route choice of truckers by use of road tolls and bans.

Transport Service Providers [TSPs] which are large companies as well as individual owners are the followers in the "leader – follower" relationship proposed by Gzara (2013). TSPs are unable to choose among alternative routes since there are virtually no alternatives between points of origin, Tema/Accra, and destination points in Kumasi and areas beyond. The position of carriers or TSPs to select routes that minimized their costs and enhance efficient delivery appear to be irrelevant at the moment. Nonetheless, some aspects of their transportation process are regulated by the State. Internally, TSPs have mechanisms such as trackers or sensors to check over speeding and offending truck operators sanctioned accordingly with two weeks suspension for mild offenses such as over speeding.

Truck operators indicated that some of their concerns with salary and insurance policy cover are not addressed by the regulatory provisions. Considering that their occupations are very risky, they expect that insurance policies are made to cover themselves as well as their assistants. The practice is, however, not the case. When a truck is involved in an accident, the truck owners or TSPs are the ones who deal with insurance policy providers. In the course of policy claims, affected drivers do not get compensated adequately. Truck operators maintained TSPs are more concerned with the vehicles rather than the truck operator and assistant, and this position poses recipe for disaster.

4.6.2 Location of Intermediate Stops and Truck Operators' Hours of Service

The operations of truck operators are maximized with supporting infrastructure like intermediate rest stops. By convention truck operators need to rest enough to safely transport products. This sleep and rest are only made possible or enhanced with the creation of intermediate rest stops along major highways used in transporting hazardous materials. In addition to siting of intermediate rest stops is the need to have Hours of Service or driving time regulated as it goes a long way to help prevent accidents. Table 4.6.2 provides a summary the Hours of Service truck operators along the Tema – Accra – Kumasi put into driving on a typical journey.

Table 4.6.2: Hours of Service of Truck Operators on the Tema – Accra – Kumasi Highway

Hours of Service (hours)	**Frequency**	**Percentage (%)**	**Cumulative Percentage**
2	1	0.6	0.6
3	11	6.5	7.1
4	125	73.5	80.6
5	15	8.8	89.4
6	14	8.2	97.6
7	4	2.4	100.0
Total	**170**	**100.0**	**-**

Source: Field Survey, November 2015.

Studies such as those by Kara and Verter (2004), Heinitz and Hesse (2009), Heaton (2005) and Jensen and Dahl (2009) have shown that Hours of Service can be used to prevent accidents involving trucks in general and hazardous material transporting trucks in particular. Results from the study show that Hours of Service regulations for truck drivers within the West African Hub are being complied with to a large extent. The mean hours of service of truck operators is 4.25 hours with a standard deviation of 0.8 hours while the modal Hours of Service is 4 hours. The standard deviation of 0.8 hours suggests that there is relatively low variation in the hours of service for hazardous material truck operators. Cumulatively, 80.6% of truck operators attested to breaking their journeys for rest after four (4) hours or less of continuous driving. This is good for the truck operators' health and prevention of accidents. However considering that a whopping 19.4% of truck operators do not comply with the 4 hour regulation stipulated by the West Africa Trade Hub (2010) there are implications for safety on highways. Some of the truck operators drive continuously for between 5 and 7 hours before breaking their journeys; having negative impacts on health (Iwasaki, Takahashi and Nakata 2006). The phenomenon may be attributed to the lack of intermediate rest facilities for truck operators along the corridor.

Currently, travelling along the corridor it would be observed that there are no intermediate facilities such as a truck park designated for freight trucks let alone hazardous material trucks. Truck operators are compelled to park on the shoulders of the road at any point they feel is safe to park and have a nap or pass the night. Other truckers park at fuel filling stations and major road intersections like the Nkawkaw by-pass. Hazardous materials truck operators are unable to park, for safety reasons, at existing rest stops such as Linda Dor Rest Stop and Paradise Resort because the products they are transporting are highly risky and hazardous. This is so because these rest stops are points of convergence for passenger buses and other private car drivers and any accident involving hazardous material trucks at these points will have devastating consequences.

Truck operators will comply with Hours of Service regulations if the necessary enabling environment is created for them to do so. Indeed, Heaton (2005) and Jensen and Dahl (2009) have shown that regulations on driving hours will better function when intermediate facilities are provided. On the Tema – Accra – Kumasi corridor, the absence of intermediate rest stops designated for freight truckers in general and hazardous materials truckers in particular has compelled some truck operators to flout existing regulations.

Hours of Service and average speed levels can affect the location or siting of intermediate rest facilites. Considering that average speeds are 65 km per hour, mandated Hours of Service being 4 hours after continuous driving and major origin of trucks being the Tema area, the location of intermediate rest facilities could be sited around Nkawkaw. By the fourth hour a truck travelling at a speed of 65 km per hour would have covered about 260 km but due to congestion at some sections and a non-uniform speed, truck operators normally break their journeys between Apedwa and Anyinam. This means that any siting of a proposed intermediate facility for truck operators should be within this segment for the facility to be utilised to the maximum.

4.6.3 Risk Prevention and Emergency Response

Risk prevention has been noted to be a key contributory factor in ensuring safe transportation of hazardous materials. In addition to risk prevention, emergency response can also be used to prevent accidents as well as reduce consequences of accidents. This sub section of the study sought to find out what risk prevention and reduction measures truck operators along the Tema – Accra – Kumasi (N6) highway adopted. There exists a number of measures that can be used to prevent risk such as controlling driving hours, driver training and route selection. In addition, measures such as the Spatial Decision Support System [SDSS], insurance as well as emergency response are in place to reduce the consequences of accidents on highways.

Table 4.6.3: Risk Prevention Measures Adopted by Truck Operators on the Tema – Accra –Kumasi Highway.

Risk Prevention Measure(s)	**Frequency**	**Percentage**	**Cumulative Percentage**
Route Selection	56	32.9%	85.9%
Spatial Decision Support System	5	2.9%	
Insurance	61	35.9%	
Emergency Response	13	7.6%	
Other	11	6.5%	
Route Selection, Spatial Decision Support System	4	2.4%	8.2%
Route Selection, Insurance	7	4.1%	
Route Selection, Emergency Response	1	0.6%	
Spatial Decision Support System, Insurance	1	0.6%	
Insurance, Emergency Response	1	0.6%	
Route Selection, Insurance, Emergency Response	10	5.9%	5.9%
Total	**170**	**100.0%**	**100.0%**

Source: Field Survey, November 2015.

The results from the study (see Table 4.6.3) show that a number of risk prevention measures are being used by truckers on the N6 highway. It can also be seen that while some truck operators put in place one method of risk prevention others use a combination of measures to do so. What is most important is that no truck operator failed to use at least one method to prevent risks.

Truck operators on the corridor largely (85.9%) use only one method of risk prevention or another. The most widely used methods of risk prevention were insurance (35.9%) and route selection (32.9%). Respectively, 8.2 % and 5.9% of truck operators employ a combination of two methods and three methods to prevent risks. It is alarming that such large proportion use only one method of risk prevention. Risk is a multiplicity of factors and as such a mixture of measures are required to deal with it. As evident from Table 4.6.4, truck operators that were involved in some hazardous materials incident/accident in the last 10 years (78.9%) were largely those who have used only one method of risk prevention whereas 21.1% employed a combination of two measures to mitigate accident risks. Those that combined 3 measures were not involved in any accident/incident in the last ten years of their operations. These results emphasize the need to employ more preventive measures in an attempt to reduce risks of hazardous materials transportation, especially on highways.

According to Frank, Thill and Batta (2000) the use of route selection presents operators with efficiency considerations as well as population exposure. However, in this study, it was found that route selection is influenced by lack of alternatives and leaves a lot more population at risk considering that the highway passes through major towns and cities such as Accra, Suhum, Anyinam, Konongo and Ejisu; to mention a few. In these towns, the road is considered an avenue for physical development due to increased accessibility and economic opportunity it offers. As it were, more population settle along roads and use the shoulders as 'markets' to trade and this exposes high proportion of the population to risk of hazardous materials accidents.

Table 4.6.4: Distribution of Number of Accidents Truck operators were involved in by the Risk Reduction Measure Adopted

Risk Prevention Measure	**Number of times involved in any incident/accident**				**Total**
	0	**1**	**2**	**3**	
Route Selection	48	6	1	1	56
Spatial Decision Support System	4	1	0	0	5
Insurance	50	8	3	0	61
Emergency Response	13	0	0	0	13
Other	9	1	1	0	11

Route Selection, Spatial Decision Support System	4	0	0	0	4
Route Selection, Insurance	5	2	0	0	7
Route Selection, Emergency Response	0	0	1	0	1
Spatial Decision Support System, Insurance	1	0	0	0	1
Insurance, Emergency Response	0	1	0	0	1
Route Selection, Insurance, Emergency Response	10	0	0	0	10
Total	**144**	**19**	**6**	**1**	**170**

Source: Field Survey, November 2015.

The use of insurance appears to be more of a reactive measure than a preventive one and because 35.9% of truckers resort to this method, there is more risk exposure than truckers would have thought. In addition to insurance being a reactive or responsive measure, truckers reported prolonged period of insurance claim recoveries (see Table 4.6.5).

Table 4.6.5: Insurance Claims Payment/Recovery Period for Truck Operators.

Period of claim payments	Frequency	Percent
within a month	7	4.1
within 3 months	58	34.1
within 6 months	86	50.6
within 12 months	16	9.4
more than a year	3	1.8
Total	**170**	**100.0**

Source: Field Survey, November 2015.

It would also be observed that the use of Spatial Decision Support Systems [SDSS] is not predominant among truck operators on the Tema – Accra – Kumasi Highway. This is partly explained by the volume of information or data base required for its efficient usage (Trépanier, Leroux and de Marcellis-Warin, 2009). At the moment, this data base is lacking and as such the method is not widely used. Beroggi and Wallace (1995) proposed re-routing as a Spatial Decision Support System that enables a dispatcher to determine alternative routes in the unlikely event of a hazardous materials accident. Be that as it may, the technology is efficient only in cases where there are alternative routes for other motorists to use. Seeing that truck operators on the N6 highway are captive to this route, the use of re-routing seems unsuitable. Another SDSS is proposed by Zografos and Androutsopoulos (2008) which has the following functionalities:

(i) the ability to determine alternative routes for transporting or distributing hazardous materials bearing in mind risk and cost minimization;

(ii) the abilility to identify locations that suit emergency response service providers such that their efforts are timely and help to minimize negative consequences; and

(iii) the ability to determine alternative paths for evacuation from the area impacted to safer zones within the shortest possible time.

In all three functionalities, only the ability to identify suitable locations for emergency response service providers appears feasible. The other two are all based on alternative routes which are non-existent at the moment. In actual sense, the location of suitable locations for emergency response service providers can be aided by identifying sections that are prone to accidents. Truck operators have noted some segments of the corridor that are considered dangerous zones (Breku Forest Reserve, Konongo Climbing Lane, Apedwa to Bunso Junction) and these can be used in conjunction with other requirements to emphasize the use of Spatial Decision Support system on highways.

In addition to these established risk reduction measures other methods used by truck operators to ensure safe transportation and delivery of products are enlisted in Table 4.6.6. It is worth noting that truck operators control driving hours/ Hours of Service and engage in regular training in a bid to forestall any accident when transporting products.

Table 4.6.6: Measures used by Truck Operators to Ensure Products Get to Destinations Safely

Measure	Frequency	Percent
Regular training	54	31.8
Controlling driving hours	83	48.8
Container specification	4	2.4
Others	3	1.8
Regular training and controlling driving hours	23	13.5
Regular training, controlling driving hours and container specification	3	1.8
Total	**170**	**100.0**

Source: Field Survey, November 2015.

Emergency response is another all important measure that is employed to reduce risks or consequences of vehicular accidents, particularly ones involving hazardous materials. This function is enhanced by suitable location as well as availability of specialized staff and equipment to deal with any such occurrence. In this section of the study, attention is on how hazardous materials truck operators respond in times of accidents and their preparedness and promptness to deal with incidents when emergency service providers have not arrived.

Because of the specialized and risky nature of their operations Transport Service Providers [TSPs] do not rely largely on wayside mechanics to fix their vehicles when there is a fault. Rather, they have their own specially trained mechanics to work on their vehicles. These service providers are located at their transport "yards" where they operate from. Whenever, there is an incident, especially with the vehicles, the truck operators communicate with their service providers from the "yard". From the field data collected, it is evident that 61.2% of truck operators have their own emergency response teams whereas the remaining 38.8% do not have such teams. These operators who do not have emergency response teams, usually, transporters from small and individually owned Transport Service Providers [TSPs], rely on services provided by wayside mechanics. However, those TSPs that have emergency response are the medium sized and larger ones such as TT Brothers, JK Horgle, Ahiadome, Okodatt, Kodson, Goil and Total Ghana Limited.

In addition to the foregoing, truck operators are supposed to have emergency response kits on their trucks. Some of such emergency response kits include fire extinguishers, foam, rags, bucket, saw dust, cutlasses, pick-axe and shovels. They are to be used by truck operators as a form of "first aid" in the event of an incident/accident. In case of an oil spillage in small quantities, for example, the saw dust and the rag are used to mop up the spilled oil. But where spillage is in large quantities, then the shovels, pickaxe or cutlasses are required to channel the spilled fuel into dug out holes for safety before the emergency response teams are called upon. Survey results show that 98.2% of hazardous materials truck operators have these emergency response kits in their vehicles with 1.8% not having them. Having a very large proportion of truckers with emergency response kits is a step towards safety, but, the minimal number that do not have implies an indictment of regulatory framework in place to monitor the hazardous materials transportation industry. But with increased vigilance and an extra effort from regulatory institutions the system could be sanitized entirely where all truckers by compulsion will have in place the necessary emergency response kits before embarking on any trip.

Operations of hazardous material truckers are enhanced when the needed infrastructure is in place and functional. The next sub-section takes a closer look at road infrastructure and ancillary facilities that are required to ensure safe and efficient transportation of hazardous materials on highways in the country.

4.6.4 Road Infrastructure and Facilities for Truck Operators

The operations of truck operators are enhanced with good road infrastructure and complementary facilities that aid their work in place. Infrastructure has been noted by the HMCRP (2009) to be a parameter in establishing the cause of accidents involving hazardous material trucks. Here, some of the proximate causes are the condition of the road, surfacing type, type of road and speed limits. The unavailability of road markings and signages also pose threats of accidents on the highways, particularly for freight truck transporters.

In terms of road condition the entire corridor, 293.3 km in length, is in good condition with a few patching works required between Suhum – Bunso section (see Table 4.6.7). This road condition compares favourably with the national average of 42% "Good", 28% "Fair" and 30% "Poor" (MRH, MoT and GSS, 2012). This is anticipated considering that the surface type is entirely bituminous with asphaltic concrete on the Tema – Accra section.

Table 4.6.7: Characteristics of the Tema – Accra – Kumasi Highway by Homogenous Sections

ID	Name	Surface Class	Length (Km)	Width (m)	No. of Lanes	Road Condition
S1	Tema-Accra	Concrete	22.6	14.00	4	Good
S2	Accra-Ofankor	Bituminous	15.00	14.00	4	Good
S3	Ofankor-Nsawam	Bituminous	23.00	14.00	4	Good
S4	Nsawam-Suhum	Bituminous	38.00	7.00	2	Good
S5	Suhum-Bunso	Bituminous	32.20	7.00	2	Good
S6	Bunso-Nkawkaw	Bituminous	57.20	7.00	2	Good
S7	Nkawkaw-Konongo	Bituminous	52.10	7.00	2	Good
S8	Konongo-Ejisu	Bituminous	35.00	7.00	2	Good
S9	Ejisu-Kumasi	Bituminous	18.20	14.00	4	Good

Source: Ghana Highway Authority, 2015.

In addition to the foregoing, it can be seen from Table 4.6.7, that large segments of the road has 2 lanes with close to 80km being 4 lanes. The 4-lane sections are noted to be in large towns, for example between Tema – Accra and Ejisu – Kumasi, where traffic volumes are very high averaging over 3,000 vehicles. As has been mentioned earlier, average speed for hazardous materials truck operators was 65 km per hour.

To enhance operations of truck operators some road infrastructural facilities were in place including climbing or distress lanes in difficult sections, for example, at Konongo; warning signs; crash barriers; weighbridges; reflectors on the road to warn them particularly at night; as well as road markings. A greater proportion, 81.8% of truck operators were of the view that road markings were enough and 28.8% of truck operators opined that these markings were not legible enough. Rest or intermediate facilities designated for freight transporters, principally, hazardous materials transporters were entirely non-existent.

With the road in “Good” condition and ancillary facilities in place accidents involving freight trucks are expected to be low with an even lower risk for hazardous materials trucks. In the year 2015 the Motor Traffic and Transport Department [MTTD] of the Ghana Police Service, Anyinam District recorded 3 incidents involving hazardous materials trucks. They maintained, however, that these incidents were minor without any fatalities. In their opinion, accidents involving freight trucks are largely caused by lack of maintenance, carelessness and negligence, inconsiderate driving and failure to observe traffic rules on the part of truck operators. The Anyinam MTTD does not patrol the highway but rather they conduct occasional checks. Diversion of fuel was noted to be rampant among some Bulk Road Vehicles [BRVs] or petroleum tanker operators and accordingly when they suspect any such action on-going they conduct the road checks.

4.6.5 Operational Challenges of Hazardous materials Truck Operators

Truck operators maintained that their operations were hampered by the lack of intermediate rest facilities, frequent and unnecessary overtaking by other road users, particularly, VIP bus drivers as well as too many toll booths. Apart from the aforementioned, truck operators reported that frequent speed ramps and tables, the small nature and radii of roundabouts in the Kumasi area affect their operations. Negotiating in a small roundabout becomes difficult for truck operators because their vehicles are long and heavy due to loads.

4.7 Summary of Chapter

This chapter has critically examined what is happening on the road currently for hazardous materials truck operators. In particular, their background biostatistics, vehicles they used and products transported. It also examined operational characteristics and challenges that are hampering the smooth operation of truck operators as well as accident statistics on the corridor, causes and consequences and emergency response mechanisms in place to deal with such. Following an analysis of the data gathered from the field, the next sections of the study outline summary of findings and discussions in relation to existing published works and practices elsewhere. Recommendations are proposed subsequently and areas for further research were also outlined.

CHAPTER FIVE

SUMMARY OF FINDINGS AND DISCUSSION OF RESULTS

5.1 Introduction

The foregoing Chapter was devoted to an analysis of survey results and interviews with relevant stakeholders in the hazardous materials transportation industry. Following the analysis, this chapter is focussed on summary of findings from the analysis on one hand, and a discourse or discussion of these results within the context of already existing literature and academic discourse on the other hand. Specifically, the various research questions are answered and discussed taking cognisance of literature reviewed and existing transport policy of Ghana.

5.2 Nature and Characteristics of Hazardous Materials Transportation

5.2.1 Main Hazardous Materials Transported

The surveys revealed that the main hazardous materials transported along the Tema – Accra – Kumasi corridor were petroleum products. Though there were other hazardous materials, such as cyanide and LPG transported on the corridor, they were not as frequent as petroleum products. Indications are that 2,500,000 litres or 60 daily shipments of petroleum products from the Bulk Oil Storage and Transportation [BOST] depot in Tema are transported to the Kumasi depot and areas beyond Kumasi.

5.2.2 Age, Experience and Accident Involvement of Hazardous materials Truckers

For truck operators, experience comes with age and, as expected, older drivers were found to have more years of experience compared to younger drivers. A positive and significant coefficient of determination (R^2) of 0.667 was found between these two variables; suggesting that as age of a truck operator increases, there is an increase in his level of experience. The US Department of Transportation, Federal Motor Carrier Safety Administration [FMCSA] (2005) opined that age of driver has a bearing on the level of involvement in accidents. Findings from this study show that older drivers were involved in more accidents in the last ten years compared to younger drivers. Similarly, a study in Australia by Duke, Guest and Boggess (2010) reveals that accidents among truck operators were higher for both younger and older truck operators; depicting the characteristic U-shape distribution. They observed higher accident rates for truck drivers aged less than 27 and those aged more than 60 years.

In contrast, Borowsky, Shinar and Oron-Gilad (2010) as well as Borowsky, OronGilad and Parmet (2009) have shown that older and experienced drivers had the ability to detect hazards and, consequently, are able to avoid accidents. Consequently, these drivers are not overly involved in road accidents. Current findings from this study may appear limited, because it was also found that 25.9% of truck operators had less than 5 years of experience; an indication that they were not driving hazardous material trucks in the whole of the last ten years. This may account for the seemingly high accident rates for older truck operators. In addition, the study by Borowsky,
Shinar and Oron-Gilad (2010) was a controlled 'indoor' experiment; which is not in a natural setting, in which case the truck operators would have been prompted and biased in their decisions. As a result, their finding may be skewed towards older truck operators.

It is evident from current findings that, the number of accidents a truck operator is involved in is not entirely explained by his age. Other factors including prevailing weather condition, Hours of Service, mechanical defects, speed levels as well as age of packaging materials among other factors. Indeed, the HMCRP (2009) provides a detailed list of likely causes of accidents involving hazardous freight.

5.2.3 Hours of Service and Intermediate Rest Facilities

Studies, including those by Duke, Guest and Boggess (2010) as well as Summala and Mikkola (1994), have shown that controlling Hours of Service or driving hours is a major step towards reducing or minimizing accidents for truck operators, particularly hazardous materials truck operators. Indeed, as a general best practice the world over, truck operators are mandated to break their journeys after four consecutive hours of driving. Currently, on the Tema – Accra – Kumasi highway, there appears to be a fairly high level of compliance with this regulation. Cumulatively, 80.6% of hazardous material truck operators abide by this regulation, breaking their trips after between two to four hours of continuous driving. Having most hazardous freight transporters breaking after the fourth hour of continuous driving is a good indication that they will not be likely to dose of in the course of transportation which might result in accidents.

It is also worthy of note that about 20% of truck operators flout the Hours of Service Regulation of four hours with some driving continuously for up to seven hours. To a large extent these truck operators who flout the mandatory four hours break do so partly because of the non existence of intermediate facilities designated for such rests. Here, the leader and followership scenario proposed by Gzara (2013) does not seem to work as the regulator or state institutions have not provided necessary facilities to ensure compliance. Undoubtedly, there could be better and higher levels of compliance if the enabling environment is created in the form of truck parks (Heaton, 2005; and Jensen and Dahl, 2009). However, Carrese, Mantovani and Nigro (2014) arguing for the provision of truck parks, maintained that these parks must provide adequate security. In order to make truck parks financially viable investments, there must be studies on willingness of truck operators to pay for such facility and level of services on offer.

In a recent study on feasibility of the proposed Boankra Inland Port project, which will provide all these facilities including warehousing, cold storage and security among others, freight trucks operators have expressed their willingness to pay for the services to be rendered. With this general commitment from freight transporters, it will be prudent on the part of hazardous freight transporters to also use the services of freight parks or truck terminals along the corridor. Caution must be exercised not to put together "normal" freight with hazardous freight to forestall any eventualities. In furtherance of this, having separate freight terminals for normal freight and a dedicated terminal for hazardous freight will be a step in the right direction.

The absence of intermediate rest facilities only worsens the plight of truck operators because following long hours of continuous driving fatigue sets in and then they become vulnerable to accidents. Summala and Mikkola (1994) studied the effects of age, fatigue and alcohol consumption on fatal accidents among car and truck drivers. Their conclusion was that fatigue was less of a problem for truck operators. Taking this finding as valid, the introduction of intermediate rest facilities will only yield more positive effects.

5.3 Hazardous materials Transportation Risks on the Tema – Accra – Kumasi Highway

5.3.1 Risks and Accident Rates involving Hazardous materials Transporting Trucks

The risks involved in transporting petroleum products are both an accident risk and an exposure risk (Saccomanno and Chan, 1985; Kazantzi, Kazantzis and Gerogiannis, 2011). As Kazantzi, Kazantzis and Gerogiannis (2011) have put it, accidents involving hazardous materials are likely to be one of either a mere accident, in which case only products and vehicle involved are damaged, or an exposure, where populations, property and environment are exposed to harm as a result of any accident. There could also be combined cases where there is both an accident and an exposure of populations, property and environment to risk as in the case of petroleum products. However, considering that petroleum products form a huge chunk of all hazardous materials transported on the Tema – Accra – Kumasi corridor, there is both an accident and exposure risk associated with hazardous material accidents. Indeed from the analysis it was realised that probability of a hazardous material accident ranged between 0.0000016 and 0.0000060 accidents per vehicle-km. Accident probabilities were higher on relatively longer road sections, including those between Bunso – Nkawkaw and Nkawkaw – Konongo (see Table 4.5.5).

The reported accident probabilities on Bunso-Nkawkaw and Nkawkaw-Konongo sections are higher partly because these sections are long stretches spanning over 50 km, with few speed ramps and tables, where truck operators tend to speed. For example, the Nkwakaw bypass is a four-lane dual carriageway that runs on the outskirts of the Nkawkaw township with virtually no communities along the stretch.

Consequently, truck operators tend to "overspeed" on this section and this may account for the relatively high probabilities of accidents on such long stretches. A sound justification for the construction of bypasses around most towns is to reduce traffic congestion and also avert road crashes. However, if accident probabilities are high on this sections pertly because of over speeding, it is only prudent to have speed management tolls such as speed ramps, rumble strips and horizontal curvatures to control over speeding.

Considering the accident probabilities and the populations at risk of hazardous material accident, it was estimated that 0.09144 inhabitants living within high risk zones along the highway stand a risk of a hazardous materials accident per vehicle-km involving a single shipment. Given that there are about 60 truck shipments of hazardous materials everyday, indications are that 5 inhabitants per vehicle-km are likely to be killed or injured from an accident involving a hazardous materials truck; translating into 1,467 inhabitants along the entire stretch from Tema through Accra to Kumasi. With very low accident probability 0.0000770 or (77×10^{-6}) the consequences based on pessimistic estimates could be about 1500 human lives in addition to property loss and decline in environmental quality.

5.3.2 Risk Prevention and Management

Transportation of hazardous materials is challenged with a lot of risks; and consequently, a number of measures have been adopted and used to mitigate such risks. From the review of literature, it was realized that there were both preventive measures and also some measures used to mitigate or minimize the extent of damages likely to occur in the event of an accident. The preventive measures include toll policies, establishing inspection stations, driver training, controlling driving hours, vehicle and container design as well as specification. The measures that are aimed at reacting to accidents, in a bid to reduce devastating consequences include: emergency response planning where emergency service providers are located along roads, especially at dangerous sections, re-routing of vehicles in times of accidents as well as route selection. It must be noted, however, that route selection could be treated both as a preventive measure; in which case specific routes are dedicated to transporting hazardous materials, and a reactive measure, where some roads are closed to traffic in order to deal with accidents.

From the surveys, it was realized that all truck operators along the Tema – Accra – Kumasi Highway adopt one method or a combination of methods to prevent risks. Insurance was the most widely used method (35.9%). Although insurance may be more of a reactive than preventive measure its wide use can be attributed to the dire consequences associated with even a single hazardous material accident. However, with low probabilities of accidents involving hazardous material trucks, the seemingly high dependence on insurance could be explained in part by the consequences and not to prevent the accident from happening in the first place. Considering that this method appears to be rather a reactive measure, its dominance is challenged by the inability to be used in preventing risks. Knowing that insurance covers products and persons affected in times of accident, some hazardous truck operators may be complacent and not take proactive measures in risk prevention.

Route selection is the next widely used method of risk prevention with 32.9% of hazardous material truck operators adopting this method. Route selection offers advantage of minimizing costs as was argued by Frank, Thill and Batta (2000).

However, it also has the disadvantage of exposing only populations that live along selected routes to risks of hazardous materials accidents; resulting in resistance against route selection or designation. For long distance journeys, even though route selection comes with some added advantages, it does appear not to be desired because of lack of alternative highways or routes. In the current study, for example, truck operators between Tema/Accra region and Kumasi as well as areas beyond Kumasi are confined largely to the Tema – Accra – Kumasi (N6) highway for lack of alternatives. In effect, route selection as a means of risk prevention and management is suitable for more frequent internal movements or shipment of hazardous materials between origins and destinations.

To a very large extent, driver training has been used extensively in the hazardous material transportation industry. This is evident from the study as 90.6% of truck operators reported having undertaken some professional training programs albeit at different intervals. Kara and Verter (2004) as well as Erkut, Tjandra and Verter (2007) have argued for this method of risk prevention to yield desired results of preventing accidents. However, the responsibility of training truck operators rests on employers, in this case Transport Service Providers [TSPs]. Major TSPs including Vehrad Haulage and Transport Company, Total and Goil Ghana Limited as well as medium sized ones like TT Brothers, JK Horgle, Ahiadome, Kodson, Legacy and Okodatt provide regular professional training for their truck operators. What is not clear is that, given that there are a number of TSPs in this sector their respective requirements may differ. It is possible that while some TSPs will attach priority to expansive training, others that are specialized in transporting particular products, such as petroleum transporters, may concentrate on product safety. Indeed, findings from Kuncyté *et al.* (2003) suggest that in Sweden emphasis was placed on accreditation of training institutions whereas in the Netherlands prominence is given to the examinations used in testing drivers who have undergone the training. In Ghana, there is no distinct regulatory institution responsible for ensuring professional training of hazardous material truck operators. Consequently, content of professional training as well as examinations are left in the hands of the various Transport Service Providers.

In container specification, for example, it was found that all truck operators used appropriate packaging material for transporting the various products. Truck operators transporting petroleum products, for example, use bulk tankers with the required labels and placards. Though Milazzo *et al.* (2009) have acknowledged that labelling hazardous material trucks puts them at potential terrorist attacks and public fear and panic, their use as a measure to mitigate risks cannot be overemphasized; and subsequently, it has been used extensively on the Tema – Accra – Kumasi corridor. However, the debate on whether to promote this method of risk prevention in the wake of rising terror in the West African sub-region still lingers on. To an extent, some scholars might still advocate for this method considering it had yieled some results in countries where it has been practiced. Others, who may not be in favour of the existing situation, can argue for its abolishment or withdrawal of use.

In all the preventive measures acknowledged from literature, the use of tolling policies as well as inspection stations are virtually non-existent in Ghana. For tolling policies to work effectively there ought to be a number of other road alternatives such that high tolls are charged on roads that are not to be opened to hazardous materials transport. This tool, as it stands, can only be used in built up parts of town to restrict the use of certain road segments. However, inspection stations, on the other hand, will prove to be effective on highways compared to intra city roads. Inspection stations, when in place, will further strenthen compliance with laid down rules and regulations governing the transportation of hazardous materials particularly on highways. As a temporary measure, mobile inspection stations can be used just as is done for axle load control to help strengthen enforcement and compliance with hazardous material transportation regulations.

In spite of the foregoing preventive or proactive measures, there still persists some level of accidents involving hazardous materials, and as such reactive or mitigative measures also need to be in place to deal with such unlikely accidents. While the use of Spatial Decision Support System [SDSS] is extensive in more developed countries (Zografos and Androutsopoulos, 2008; Beroggi and Wallace, 1995), it appears to be under utilized in a developing nation like Ghana. This phenomenon could be explained partly by the unavailability of data required in building the database out of which support decisions are made. Even when the required database is in place, the use of SDSS is mainly centered around re-routing of vehicles to other roads in the event of accidents. Considering that there is virtually no alternative to the Tema – Accra – Kumasi highway, the use of SDSS would not yield the full benefits it offers. However, in the mean time, some Transport Service Providers such as Total and Shell Ghana Limited have installed vehicle tracking devices on their vehicles, which helps to know the whereabouts of vehicles at any point in time. With this functionality, it cannot adequately support decision making in the time of accident, but, will be able to monitor the movememt of trucks to prevent a situation where truck operators divert from designated routes. One interesting feature of this tracking system is the ability to spot any stationary position of the truck at any point in time, and therefore, can help to ensure that truck operators do not park or stop at areas that have high risks and renders the trucks and products more vulnerable.

In the absence of a more sophisticated SDSS, truck operators use rudimentary tools and methods such as fire extinguishers, foam, rags, bucket, saw dust, cutlasses, pickaxe and shovels to deal with some mild cases. However, when the scale of accident is large, they resort to their respective private garages or "yards" for emergency services. In addition, the services of the Ghana Police Service, Ghana Ambulance Service as well as the National Road Safety Authority are solicited during accidents. This view is corroborated by discussions with the Anyinam MMTD who attested to receiving distress calls from truck operators when there is an accident. The emergency service response is enhanced by the emergency contact numbers displayed on hazardous material trucks.

From the foregoing discussions, it is safe to conclude that a lot of measures are in place to prevent accidents on one hand and to deal or react to accidents on the other hand. However, the use of mobile inspection stations could be adopted to ensure maximum compliance among hazardous material truck operators on the Tema – Accra – Kumasi highway, in particular, and all freight transporters in general.

5.4 Operational Characteristics of Hazardous Material Truck Operators

5.4.1 Capacity of Vehicles Used in Transporting Hazardous Materials

Identifying the capacity of vehicles used in transporting hazardous materials is important in order to understand the risks posed. In this study, it was realized that Larger Capacity Vehicles [LCVs] were predominantly used albeit with a few smaller capacity ones. The few smaller capacity trucks were being used to service fuel filling stations directly with products. In order to reduce the number of truck shipments made, HMCRP (2009) as well as Duke, Guest and Boggess (2010) propose the use of Longer Combination Vehicles. Longer Combination Vehicles would appear to be efficient when there are lanes dedictaed solely for freight transport; hence there will be no need to switch lanes during transport. However, considering that in Ghana there are no dedicated roads for freight transport, the use of Longer Combination Vehicles will appear to be out of place, especially, for hazardous freight. Because of the nature of such products, transporting them in Longer Combination Vehicles will reduce the risk of accidents because fewer shipments can accommodate large volumes of products. This not withstanding, any accident involving a long combination vehicle will imply more consequences given that the area affected will be larger compared to a single 6-axle truck and more volumes of the material in question are exposed to the public and environment. Consequently, the use of Longer Combination Vehicles are not to be encouraged in the short to medium term barring the provision of dedicated lanes to hazardous material transportation by road or rail is in place.

In addition, it has been opined by de Palma, Kilani and Lindsey (2008) that, to enjoy the full benefits of dedicated lanes for trucks several factors come into play; including the relative volume of trucks as agianst cars, safety hazards posed by different vehicle types and value of travel time for each vehicle type. Considering that hazardous material traffic volumes form only about 1% of total vehicles per day (see Table 3.5.1), having dedicated lanes will rather be uneconomical and, besides, there are sections of the Tema – Accra – Kumasi highway that have two lanes and two directions (see Table 4.6.7) which will not support dedication of lanes for particular vehicles. In the short term, because of very high unitary rates for road construction (US$ 613,929 per lane km) in Sub-Saharan Africa (Africon, 2008), constructing additional lanes to be dedicated to the transportation of hazardous materials will not be economical. However, in the long term, when traffic volumes might increase and economic benefits outweigh economic costs of constructing new and dedicated lanes this option could be considered.

The study findings show that 75.9% of trucks used in transporting hazardous materials are 6-axle trucks with permissible axleload of 60 tonnes. The use of such larger capacity trucks, Guo and Verma (2010) argue, has the potential to reduce accident risks because fewer truck trips will be required to ship large volumes. Much in the same vein public fear and panic, expressed in terms of potential terrorist attacks, is assuaged because there will be fewer shipments of hazardous materials as has been argued by Milazzo *et al.* (2009). Consequently, the use of larger capacity trucks could be promoted, especially for bulk hazardous materials such as petroleum products. Nonetheless, caution must be exercised because of potential abuse which may culminate into an institutionalised overloading of freight trucks; which will worsen the deterioration of the study corridor.

5.4.2 Maintenance Culture and Condition of Trucks

The sheer harmful nature of hazardous materials warrants the use of vehicles that are in good condition at all times they are used in transporting products. Any mechanical fault with the vehicle could degenerate into fatal accident with severe consequences. The condition of hazardous material trucks is tied, invariably, to the maintenance culture adopted by truck operators. The study's findings indicate that all truck operators undertake maintenance, although at varied intervals. This finding suggests an improvement in maintenance culture as Maunder and Pearce (2001) also found that few truck operators in Ghana followed scheduled maintenance.

The hazardous material truck operators' maintenance culture appears to be better than truck operators in general, partly because of stringent measures put in place by industry stakeholders to ensure safety during transportation of hazardous materials. For example, from the interview with Air Liquide Ghana Limited, they contended that no truck can be loaded with products unless it passes a series of checks; including: tyres, battery terminals, packaging materials and aeration. Similarly, the National Petroleum Authority [NPA] conducts tests on the vehicles used to transport petroleum products and deems a vehicle 'fit' to be used. When a vehicle is declared fit to be used in transporting petroleum products, it is verified by NPA stickers displayed on each truck which is renewable after every six months. Vehrad Transport and Haulage Company, transporters of cyanide to mines both locally and internationally, also perform series of checks on their trucks on a daily basis before dispatching a truck to transport products. The checks include mileage or kilometers travelled, diesel oil level, brake fluid level, water coolant level, batteries and terminals, trailer coupling system, reverse, brake and indicator lights, steering system, seatbelts as well as fire extinguishers. A sample of the checklist is attached as Appendix 5a.

Another key finding is the resort, by hazardous truck operators, to the use of their respective Transport Service Providers' company owned garages for maintenance rather than private wayside mechanics. From the study by Maunder and Pearce (2001), it came to light that drivers in general do not engage in preventive or proactive maintenance. Instead, they visited maintenance shops when vehicles developed faults. However, current findings indicate that majority of hazardous material truck operators undertake preventive maintenance. This could be explained by the sheer nature of products they carry and risks associated with potential accidents.

5.5 Summary of Chapter

This chapter sought to present a summary of findings from the study following which study results were discussed in line with current body of knowledge on the transportation of hazardous materials on highways. Specifically, the study's results are presented along the same lines as the research questions and subsequently subjected to scrutiny within the context of existing literature. In detail, the main types of products transported, the transporters (in terms of age, level of experience, Hours of Service) as well as the vehicles (their ages, capacity, current condition and maintenance culture) used were discussed. In addition, various risk prevention measures adopted by truck operators on the Tema – Accra – Kumasi corridor were presented and discussed. Truck operators' risk management measures were also discussed within the context of existing literature.

Following these discussions, the next section, Chapter Six, is dedicated to recommendations. These recommendations are tailored to address existing challenges within the hazardous material transportation industry as well as to help improve upon current gains or achievements. In addition, gray areas or areas for further research are highlighted following which a conclusion is drawn to wrap up the entire study.

CHAPTER SIX
RECOMMENDATIONS AND CONCLUSION

6.1 Introduction

The transportation of hazardous materials on highways poses a great measure of risks to humans, property and the environment. Notwithstanding these threats or risks, there are frequent shipments of such materials on a daily basis, particularly on highways. As a result, research is required to assess the extent of such risks, in addition to understanding the preventive and mitigation measures employed by various stakeholders in dealing with the situation. The objective of this study is to fill the void in literature pertaining to transportation of hazardous materials on the Tema – Accra – Kumasi (N6) highway, the most heavily trafficked highway in Ghana. Specifically, the study assessed the hazardous materials that are transported, their volumes as well as origin and destination flows. In addition, age characteristics, of both truck operators and vehicles used in the process of transportation, were also outlined. Various accident preventive measures employed by relevant stakeholders were documented in addition to mitigation measures.

The preceding chapters were centered on general background or introduction to the study, review of pertinent and current literature on transportation of hazardous materials, research methodology adopted for the current study, presentation and analysis of field results as well as a discussion of research findings in the broader context of existing literature or body of knowledge on the subject.

As part of the study's mandate, this Chapter is dedicated to making recommendations, for the short, medium and long terms, to address pertinent areas that require some efforts to be improved upon. Also, where new measures all together are required, recommendations are put forth to address them. Following these, areas for further research on the topic are proposed. These are intended to elaborate further on understanding the characteristics of road transportation of hazardous materials, particularly on highways. Conclusion to the entire study is outlined subsequently.

6.2 Study Recommendations

This research, in itself alone, cannot be a panacea to the myriad of challenges pertinent in the hazardous materials transportation industry. The following recommendations are made based on the study's findings to enhance the operations of truck operators, and to ensure general safety in the transportation of hazardous materials. These recommendations are, however, structured under short, medium and long term interventions to facilitate what ought to be done subsequently.

6.2.1 Short Term Recommendations

The study's findings point to the fact that Hours of Service regulation is not adhered to by some truck operators. The extent of non-compliance (about 20%) among hazardous material truck operators is high. However, evidence from this study and elsewhere have shown that, factors such as the absence of intermediate rest facilities and inspection stations contribute to truck operators' non-compliance with Hours of Service regulation. Consequently, in the short term, the following recommendations, aimed at ensuring maximum compliance among hazardous material truck operators, are listed and discussed seriatim:

6.2.1.1 Establishment of Mobile Inspection Stations

Traditionally, static inspection stations have been used to monitor compliance among freight truck operators generally. With inspection stations coupled with strict enforcement of regulations in place, non-compliant hazardous material truck operators will be compelled to adhere to laid down rules and regulations. At the moment, partly because regulatory mandate is shared among different institutions such as the Environmental Protection Agency [EPA], Ghana Highway Authority [GHA] and National Petroleum Authority [NPA], enforcement on the roads is virtually nonexistent, except for on-the-spot checks by the MTTD of Ghana Police Service. However, with the introduction of mobile inspection stations by the National Road Safety Authority [NRSA] in collaboration with the Ghana Highway Authority [GHA], which will function as a "one stop shop" with all the relevant institutions' rules and regulations, the level of compliance among hazardous freight transporters will be boosted to ensure safe transportation of products between origins and destinations.

Concerning Hours of Service regulation, documentation showing time of departure from origin as well as the journey plans of truck operators will help inspection officers to effectively monitor truck operators. Hall and Intihar (1997) have acknowledged that the paperwork associated with inspection stations is burdensome. However, the proposed mobile inspection units should adopt a more convenient computer based verification of documentation just as the Ghana Community Network [GCNet] Services Limited does with transit trucks that are used to transport freight across national borders to and from Sahelian destinations; including Burkina Faso, Niger and Mali.

6.2.1.2 Promoting the use of Tracking and Communication Devices

While the use of tracking and communication devices is already in place, it is limited to only larger Transport Service Providers [TSPs] such as Shell Ghana Limited, Total Ghana Limited and Vehrad Transport and Haulage Company Limited. Considering the advantages offered by this method; including: ability to monitor products and vehicle movements as well as controlling over speeding, policy interventions to deal with over speeding and hours of service regulation should be geared towards a complete utilization of vehicle tracking among all TSPs. Consequently, it is recommended that all Transport Service Providers [TSPs] install and use tracking and communication devices on their trucks. The tracking information can be displayed on a shared computer based platform where the National Road Safety Authority, TSPs as well as other road sector agencies including the Ghana Highway Authority can monitor in real time the operations of truck operators that transport hazardous materials in particular.

In addition to the aforementioned advantages, tracking devices will also ensure that hazardous material transporters park their trucks at designated Safe Parking Places [SPPs] in the short term. TSPs can monitor truck locations and also uncover any diversion of products once the vehicle conveying the products sets in motion. The introduction of tracking devices will help to reduce the risks or dangers that are posed by some truck operators who park in unsafe locations such as the Nkawkaw bypass.

6.2.2 Recommendations for the Medium Term

While encouraging the adoption of the short term recommendations to give a ‘quick fix’ response to the issues raised by the study, the following recommendations also hold valid for the medium term:

6.2.2.1 Establishment of Intermediate Rest Facility

Transporting hazardous freight over long distances comes with fatigue or exhaustion rendering truck operators vulnerable to accidents. In order to forestall such eventualities, Hours of Service regulations of four hours (where truck operators break their journeys to rest) have been used as a best practice over the world. On the Tema – Accra – Kumasi corridor, it was observed from the study that some truck operators were defying this regulation partly because of lack of designated intermediate rest facilities.

It is recommended that in the medium term, designated Safe Parking Places, which constitute an integral part of road infrastructure, are constructed by the Ghana Highway Authority for hazardous material trucks at a location just around Nkawkaw.
Considering that all the hazardous materials transported on the Tema – Accra – Kumasi highway originate from the Tema/Accra area, and have destinations largely in Kumasi, the intermediate rest facility should be sited around the Nkawkaw area on the outskirts of the township. The choice of location takes cognizance of average speed levels as well as mandatory Hours of Service regulation.

This facility should be installed with all the relevant ancillary services such as wash rooms, bed spaces as well as grocery or snack shops to enhance its usefulness. This intermediate rest facility can be laced with mobile inspection stations such that both inspection and mandatory rest are observed at a go. This would save valuable time, ensure timely or just-in-time stock delivery and also ensure that safety precautions are being adhered to in the process of transporting hazardous materials.

6.2.2.2 Controlling Age and Experience of Hazardous materials Truck Operators

This will require efforts from the various state institutions mandated with ensuring safe transportation of hazardous materials, particularly Driver and Vehicle Licensing Authority [DVLA] and National Petroleum Authority [NPA]. By this measure, only truck operators who have at least 5 years of experience in handling non-hazardous products, and in addition, are aged more than 25 years should be permitted to transport hazardous materials.

Considering that truck operators aged between 21-30 years (22.1% of all truck operators interviewed) account for about 20% of all accidents observed in the last 10 years, gives credence to the fact that they have relatively less experience in handling such trucks, and as such were more susceptible to accidents. This recommendation is aimed at making sure that younger truck operators gather some experience from handling non-hazardous freight before moving or graduating on to handle hazardous freight. With additional professional training, albeit at frequent and regular intervals, in handling or transporting hazardous materials, the rate of accident will be reduced further. Indeed, Erkut, Tjandra and Verter (2007) have demonstrated that driver training has a positive bearing on accidents, and consequently, ensures safe and efficient transportation of hazardous materials on highways.

6.2.2.3 Promoting Public Education and Creating Awareness on Hazardous Materials

Although hazardous product shipments are made on a daily basis little attention has been paid to educating the citizenry, particularly inhabitants living in communities along the Tema – Accra – Kumasi Highway who are at high risk, on the dangers of coming into contact with such products. In addition, they are not even aware of any defense mechanism to provide first aid or deal with any accidents involving hazardous materials. For the time being, some truck labels indicate the materials that are being transported but are lacking in terms of what a victim, bystander or eyewitness can do in times of accident. From the Techiman accident in 2008 involving an overturned petrol tanker; where 22 casualties and over 50 serious injuries were recorded, it is obvious that locals, may not have an idea not to scoop fuel from accident vehicle, went ahead to do that at the peril of their lives. This could be partly because no sensitization has been carried out on dangers associated with hazardous materials during transportation.

As a consequence, there is the need for stakeholders; including: producers, transporters and regulators such as the NPA, to undertake massive awareness campaigns in all the districts, especially in communities close to the Tema – Accra – Kumasi Highway. The District Assemblies can be used as focal points to reach to the people, and when this is done successfully, local residents will be better placed to, at least, provide some form of first aid to victims while also calling for help from professional emergency response service providers.

6.2.3 Recommendations for the Long Term

In the long term, the state institutions are opened to a number of options to choose from considering the time frame involved, usually more than five years. Either one or a combination of the recommendations is expected to yield maximum returns in terms of ensuring economic, social and environmental sustainability. The following recommendations are put forth for the long term:

6.2.3.1 Promoting the Use of Environmentally Friendly Means of Transport

Transporting hazardous materials by road has the long term impact of causing deterioration of road pavement, considering that these products are transported in large volumes; even though hazardous material truck operators do not exceed axle load limits on the Tema – Accra – Kumasi corridor. The study's findings also show that petroleum products are the most dominant products transported. Already, studies such as Poku-Boansi, Okyere and Adarkwa (2012) have shown that current road transportation situation in Kumasi, and other cities in Ghana, is not sustainable. There are high levels of greenhouse gas [GHG] emissions associated with burning of fossil fuels during road transportation (Demir, Bekta and Laporte, 2014). As a long term measure, the Ministry of Transport should as a matter of policy compel the Bulk Oil Storage and Transportation [BOST] Company Limited to use rail tanks in transporting hazardous materials from production centers clustered in the Accra/Tema area to the consumption centers dotted across the country. It has been part of government agenda to reconstruct the Eastern Railway Line and an Inland Port at Boankra, near Kumasi. When this becomes operational in the long term hopefully, then hazardous freight can all be shipped to Kumasi and areas beyond it using the services of the railway operator. Reason and Crepaldi (2009) argue that trains offer three times more fuel efficiency compared with trucks and that when 1% of truck freight is diverted on to the rail, it will reduce greenhouse gas emissions by 1.2 million tonnes annually.

Aside the use of rail as an environmentally friendly means of transport, the partnership of the Volta Lake Transport Company [VLTC] and Bulk Oil Storage and Transportation [BOST] Company Limited should be explored further so that capacity will be increased to have all petroleum product shipments destined for Kumasi and areas beyond it to be transported by barges on the Volta Lake.

These accentuate the need to adopt rail and water transportation of hazardous materials. Besides, helping to reduce greenhouse gas emissions, the use of water transport and the rail will imply longer lasting road pavements, reduced congestion in towns and an overall improvement in the economy both at local and national levels.

6.2.3.2 Establishing Dedicated Hazardous materials Emergency Response Teams

Emergency response as it stands now is rendered by the Ghana Police Service, National Disaster Management Organization [NADMO], Ghana Ambulance Service as well as

Ghana National Fire Service [GNFS]. These institutions have a general mandate to deal with any kind of accidents. However, considering the rather peculiar nature of hazardous materials, and unconventional response measures required, it is recommended that in the long term, a National Hazardous materials Emergency Response Team is established as an arm of the National Disaster Management Organization [NADMO] and equipped with state of the art equipment to combat any accidents involving hazardous materials.

Companies or producers may have in place their respective hazardous materials response teams (Stephens, 2009) and, indeed, as was confirmed in this study, various TSPs including: Vehrad Haulage and Transport Company Limited, Shell Ghana Limited and Total Ghana Limited, have in place emergency response teams that are called upon in times of accidents. However, because these emergency response teams are stationed in Accra and Kumasi, it takes a lot more time for them to react. The effectiveness of emergency response operations borders on timeliness of interventions, and as a result, locating dedicated hazardous material emergency response teams along the Tema – Accra – Kumasi route as well as other major transportation routes, is a step to reduce the consequences of accidents. The quality of service with its attendant swiftness to be provided by the emergency hazardous materials team will be appreciated by both affected communities as well as truck operator victims. This will contribute in dealing with traffic disruption or delays, loss of valuable working hours and corresponding impact on GDP as well as destruction of lives, property and environment that come about as a result of hazardous material accidents.

6.3 Areas for Further Research

It is true that research on hazardous materials burgeoned from the late 1970s (Corn, 1993), but following from the review of literature, it appears that these researches are concentrated in developed countries such as America, Australia and Canada. In developing countries such as Ghana, very little has been done. This study, while concentrating on a selected highway in Ghana, is a contribution to the global discourse on the subject of transportation of hazardous materials. Being a rare one in the planning discipline, it will help policy makers to appreciate the current trends in terms of challenges and prospects that can be leveraged to improve freight transportation in general, and safeguard public safety in the transportation of hazardous materials.

There are, however, a few gray areas, in terms of research that need to be researched into further to boost the knowledge base on transportation of hazardous materials in Ghana. These areas are outlined as follows:

- The current study focused on selected hazardous materials even though other materials are considered hazardous, and are transported on major highways across the country. A full blown study to understand how other hazardous material classes are transported on Ghana's highways; and especially, how each hazardous material class is transported will be in order. When these studies are done, results can influence public discourse on the subject and promote the need for an all-encompassing regulatory framework to guide the transportation of hazardous materials in Ghana.
- The focus of the current study is on highway transportation of hazardous materials taking the Tema – Accra – Kumasi (N6) highway as a case. Further studies will be required on other highways including the George Walker Bush Highway (N1). In addition, there are other routes for the internal distribution of petroleum products to feed various filling stations using smaller capacity vehicles in a rather frequent manner; posing more risks in cities such as Accra, Tema and Kumasi. Further studies are required to understand the operations of internal fuel distribution petroleum tankers; including: frequency of operations, risks posed and challenges faced by truck operators in the process.
- From this study, a strong case has been made for the establishment of an intermediate rest facility on the Tema – Accra – Kumasi highway. In recent times, the Government of Ghana has adopted the Public Private Partnership [PPP] modules in providing and maintaining public infrastructure such as roads. To ensure sustainability in such arrangements, private concessionaires are interested in financial viability whereas the State concerns itself with economic viability. However, the effective and full utilization of intermediate rest facility borders on truck operators' willingness to pay and use the facility.

  Therefore, a full blown study with the mandate of establishing willingness to pay among hazardous material truck operators is required.

6.4 Conclusion of the Study

The objective of this study was to explore and explain the transportation of hazardous materials on the Tema – Accra – Kumasi (N6) highway. It is obvious that there are daily shipments of hazardous materials, particularly, petroleum products and these shipments endear persons, property and environment to potential risks. Although accidents involving hazardous materials are rare, the consequences from just a single accident could be dire, and as such the need to understand how the process of transportation is undertaken. Some study variables including: age and level of experience of truck operators, formal education and professional training, hours of service, configuration of vehicles used, their conditions as well as maintenance culture adopted were used to give a clearer understanding of the current trends in transportation of hazardous materials.

Some of the study's findings indicate that there exists some level of non-compliance from a section of truck operators, intermediate rest facilities necessary to facilitate observation of mandatory rest periods were absent and truck operators used a range of measures including controlling driving hours as well as speed limitations to prevent accidents.

In the light of these findings, some policy recommendations have been proposed to contribute to ensuring safe transportation of hazardous materials on highways in Ghana. These include the setting up of intermediate rest facility interlaced with mobile inspection stations, which are aimed at enhancing the level of compliance to Hours of Service regulations as well as general operational safety.

The study has adequately addressed all the research questions and objectives. However, some few areas are not clear. These include how hazardous materials are transported within the towns. These have been highlighted as keys areas for further research.

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APPENDICES

Appendix 2a

Hazards and Chemical Properties of Various Hazardous Materials

Hazardous Material	Hazard	Chemical Properties
Corrosive Gases: ▪ Chlorine ▪ Ammonia Corrosive Acids: ▪ hydrochloric acid used in the chemical industry to produce polyvinyl chloride (PVC) ▪ phosphoric acid for the manufacture of fertilizers, ▪ Caustic soda for manufacture of	▪ ▪ Destroy body tissues on contact Can irritate the ▪ skin and even burn eyes If inhaled, can irritate nose, throat and lungs If ▪ swallowed, destroy the lining of the mouth, stomach and throat	pH of 2 or lower; and pH of 12 and higher

Flammable liquids: ▪ Petrol ▪ Diesel ▪ Kerosene	▪ Can cause burns as a result of fire	Flash point of 38˚C (lowest temperature at which it gives enough vapour to form an ignitable mixture)
Toxic Materials: ▪ Polychlorinated biphenyls (PCBs) ▪ Dioxin ▪ Furniture Polish ▪ Paints	▪ Poisonous Cause ▪ health effects like acne or rashes to the skin	Flashpoint of between 170˚C to 380˚C

a

VEHICLE TYPES AND THEIR CLASSIFICATION

Vehicle Type	Classification
Taxis	**Light**
Saloon cars	
Pickup/Van	
Small/mini bus	
Medium bus	**Medium**
Large bus	
Light truck	
Medium truck	
Heavy truck	**Heavy**
Semi-Trailer (Light)	
Semi-Trailer (Heavy)	
Truck Trailer	
Extra Large Truck	
Others	

Source: Ghana Highway Authority (2015).

Light trucks comprise 2-axle trucks with single rear wheels or 2-axle trucks with twin rear wheels less than 10 tonnes.

Medium trucks comprise 2-axle trucks with twin rear wheels of at least 10 tonnes.

Heavy trucks comprise 3-axle rigid trucks, including tankers.

Semi/Trailers (Light) are semi-trailers with any configuration of 3 axles.

Semi/Trailers (Heavy) are semi-trailers with any configuration of 4 axles.

APPENDIX 3

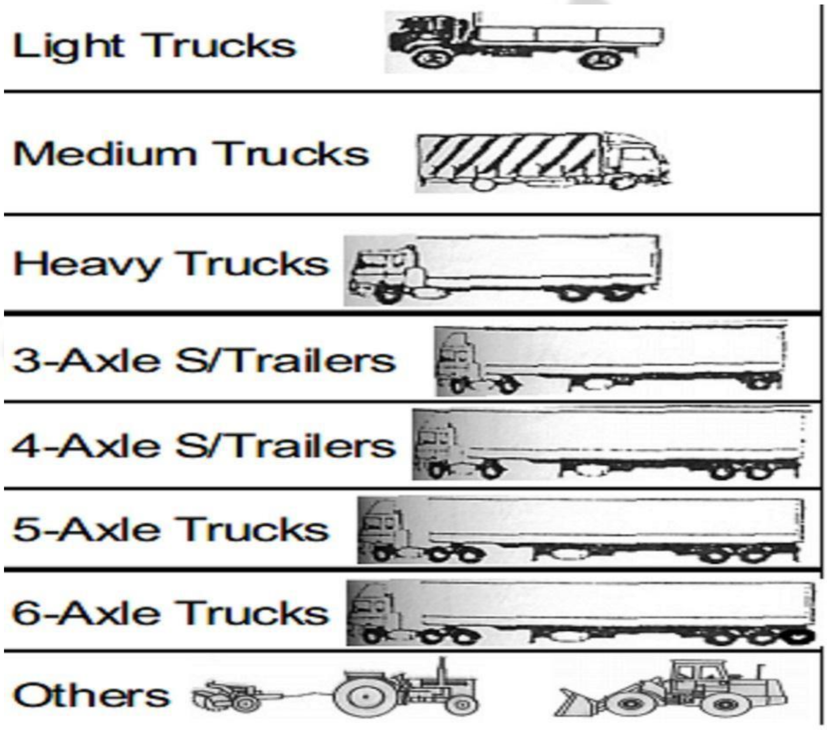
APPENDIX 3a continued

Truck Trailers are large trucks with any configuration of 5 axles.

Extra-large trucks are extra-large trucks with any configuration of 6 axles.

Other mobile and construction equipment include tractors, bull-dozers, graders, or other heavy agricultural or constructional machinery.

Source: ITP Ghana, 2010



b

RESULTS OF THE HOURLY UNCLASSIFIED GROUND COUNT ALONG THE ACCRA – KUMASI HIGHWAY

ROADSIDE TRAFFIC SURVEY ON THE ACCRA-KUMASI ROAD			
CENSUS LOCATION:	KNUST POLICE STATION ROUND ABOUT		
DATE:	13/11/2015		
DIRECTION:	BOTH		
TIME	TO KUMASI	TO ACCRA	BOTH
06:00 - 07:00	714	623	1,337

07:00 - 08:00	1,028	705	1,733
08:00 - 09:00	1,004	709	1,713
09:00 - 10:00	945	837	1,782
10:00 - 11:00	912	879	1,791
11:00 - 12:00	960	787	1,747
12:00 - 13:00	952	635	1,587
13:00 - 14:00	964	825	1,789
14:00 - 15:00	867	1,061	1,928
15:00 - 16:00	1,058	1,139	2,197
16:00 - 17:00	802	815	1,617
17:00 - 18:00	819	798	1,617
TOTAL	11,025	9,813	20,838

Source: Field Survey, 2015

c

SAMPLE SIZE CALCULATION

Confidence Interval = 95% with corresponding z – value of 1.96

Margin of error, Δ = 5%

Proportion of traffic being hazardous, p = 12% = 0.12 n

= sample size

$$n = \left(\frac{z}{\Delta}\right)^2 p(1-p)$$

$$n = \left(\frac{1.96}{0.05}\right)^2 \times 0.12 \times (1-0.12)$$

n = 162.7

d

LIST OF STAKEHOLDERS INTERVIEWED IN THE SURVEY

a) Motor Transport and Traffic Department, Ghana Police Service, Anyinam, Eastern Region;
b) Ghana Highway Authority – Safety Department, Accra;
c) Environmental Protection Agency, Accra;
d) Air Liquide Ghana Limited, Kumasi Factory;
e) Chemico Limited, Tema;
f) Sidalco Ghana Limited; and
g) Bulk Oil Storage and Transportation Company Limited.

Appendix 3e

Questionnaires for Truck Operators

Name of Operator: ………………………Vehicle Registration Number: ……………
Date of interview: ……………………. Location/Cluster: …...…………… 1. How old are you?

[ ] 20 years and below [ ] 21-25 years [ ] 26-30 years [ ] 31-35 years
[ ] 36-40 years [ ] 41-45 years [ ] 46-50 years [ ] 51-55 years
[ ] 56-60 years [ ] more than 60 years

2. For how many years have you been driving such trucks?
   [ ] less than 6 years [ ] 6-10 years [ ] 11-15 years [ ] 16-20 years
   [ ] 21-25 years [ ] 26-30years [ ] 31-35 years [ ] 36-40 years
   [ ] above 40 years
3. What is the last level of education you attained?
   [ ] Never [ ] Primary [ ] JHS [ ] SHS [ ] O/A level [ ] Tertiary
4. What products are you transporting?
   [ ] Petrol [ ] Diesel [ ] Kerosene [ ] LPG [ ] Chemicals [ ] Agro-chemicals [ ] Acids [ ] Paints
   [ ] Other (Please Specify) …………………..
5. Volume of goods being transported …………………….
6. What is the Gross Vehicle Weight (GVW) when loaded with your products? ……
7. Origin of freight ………………………………………..
8. Destination of freight
   [ ] Kumasi [ ] Sunyani [ ] Techiman [ ] Tamale
   [ ] Bolgatanga [ ] Transit to Mali, Burkina Faso, Niger [ ] Wa
   [ ] Other (please specify) ……………………….
9. Cost of transporting hazardous freight? GH₵……………………… 10. Which license class do you possess?
   [ ] A [ ] B [ ] C [ ] D [ ] E [ ] F
11. For how many years have you had this license class?
    [ ] less than 1 [ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5 [ ] 6+
12. Have you had any professional training to transport hazardous materials? [ ] Yes [ ] No
13. When did you have the professional training?
    [ ] less than 1 year [ ] 2-5 years [ ] 6-10 years [ ] 11-15 years [ ] 16-20 years [ ] 21-25years [ ] 26-30 years [ ] 30 + years
14. What were you taught during professional training?
    ………………………………………………………………………………………
    ………………………………………………………………………………………
15. Are you assigned any designated routes for transporting hazardous materials?
    [ ] Yes [ ] No
16. If yes, which route(s) are you assigned to?
    ………………………………………………………………………………………

…………………………………………………………………………………………

17. How many hours do you often drive before breaking the journey [Hours of Service]?

    [ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5 [ ] 6 [ ] 7

Appendix 3e continued

18. What time of the day do you often travel/transport hazardous materials?

    [ ] between 6am to 12 noon [ ] between 12 noon to 6 pm
    [ ] between 6pm to 12 midnight [ ] between 12 am to 6 am
    [ ] between 6am and 6pm [ ] Other (specify) ………

19. How many times have you been involved in any incident/accident while transporting hazardous materials in the last 10 years?

    [ ] 0 [ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5 [ ] 6+

20. What type of accident(s) were you involved in?

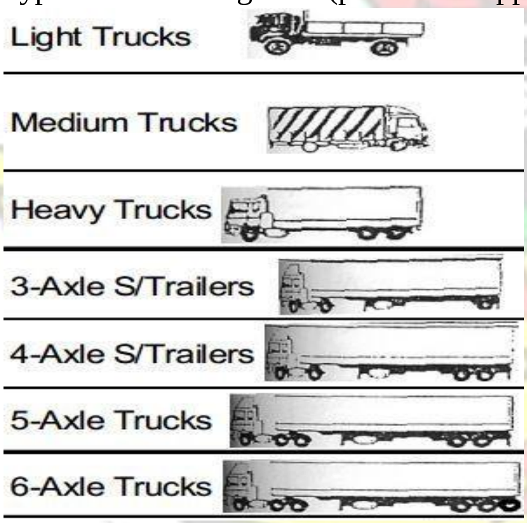
    [ ] Cargo Shift [ ] Jack-knife [ ] Rollover [ ] Collision
    [ ] Fire [ ] Leakage/Spill [ ] Explosion [ ] Gas Clouds

21. Any areas designated as black spots (accident prone) on the stretch from Tema/Accra to Kumasi?

    ……………………………………………………………………………………

VEHICLE

1. Type of truck being used (please tick appropriate one).



2. How old is your truck?

    [ ] less than 6 years [ ] 6-10 years [ ] 11-15 years [ ] 16-20 years
    [ ] 21-25 years [ ] 26-30years 3. [ ] 31 and over

What is the condition of your vehicle?

    [ ] Good [ ] Fair [ ] Poor

4. How often do you maintain your truck?

    [ ] After every trip [ ] every month [ ] every quarter
    [ ] every 6 months [ ] yearly [ ] Other (please specify) ……….

5. Are these designed with safety mechanisms specifically for transporting your products?

    [ ] Yes [ ] No

6. By nature of your products, do you exceed permissible restrictions (W-2.5m, H5m, L-18m)?

    [ ] Yes [ ] No

7. If not, how do you ensure that your products are transported to desired destinations safely?

…………………………………………………………………………………………

8. Location of labels on vehicle.

[ ] None [ ] Rear/Back [ ] Right side [ ] Left side

9. Are labels durable? [ ] Yes [ ] No
10. Are labels easily read and understood? [ ] Yes [ ] No
11. What do labels indicate?

……………………………………………………………….

12. Do they show what people should do in case of an accident? [ ] Yes [ ] No
13. Is there any emergency contact displayed on the vehicle? [ ] Yes [ ] No

PACKAGING

1. What type of packaging do you use?

[ ] Carton/Boxes [ ] Tanker [ ] Drums [ ] Pallets

[ ] Container **[ ]** Bulk [ ] Other (Please Specify) ………

2. Does packaging material have any rollover protection? [ ] Yes [ ] No
3. How old are the packaging materials?

[ ] less than 1 year **[ ]** 1-2 years **[ ]** 2-5 years [ ] 5+ years

4. Do your packaging materials have any defects? [ ] Yes [ ] No 5. What defects are there, if any?

…..……………………………………………………………………………………

6. Are there special cases when you have to overload vehicle? [ ] Yes [ ] No
7. Do you acquire permission from the Ghana Highway Authority to overload? [ ] Yes [ ] No
8. What mechanisms do you put in place to prevent accidents?

………..………………………………………………………………………………

..………………………………………………………………………………………

…

REGULATIONS

1. Is your transportation process regulated by any state agency? [ ] Yes [ ] No
2. What regulations or protocols are used in regulation, if any?

…………………………………………………………………………………………

3. How do these protocols/regulations capture all your concerns as HAZARDOUS MATERIALS transporter?

…………………………………………………………………………………………

4. Which concerns of yours are not captured in the regulations?

…………………………………………………………………………………………

RISK ASSESSMENT AND EMERGENCY RESPONSE

1. By what means do you reduce/prevent risks?

[ ] Route Selection [ ] Spatial Decision Support System [ ] Insurance

[ ] Emergency response [ ] Other (please specify) ……………..…….

2. What type of risks are associated with transporting your products?

[ ] Accident risk [ ] Exposure risk [ ] Combined risk 3.

Which of the following measures do you employ to mitigate accidents?

[ ] regular training [ ] controlling driving hours
[ ] placarding/container specification [ ] Other (specify)…………………

4. Do you have any emergency response teams in case of accidents? [ ] Yes [ ] No
5. Does your vehicle have emergency response kits? [ ] Yes [ ] No
6. Do you communicate to emergency service providers in case of accidents? [ ] Yes [ ] No
7. In your view, what should be done to mitigate HAZARDOUS MATERIALS transportation risks?
   ………………………………………………………………………………………
8. What do you do in case an accident happens?
   ………………………………………………………………………………………
   ………………………………………………………………………………………
9. How do you respond in accident situations in terms of:
   Vehicle ..…………………………………………………………………
   Products.………………………………………………………………………
   Road Surface ………………………………………………………………
   Impacted people/Communities ………………………………………………

INSURANCE

1. Are your products/freight insured during transportation? [ ] Yes [ ] No
2. What is the premium paid for insurance? GH ₵ ……………………
3. In case of accident, how quick is response from your insurers?
   [ ] within a month [ ] within 3 months [ ] within 6 months
   [ ] Within 12 months [ ] more than a year
4. Does the insurance cover persons and property that may be affected?
   [ ] Yes [ ] No

INFRASTRUCTURE

1. In you view what is the condition of the Tema/Accra to Kumasi road? Placard
   [ ] Good [ ] Fair [ ] Poor
2. Average Speed limits …………………………………………….
3. What are some of the facilities provided for truck operators along the corridor?
   ………………………………………………………………………………………
4. Do you have distress lanes at difficult sections of the road? ………………………
5. How many emergency response posts are along the road corridor?
   [ ] None [ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5 and more
6. In your view are there enough road markings? [ ] Yes [ ] No
7. Are these road markings legible enough? [ ] Yes [ ] No
8. Are there any intermediate rest stops designated for hazardous materials transporters?
   [ ] Yes [ ] No
9. In your view which areas are suitable to locate such facilities?
   ………………………………………………………………………………………

…………………………………………………………………………………………

10. What facilities would you like to be installed at intermediate rest stops?

…………………………………………………………………………………………

THANK YOU!

Appendix 3f

Interview Guide for Petroleum Tanker Drivers Association

1. What is the name of the association?
2. How many members belong in the association?
3. How many litres of fuel do you receive daily/weekly or monthly?
4. Are your products insured in the course of transportation?
5. What do the insurance policies cover? Goods, vehicle and third party
6. How much premium is paid?
7. In case of accidents, how quickly do insurers honour claims?
8. What calibre of drivers do you recruit? Those already driving such trucks or you train your own group.
9. What sort of professional training do your drivers receive?
10. How often do they have such professional or regular training?
11. How do you prevent risks?
12. In the unlikely event of accident, do you have emergency response teams that you rely on? Or the Ghana Police Service and GNFS
13. Which regulations guide the transportation of such hazardous materials?
14. What guidelines are specified in these regulations?
15. Do your drivers comply with the prescribed guidelines?

Appendix 3g

Interview Guide for Ghana Highway Authority

1. How are hazardous materials (HAZARDOUS MATERIALSs) transported on our roads?
2. Are they regulated in any way?
3. How are hazardous materials transportation regulated?
4. What existing protocols or regulations are implored in HAZARDOUS MATERIALS transportation?
5. Any sanctions for defaulters?
6. How do you as an institution mitigate HAZARDOUS MATERIALS transportation accidents?
7. Are there any designated roads for HAZARDOUS MATERIALS transportation?
8. If there are, what factors accounted for their designation?

Appendix 3h

Interview Guide for Hazardous materials Importers and Producers

Name of Company: ……………………………………………………………

1. What are some of the products you produce or import?

   ……………………………………………………………………………………

   ……………………………………………………………………………………
2. On average, what have been your production level in the past five (5) years? ……
3. What percentage of your products is transported to Kumasi and beyond? ………
4. How much (weight/volume) is transported on a daily/ weekly basis to Kumasi and beyond?

   ……………………………………………………………………………………
5. How are your products transported? [road, air, water, pipelines, combination/ multimode]
6. What is your means of transport if by road? [Light trucks, Medium trucks, Heavy trucks, S/Trailer (Light), S/Trailer (Heavy), Truck trailer, Extra-large truck]
7. Are these designed with safety mechanisms specifically for transporting your products?
   [Yes No]
8. If not, how do you ensure that your products are transported to desired destinations safely?

   ……………………………………………………………………………………
9. Is your transportation process regulated by any state agency or not? [Yes No]
10. What regulations or protocols are used in regulation, if any?

    ……………………………………………………………………………………
11. Do these protocols/regulations capture all your concerns as HAZARDOUS MATERIALS transporters?
    [Yes No]
12. Which concerns of yours are not captured in the regulations?

    ……………………………………………………………………………………

    ……………………………………………………………………………………

RISK ASSESSMENT AND EMERGENCY RESPONSE

13. Do you conduct any risk assessment? [Yes No]
14. By what means do you reduce/prevent risks? [**a**. Route Selection **b**. Spatial Decision Support System **c**. Insurance]
15. What type of risks are associated with transporting your products?
    [a. Accident risk **b**. Exposure risk **c**. Combined risk]
16. Which of the following measures do you employ to mitigate accidents? [**a**. driver training **b**. controlling driving hours **c**. placarding/container specification]
17. Do you have any emergency response teams in case of accidents? [Yes No] 18. Which emergency response kits are on your vehicles?
    [a. Fire extinguisher **b.** Spill kits **c.** Tracking device **d.** Communication devices
19. Do you communicate to emergency service providers in case of accidents? [Yes

No]

Appendix 3h continued

20. In your view, what should be done to mitigate HAZARDOUS MATERIALS transportation risks?
 ………………………………………………………………………………………
21. What do you do in case an accident happens?
 ……………………………………………………..……….……………………
 ……………..…………………………………………………………………
22. How do you respond in accident situations in terms of:
 Vehicle ……………………………………………………………………
 Products……………………………………………………………………………
 Road Surface…………………………………………………………………………
 Impacted Communities………………………………………………………………

INSURANCE

23. Are your products/freight insured during transportation? [Yes No]
24. What is the premium paid for insurance? GH…………………… 25. In case of accident do your insurers respond quickly enough? [Yes No]
 ………………….
26. Does the insurance cover persons and property that may be affected? [Yes No]

DRIVERS

27. Age range of drivers ……………………………………………………….
28. Drivers' ears of experience……………………………………………………...
29. State of health…………………………………………………………………...
30. Level of training……………………………………………………………………..
31. Qualifications they hold [license A, B, C, D, E, F, G]

VEHICLES

32. Configuration of vehicles used [2, 3, 4, 5, 6, 7and more axles]
33. By nature of your products, do you exceed permissible restrictions (W-2.5m, H5m, L-18m) [Yes No]
34. What is the Gross Vehicle Weight (GVW) when loaded with your products?
 …………………
35. Do some fleet/vehicles have any defects? [Yes No]
36. Do your vehicles have labels? [Yes No]
37. What do your labels indicate, if any? ……………………………………………..
 ………………………………………………………………………………………
38. Do they show what people should do in case of an accident? [Yes No]
39. What are some of the things people should do in case of accident?

…………………………………………………………………………………………

…………………………………………………………………………………………

PACKAGING

40. What type of packaging do you use [**a**. Containers **b**. Pallets **c**. Bulk]
41. Does packaging material have any rollover protection? [Yes No]
42. How old are the packaging materials? **[a**. less than 1 year **b**. 1-2 years **c**. 2-5 years **d**. 5+ years]
43. **Appendix 3h continued**
44. Do they have any defects? [Yes No]
45. What defects are there, if any?

    …………………………………………………………………………………………
46. Are there special cases when you have to overfill containers/ overload vehicle? [Yes No]
47. Do you acquire permission from the Ghana Highway Authority? Yes No
48. What mechanisms do you put in place to prevent accidents?

    …………………………………………………………………………………………

    …………………………………………………………………………………………

INFRASTRUCTURE

49. Road condition……………………………………………………………………………….
50. Speed limits ……………………………………………………………………….
51. Warning signs and road markings (are they available and legible enough for drivers)?

    ……………………………………………………………………………………..
52. Number of Lanes and distress lanes…………………………………………….
53. Any facilities designated specifically for HAZARDOUS MATERIALS transport
    [rest stop, inspection sites]

    …………………………………………………………………………………………

APPENDIX 4a

Results of the Regression

SUMMARY REGRESSION OUTPUT								
Regression Statistics								
Multiple R	0.13045551							
R Square	0.01701864							
Adjusted R Square	-0.019164723							
Standard Error	0.522093224							
Observations	170							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	6	0.769242538	0.12820709	0.470344347	0.829611015			
Residual	163	44.43075746	0.272581334					
Total	169	45.2						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.76216	0.59885	1.27269	0.20494	-0.42035	1.94466	-0.42035	1.94466
Age	-0.00859	0.00808	-1.06264	0.28952	-0.02455	0.00737	-0.02455	0.00737
YoE	0.01296	0.00875	1.48141	0.14043	-0.00431	0.03023	-0.00431	0.03023
HoS	-0.01740	0.04992	-0.34847	0.72793	-0.11597	0.08117	-0.11597	0.08117
Truck Age	-0.00156	0.01814	-0.08581	0.93172	-0.03738	0.03427	-0.03738	0.03427
PM Age	-0.00329	0.02005	-0.16430	0.86970	-0.04289	0.03630	-0.04289	0.03630
Speed	-0.00411	0.00760	-0.54100	0.58925	-0.01911	0.01089	-0.01911	0.01089

APPENDIX 5a

Vehrad Haulage and Transport Company Limited: Daily Checklist of Trucks

Driver Name:							
Date of Issue:							
No.	Checklist	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
1	Mileage						
2	Diesel Oil						
3	Oil Level						
4	Water Coolant Level						
5	Brake Fluid Level						
6	Air System (Leakage)						
7	Tires Pressure & Condition						
8	Wheel rim/Studs/nuts						
9	Twist locks						
10	Turn table or fifth wheel						
11	Trailer coupling hose						
12	Head light						
13	Parking, brake, indicator light						
14	Warning lamp						
15	Radiator/diesel tank (cover)						
16	Reverse lights and alarm						
17	Batteries and terminal						
18	Steering system						
19	Trailer suspension						
20	Driving mirrors						
21	Seat belts						
22	Exhaust system						
23	Fire extinguishers						
24	Wiper blades & Horn						
25	Other Problems						
Results should be either good or bad Bad= X Good= √							
	Driver Signature						
	RTOM Signature						
	Workshop Signature						
	Reporting Date						
	Reporting time						

Source: Vehrad Transport and Haulage Company Limited.