Developing a Framework for Robust Safety Management in Ghana's Upstream Oil and Gas Industry

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DECLARATION

This thesis is submitted under the University of Salford code of practice for the conduct of postgraduate research degree programmes. Some parts of this research have been published in refereed conference proceedings prior to the submission of this thesis.

I hereby declare that this thesis is my unaided work and is being submitted for the award of degree of Doctor of Philosophy at the University of Salford. There is no portion of thesis that had been submitted anywhere for the award of any academic qualification.

Francis Horbah

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Supervisor: ***Prof. Chaminda Pathirage***

ABBREVIATIONS

ABSCS	American Bureau of Shipping Classing Standards
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
BSEE	Bureau of Safety and Environmental Enforcement
CNSOPB	Canada-Nova Scotia Offshore Petroleum Board
DECC	Department of Energy and Climate Change
DFI	Department of Factories Inspectorate
DHSG	Deepwater Horizon Study Group
EIA	Environmental Impact Assessment
EISs	Enviornmental Impact Statements
EMPs	Environmental Management Plan
EPA	Environmental Protection Agency
FAC	First Aid Cases
GAF	Ghana Armed Forces
GCAA	Ghana Civil Aviation Authority
GFC	Ghana Fisheries Commission
GFS	Ghana Fire Service
GMA	Ghana Maritime Authority
GMET	Ghana Meteorological Agency
GNPC	Ghana National Petroleum Corporation
GPHA	Ghana Ports and Harbour Authority
HPCL	Hindustan Petroleum Corporation Limited
HSE	Health, Safety and Environment
ICAO	International Civil Aviation Organization
ICSD	The Institute of Company Secretaries of India
IEC	International Electrotechnical Commission
INSAG	International Nuclear Safety Advisory Group
IOGP	International Association of Oil and Gas Producers
IRGC	International Risk Governance Council
ISO	International Organization for Standardization
KMO	Kaiser-Meyer-Olkin
LTI	Loss Time Injuies

LWC	Loss of Well Control
MHIs	Major Hazardous Industries
MTC	Medical Treatment Cases
NADMO	National Disaster Management Organization
NAENRC	National Academy of Engineering and National Research Council
NASEM	National Academies of Sciences, Engineering, and Medicine
NSC	National Safety Council
OCS	Outer Continental Shelf
OCSPM	Outer Continental Shelf Performance Measures
OECD	Organisation for Economic Cooperation and Development
OGUK	Oil and Gas UK
OHSAS	Occupational Health Safety Assessment Series
PC	Petroleum Commission
PER	Preliminary Environmental Reports
PIAC	Public Interest and Accountability Committee
PNDCL	Provisional National Defence Council Law
PSA	Petroleum Safety Authority
QRA	Quantitative Risk Analysis
RCN	Research Council of Norway
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations
SRA	Society for Risk Analysis
RWC	Restricted Work Cases
TEN	Tweneboa, Enyenra, Ntomme
TRIR	Total Recordable Incident Rate

GLOSSORY OF TERMS

Term	Definition
Safety	Safety is the state of being free from unacceptable consequences (Li & Guldenmund, 2018).
Risk	Potential loss of injury, life, destroyed or damaged assets, and community within a specific time (Noy & Yonson, 2018)
Fatalities	Cases involving one or more deaths of people due to a work-related incident either instantly or delayed (IOGP, 2019a)
Cut, puncture, scrape	Those abrasions, scratches and wounds that can penetrate the human skin (IOGP, 2019a)
First Aid Cases	Cases that are not adequately serious to be reported as medical treatment or more serious cases but still require minor first aid treatment (IOGP, 2019a)
Incidents	Those unplanned or uncontrolled events that have resulted in at least one fatality, recordable injury, or physical or environmental damage (CNSOPB, 2018; IOGP, 2019a)
Injuries	Those injuris like cuts, fractures, sprains, amputations, others., or any fatality, resulting from work-related activities or from exposures containing a single incident in the workplace including one-time chemical exposure, deafness from explosion, back disorder from a slip or trip, insect or snake bite (Stout & Linn, 2002; IOGP, 2019a).
Loss Time Injuies	Non-fatal cases involving a person being unfit to work on any day after an occupational injury (IOGP, 2019a)
Medical Treatment Cases	Those cases that are not severe enough to be reported as fatalities, loss time injuries or restricted work cases but are more severe than requiring simple first aid treatment (IOGP, 2019a)
Near-misses	Those unplanned or uncontrolled events that have not resulted in recordable injury or physical damage or environmental damage but have the potential to do so in other situations (NSC, 2013; IOGP, 2019a)

Restricted Work Cases	Non-fatal or loss time injury cases but did not result in a person being unfit for full performance of his or her regular job on any day after the occupational injury (IOGP, 2019a)
Onshore	All activites and operations taking place within landmass that include those on swamps, lakes and rivers (IOGP, 2019a)
Offshore	All activites and operations taking place at the sea that bays and other inland seas directly connenting to the oceans (IOGP, 2019a)

ABSTRACT

Ghana, as an emerging oil and gas producing country, is expected to have an improved, or a new approach to manage safety to prevent major hazard incidents in the industry. Given the country's experience of poor risk governance regimes before the emergence of the upstream oil and gas industry, it has become imperative to develop a robust safety management regime that can deal with the complexity, uncertainty and ambiguity of risk associated with upstream oil and gas operations. The current safety management regime is underpinned by an engineering risk assessment approach which is inherently inadequate in handling uncertainties of knowledge and potential surprises relative to major hazard incidents. This study aims at developing a framework for robust safety management in Ghana's upstream oil and gas industry. The study followed design science research as its methodological approach, which involved six data collection stages. Data collection methods included documents, quantitative safety data, questionnaire surveys, semi-structured interviews, workshop and focus groups. It must be indicated that the questionnaires recorded a 70.7% — response rate of 300 samples. There were 14 participants involved in the semi-structured interviews, 12 participated in the workshop and 9 for the focus group validation. Data analysis included content analysis, descriptive statistical analysis, factor analysis, and multiple regression analysis. The key findings of the review of the safety statutory and regulatory documents indicated that Ghana's regulatory regime is not robust as there is incoherence and limited scope of the existing regulatory and institutional framework. Main findings of the analysis of the safety statistical data shown a rising trend of incidents mainly triggered by hydrocarbon releases, struck by/impact, falls from height/dropped objects and equipment failure. The key findings of the questionnaire surveys indicated that safety climate factors such as safety supervision, management of change, safety empowerment, safety policies, safety rules and procedures, safety behaviour, safety priority, supportive environment, equipment maintenance and safety communication have a predictive influence on incidents risks. The semi-structured interviews indicated weak risk governance in the industry. The critical safety barriers to the implementation of safety management systems related to poor safety culture issues and lack of investment in safety research and development. A conceptual framework was developed and evaluated to improve safety management in Ghana's oil and gas industry. The study contributed knowledge towards improving the management of complexity, uncertainty and ambiguity of risk associated with the upstream oil and gas industry in Ghana.

CHAPTER 1: INTRODUCTION

1.1 Introduction

This chapter presents the introductory part of the study which introduces the research background, research justification, the research aim and objectives, research scope, research methodology, organisation of the study and the summary of the chapter.

1.2 Research Background

The global economies and infrastructure continue to depend mainly on petroleum products to achieve other important societal goals. This makes the oil and gas industry to be an essential part of the world energy system. The upstream oil and gas industry (i.e. exploration, development, and production and decommissioning related activities) involves complex operations including include large-scale investment, application of sophisticated analytical methods, heavy engineering, and complex projects that need to be managed well to avoid major accidents in the industry. Many aspects of the upstream activities are inherently hazardous that pose risks to human lives, properties and the environment. Managing the safety of these operations entails a partnership of all the performances of the regulatory authorities, industry, labour and other stakeholders to ensure that activities are conducted safely (Lindøe et al., 2014). However, several operations in the past had been marred by the sporadic occurrence of major hazard incidents which resulted in multiple consequences such as the loss of human lives, damage of properties and environmental pollutions (Baram et al., 2014; Attwood, 2017). Even though many advances have been made to the process of safety management in the industry, human and organisational factors continue to contribute to most of the hazard incidents and process failures today (Pariyani & Reniers 2018). This poses a challenge to developing oil and gas countries with weak risk governance structures.

Ghana's industrialisation continues to expand with the existence of several different types of industries. After a successful discovery of commercial quantities of oil and gas in 2007, the upstream oil and gas sector had received many investments from the government and multinational companies for the development of the industry. However, the ambition of any oil and gas organisation is to commence production and maximise recoverable hydrocarbon resources for markets quickly. Ghana became an emerging oil and gas producing country after its first oil production in 2010 from the Jubilee field. The offshore oil and gas operations are located approximately 60 km off the coast of the Gulf of Guinea with water depth ranging from 1200 to 1500 meters (Bergeron & Mutimer, 2012). Currently, the industry is operating with three different oil fields such as *Jubilee*, *Tweneboa, Enyenra and Ntomme* (TEN), and *Sankofa*. This indicates that the upstream oil and gas industry would be critical to Ghana's economic development agenda. Given the need to maximise production, there is also a requirement placed on these organisations to ensure that they conduct their hazardous activities in a manner to prevent humans, facilities and the environment from unacceptable risks.

However, the upstream oil and gas industry commenced under the country's pre-existing weak risk governance structure. Unlike matured oil and gas regulated countries where government defines the Health, Safety and Environment (HSE) regulatory regime for the industry, Ghana's upstream oil and gas activities were conducted under fragmented and limited pre-existing safety regulatory infrastructure under weak regulatory bodies. In this regard, the upstream oil and gas operations had been executed in an integrated team fashion along with internal safety controls. After several years of lack of government effort to develop a befitted safety regime to prevent major hazard incidents from the industry, a new regulatory authority was established in 2013 under the *Petroleum Commission Act* (Act 821) with the subsequent safety enactments of *Petroleum (Exploration and Production) Act* (Act 919) and *Petroleum (Exploration and Production) HSE Regulations* (L.I. 2258) in 2016 and 2017 respectively.

The current safety regime for Ghana's upstream oil and gas industry is underpinned by the safety case approach. This regime requires every oil and gas company in the industry to submit a prepared assessment document that justifies the risk acceptability of their hazardous activities to the regulatory authority for approval. An engineering probabilistic risk assessment approach mainly drives existing safety management. This approach features potential complexity, uncertainty and ambiguity of risk issues. However, earlier experience of risk governance in the country's industrial environment had always created negative consequences to human lives, facilities and the environment (Norman et al., 2015). Despite pre-existence of all the regulatory bodies in the country, industrial accidents in the Ghanaian industry sectors continue to rise due to poor implementation of safety management systems (Atombo et al., 2017). The literature indicated that the economic cost of these industrial accidents in the country is estimated to be $16 million annually. An earlier paper by Kotey (2016) reported some occurrence of incidents in the development phase of the Jubilee field that included near-misses, injuries, process safety events and environmental events. These incidents were attributed to the lack of "operational discipline" or "management deficiencies" in the industry. Operational discipline is about performing all tasks correctly every time. These issues are related to safety management.

Safety management is a matter for both the state and the industry that involves the prescription of norms and activities to see to it that these norms are duly complied (Kaasen, 2014). Safety management is a control problem. There are several organisations in the industry, including state and non-state actors involved in the oil and gas operations. Currently, the government of Ghana has passed a local content law that requires the majority of the local workers and companies to be recruited to participate in the industry. This policy seeks to drive maximum benefits from the exploitation of oil and gas resources. However, it is reported that a gap exists between knowledge and professional practices of the indigenous workforce trained for Ghana's oil and gas activities (Benin, 2017). It is reported that most local organisations lack the technical expertise to undertake oil and gas activities in a way that meet international standards (Ackah & Mohammed, 2018). This has implication for safety management in the country's oil and gas industry. Given the pre-existing risk governance challenges in the country, a proactive approach with learning capability is needed to manage safety in Ghana's emerging oil and gas industry.

1.3 Research Justification

Several major accident enquiry reports (e.g. Cullen, 1990; CSB, 2014) and scientific studies (e.g. Niven & McLeod, 2009; Broni-Bediako & Amorin, 2010; Baram et al., 2014; De Almeida & Vinnem, 2020) have indicated the inherently hazardous nature of the upstream oil and gas operations. These upstream oil and gas operations are associated with risks that have multiple potential consequences to human lives, properties, environment as well as economic costs. Generally, the industry had been marred by major accidents resulting in the erratic occurrence of blowouts, explosions and fires with multiple injuries and deaths among workforce, destroyed or damaged facilities, triggered major oil spills that polluted vast offshore and coastal areas with further destroyed ecosystems, high economic cost and disruption of security of energy supply.

It is established that 20-50% of workers in developed countries have access to sufficient occupational health and safety services, whereas developing countries have only 5-10% (LaDou, 2003; cited in Ncube & Kanda, 2018). Studies have indicated that Ghana, as one of these developing countries, is lagging behind effective safety practices (Annan et al., 2015 Agyekum et al., 2018). There are many challenges with existing safety management practices in the country including lack of comprehensive national safety policies, current safety laws remain outdated, fragmented, and none-deterrent; weak safety infrastructures, lack of resources for existing regulatory institutions and many others (Dwumfour-Asare & Asiedu, 2013; Mustapha et al., 2016; Atombo et al., 2017; Acheampong & Akumperigya, 2018). Given the critical importance of the upstream oil and gas industry to the energy needs and economic growth of Ghana coupled with the increasing investment in exploration and production-related activities, safety needs to be given adequate attention in the industry.

It must be indicated that after several years of oil and gas production in the country, the real picture on safety performance has not been adequately established. As required by the global forum, every member country must submit its yearly safety key performance indicators to the International Association of Oil and Gas producers (IOGP). As it stands now, no safety indicators had been provided yet by the country. However, an earlier indication by Kotey (2016) on some reported incidents during the development phase of the Jubilee field, could not provide an account of the safety indicators of the exploration and production-related activities. Although these reported incidents were less severe in terms of their consequences, Heinrich's (1931) accident Triangle theory clearly indicates that unsafe acts and conditions may begin with minor incidents, and surprisingly lead to less frequent but significant major accidents. According to Bellamy (2012), near-misses or minor injuries have less severe consequences but expose the weaknesses in the system. These preliminary results provide a significant basis for an in-depth empirical study to be carried out to define the safety problem adequately in the industry.

The introduction of local content policies in the upstream oil and gas industry in Ghana has implications for safety management. Local content refers to the *"added value brought to a host nation or region locally through workforce development (employment and training of local workforce) and investments in supplier development in terms of developing and procuring supplies and services locally"* (Daher, 2015, p.3). Given the globalisation nature of the industry, the majority of the operating companies bring along expatriates with the technical know-how and experience. Contrarily, the local content policies allow the majority of the local workers to be employed in the industry. As shown in Table 1.1, in ten years, the majority of the workforce (70-80%) in both managerial and technical levels must be local people in any organisation in the industry. It also allows more outsourcing of local companies into construction-related activities in the industry. The construction-related activities including maintenance and fabrication activities are indicated to be growing mainly in the development and production phases of the upstream oil and gas industry (Misiti & Hebert, 2016; Popat et al., 2018). For example, in the annual report of Tullow Ghana (Tullow Ghana, 2014), 86% of the workforce recruited for the TEN oilfield projects represented Ghanaian workers and many local companies were involved in: supply of support activities (*in exploration stage*); fabrication activities (*in development stage*); maintenance and repair of equipment activities (*in production stage)* demolition, waste management and fabrication activities (*in decommissioning & restoration stage*). As shown in Figure 1.1, the local requirement has been relevant in involving more Ghanaian contracting companies in the upstream oil and gas industry. Studies on local content in the Ghanaian upstream oil and gas industry have established that local workers and companies lack the technical expertise required by the international standards (e.g. Peter & Arthur, 2014; Ackah & Mohammed, 2018). The implications for safety management may include compromising the quality of training and competence and the right attitudes to safety. This is because these are important influences to assure operational integrity (SPE, 2014). Human and organisational factors still continue to contribute to many of these hazard incidents and process failures today (Pariyani & Reniers, 2018). The consistent quality of local human and organisational performance is critical in the operational safety of Ghana's Oil and Gas industry. This makes local labour and contracting organisations essential in the risk governance of the industry.

Table 1.1 Ghana's local content requirements for the upstream oil and gas industry

Human Resource Component	**Inception**	**Five Years' Time**	**Ten Years' Time**
Management staff	30%	50-60%	70–80%,
Core technical staff	20%	50-60%	70-80%
Other staff	80%	90%	100%

Fig. 1. 1 Fabrication activities in Ghana's upstream oil and gas industry

Source: J & P Engineering Ghana

However, there is no adequate empirical research that had explicitly defined the safety management problem in Ghana's upstream oil and gas industry. The current probability-based risk assessment approach underpinning the existing safety management is found inadequate to capture background knowledge linked to the hazards. As a result, uncertainties of knowledge and potential surprises characterised operations (Aven & Renn, 2018). Given these challenges in the industry, there is a need to provide an integrated research that would develop a framework to address these challenges in the industry.

1.4 Research Aim and Objectives

The aim of this study is to develop a framework for robust safety management in the upstream oil and gas industry in Ghana.

As indicated earlier, the problem confronting safety management in Ghana's upstream oil and gas industry has not been defined adequately. In establishing awareness of the safety management problem, the issues relating to risk governance must be examined. In this regard, the robustness of existing safety regulatory regime, safety performance indicators, safety climate and safety management systems are worth considering in this research. The robustness of the safety regulatory regime, industry safety performance, safety climate perception and the implementation of existing safety management systems are critical for safety management. Given the aim of this research, the following research objectives are to be achieved:

1. Assess the robustness of existing safety regulatory regime of Ghana's upstream oil and gas industry.
2. Identify the safety regulatory issues in Ghana's upstream oil and gas industry.
3. Examine the safety performance indicators of Ghana's upstream oil and gas industry.
4. Assess workers' perceptions of the influence of safety climate on hazard risks in Ghana's upstream oil and gas industry.
5. Explore the drivers and barriers to a robust implementation of safety management systems in Ghana's upstream oil and gas industry.
6. Develop and refine a framework for robust safety management in Ghana's oil and gas industry.

1.5 Research Scope

This study focuses on establishment of the safety management problem and development of a framework that would serve as a practical guide to manage safety in the upstream oil and gas industry in Ghana. Safety management involves the prescription of safety norms and activities to ensure the safety norms have complied. It covers the contents and practices of safety in Ghana's upstream oil and gas industry. The concept of risk governance is critical in this study as it forms the safety perspective in the upstream oil and gas industry. The robustness of safety regime, industrial safety performance indicators, safety climate and safety management systems are the main themes of this research.

The oil and gas industry involve three major operation stages: upstream, midstream and downstream (ICSD, 2018). The upstream sector is defined earlier (section 1.1) but in this study covers exploration and production related activities. The midstream includes transportation (pipelines, rail cars and tankers), storage and marketing-related activities. The downstream covers refining, processing and distribution of petroleum products-related activities. However, the decommissioning aspect of the upstream oil and gas industry is not covered. This is because Ghana's upstream oil and gas industry is an emerging one and has not reached the decommissioning stage. Thus, no decommissioning activities are currently undertaken. The upstream oil and gas operations involve large workforce (OGUK, 2019), and several activities have potential consequences to human lives, property damage, environmental pollution (Broni-Bediako & Amorin, 2010; Oppong, 2014) and disruption of energy supply. These have implications to the multiplicity of stakeholders involved in the safety management of the upstream oil and gas industry.

The risk governance in the industry covers and integration of the aspects of health, safety, security and quality. However, this study focuses on the aspect of safety, which will enable the researcher to avoid a broader scope of the study. Whether compliance or integration, safety management is a control problem. In this regard, this study focuses on developing a framework for addressing the fundamental safety control problem in Ghana's upstream oil and gas industry. In terms of the types of organisations, this study will involve state regulatory institutions, operating companies, and contracting companies.

1.6 Research Methodology

This study follows Design Science Research (DSR) as an approach to the research. This approach helps to define the safety management problem and creates a conceptual solution to improve the defined safety problem in Ghana's upstream oil and gas industry. Design science employs scientific study and develops artefacts to solve a practical problem (Kuechler & Vaishnavi, 2004). As emphasised by Heesom et al. (2008), there is a need to bridge the gap between research and industry. The DSR fulfils these two goals: truth and utility of knowledge. It goes to the extent of changing the world, improve it, and create new worlds through the creation of artefacts that can help people to fulfil their needs, solve their problem and grasp new knowledge (Johannesson & Perjons, 2014).

In this study, four steps of the DSR process are adopted: *establishing awareness of the problem*, *defining the requirements of the artefact*, *developing the artefact* and *evaluating the artefact*. A pragmatist philosophical position underpins this study because it seeks to fulfil the truth and relevance of the knowledge outcome of the research. The study adopts both quantitative and qualitative research methods for these DSR activities. In terms of the data collection methods, the study employs the following techniques: documents, safety statistical data, questionnaire surveys, semi-structured interviews, workshop and focus group. The documents cover all the safety statutes and regulations relevant to Ghana's upstream oil and gas industry. The safety statistical data include fatalities, injuries, incidents, near-misses, medical treatment cases, reported diseases, restricted work cases and first aid cases. These are key safety performance indicators applicable to the upstream oil and gas industry (IOGP, 2019a). The questionnaire data are obtained from 212 workers that include engineering professionals, operation management, contractors, maintenance/craft technicians, maintenance management and other related job categories in the upstream oil and gas industry. However, the semi-structured interview data are obtained from 14 professionals working in the industry in different managerial and supervisory roles. The participants worked in different organisation types that included regulatory institutions, government agencies, operating companies, contracting companies and the Labour union. The same participants were used to collect the data for the workshop and the focus group. It must be indicated that 12 and 9 participants participated in the workshop and focus group, respectively. The data analytical techniques included literature review, descriptive statistical analysis, factor analysis, multiple regression analysis and content analysis. This study applies this software IBM SPSS (version 25) and Nvivo (version 12) to perform the analysis.

1.7 Organisation of the Thesis

This thesis is structured into six chapters which are summarised as follows:

- **Chapter 1 - Introduction:** This chapter provides the introductory part of the study which covers the research background, research justification, research aim and objectives, research scope, research methodology and the organisation of the thesis.

- **Chapter 2 – Literature Review:** It provides the theoretical background of the study. This chapter offers a critical review of the literature relevant to safety management. It covers the risk governance in Ghana’s upstream oil and gas industry, the robustness of safety regime and its assessment, safety performance indicators, safety climate influences on hazard incident risk and safety management systems and its implementation.

- **Chapter 3 – Research Methodology:** This chapter presents the research methodology of the study. It covers the methodological approach that defines the philosophical position, the design science research as the research approach, research methods and the ethical consideration of the study.

- **Chapter 4 – Data Analysis and Research Findings:** It presents the data analysis and the research findings for the four steps of the DSR activities adopted for this study. The data analysis and key findings of documents, safety statistics, questionnaire surveys, semi-structured interviews, workshop and focus group are presented to fulfil these DSR steps establishing awareness of the problem, defining the requirements of the framework, developing the framework and evaluating the framework.

- **Chapter 5 – Discussion:** It presents the discussion of the key research findings. It bridges the gap between the literature findings and the empirical findings of the study. The discussion is structured into two parts: problem facing safety management and conceptual solution to address the problem.

- **Chapter 6- Conclusion and Recommendations:** This chapter provides the conclusion of the study. It covers the synthesis of the research objects, contribution to knowledge, research limitation and further research.

1.8 Summary

The upstream oil and gas industry is inherently hazardous as many aspects of the exploration and production activities pose risks to human lives, properties and the environment. This chapter provided the background of the research and its justification. The aim and objectives of this study were stated. The adopted research methodology was summarised and justified. The next chapter provides the theoretical background of this research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter provides a crtical review of the literature relevant to safety management in the upstream oil and gas industry. Safety management involves prescription of safety norms and compliance activities of these norms. The review covers safety regulatory regime of Ghana's upstream oil and gas industry, robustness of safety regime and its its assessment, safety performance indicators, safety climate influences on hazard incident risk and safety management systems and its implementation.

2.2 Safety Management in the Upstream Oil and Gas Industry

Safety is defined as the state of being free from unacceptable consequences (Li & Guldenmund, 2018). There are several defintions of safety management in safety literature. The concept of safety management is linked to practices, roles and functions towards realising safety in an organization (Kirwan, 1998; cited in Mearns et al., 2003). In Grote's (2012) review of the defintions of safety management, conceived it as a means to several ends that relates to promoting safety culture and organisational safety performance. Vinodkumar and Bhasi (2011) referred it as, the policies, strategies, procedures and activities implemented or followed by the management of an organisation targeting safety of their employees. Li and Guldenmund (2018) see it as the process of actualizing the safety functions. Safety is differentiated from safety management. The former is the condition, whiles the latter is the process of activities to realise it. The primary functions of safety management are the protection of human beings, property and the environment from unacceptable risks (Noy &Yonson, 2018; Li & Guldenmund, 2018). This is because safety management is as a systematic control of employee performance, machine performance and the physical environment (Heinrich et al., 1980). In this study, these functions are applied.

The literature traced the origin of safety management from the maiden *Workmen Compensation Act of 1908* which indicated that irrespective of the nature of faults, management is responsible for injuries occurrence at the workplace (Petersen, 1978; Li & Guldenmund, 2018). Since this period, occupational accidents were understood from a technical perspective. The industrial revolution was powered by boilers. In United States, the stream boilers exploded with terrifying frequency that caused 50,000 deaths and two million injuries of workers annually which led professional bodies in 1915 to quest for the development of safety codes for designs, testing inspecting and operating the boilers (Baram & Lindøe, 2014). However, scientific development of safety management is believed to have commenced with Heinrich's publication entitled "*Industrial Accident Prevention: A scientific approach*" (Heinrich, 1931). His research developed the *domino model of accident causation*, which viewed unsafe conditions and acts as the fundamental causes of industrial incidents and accidents. Heinrich's model ascribed the role of management in actualising industrial safety and efficient production. In this period, the cause of accident was more linked to human error or human factor.

In the upstream oil and gas industry, safety management started to gain more attention in 1980s after several accidents had occurred in several operations and that there was the need to manage safety. The inquiry report of the Piper Alpha disaster in 1987 recommended safety management systems for the oil and gas industry organisations (Cullen, 1990). This safety management system has become a critical regulatory requirement underpinning various safety regulatory regimes in the industry. Safety management seeks to address a multiple control problem (Björn & Rollenhagen, 2014; Li & Guldenmund, 2018). This requires prescription of safety norms and control that these norms are duly complied with (Kaasen, 2014). According to Yang et al. (2009), an effective safety management requires an optimal control of risk that are based on the multiplicity of uncertainty attributes. In this study, safety management is understood to cover risk regulations and implementation of those activities to achieve the safety functions. The risk regulation relates to those policies and rules that are made to address a particular risk. Implementation in this context relates to means to achieve the safety functions. Safety management are based on different regulatory regimes as these regimes establish the rules and standards that must govern how risks are dealt with within a specific regulatory context. The concept of regulatory regime is discussed in the next section.

2.2.1 The Concept of Regulatory Regime

The concept of regulation has several meanings in the literature. According to Levi-Faur (2011), the idea is hard to define due to its myriad application for discursive, theoretical and analytical purposes that requires clarification. For Koop and Lodge (2017), it is because of the lack of shared understanding. Levi-Faur (2011), in his discussion of the concept, captured meanings of the idea, is often employed in the literature. Sociologists and criminologists conceived regulation as a social control that emphasised shaming, issuing restorative justices and responsive command. Legal scholars viewed it as a legal instrument. Progressive Democrats understood it as a public good in the form of a tool that seeks to control profit-hungry capitalists as well as social and ecological risks. Koop et al. (2017, p. 3) categorised the conceptualisation of regulation documented in the literature (Jordana & Levi-Faur, 2004; Baldwin et al., 2012) into the following three meanings:

1. "*Promulgation of an authoritative set of rules, accompanied by some mechanism for monitoring and promoting compliance with these rules*".
2. "*All the efforts of state agencies to steer the economy*".
3. "*All mechanisms of social control – including unintentional and non-state processes*".

However, variations in the conceptualisation of regulation are mainly linked to the differences in disciplinary concerns. Political scientists, lawyers and economists underscored the first two meanings, while the socio-legal scholars stressed the third meaning. For this study, the third meaning of the regulation is applied. Regulation is one of the several social controls that are used to prevent major industrial accidents (Baram & Lindøe, 2014). Regulation as a critical social control has the potential in minimising risks posed by industrial hazardous activities to human life as well as injuries and other health-related impacts, destroy or damage to assets in society or systems, and environmental pollutions. Such an effort in minimising these risks requires regimes that can withstand or survive perturbations or external shocks. Regime implies inclusive way risk is regulated in a specific policy domain (Hood et al., 2001). Regulatory regimes become a crucial concept in the safety management of industrial hazardous activities.

Hood et al. (2001, p. 9) defined a regime as "*the complexity of institutional geography, rules, practices, and animating ideal that are associated with the regulation of a particular risk or hazard*". This understanding suggests three fundamental features of a regime: as a *system* which has emergent property, has a degree of *continuity* over time and relatively confined systems that is possible to be *specified at different levels* in the organisation. Given this meaning of regime, the regulatory regime is translated to be conceived as the "*systems for achieving regulatory goals*" (May, 2004, p. 2). The system is made up of institutional structures and the actions taken by the regulatory agencies. The institutional structures composed of three elements: (1) rules governing expected behaviour of an individual or organisation, (2) standards representing the benchmarks for compliance and (2) sanctions for non-compliance with these rules. However, it is pointed out that alteration in any of these elements may change the nature of the regime. In both research and professional contexts, instead of coordinating the social controls, the practice is always to provide a coherent and efficient institutional system that would concurrently promote the application of technological advances in the industry in maximising production while protecting humans, facilities and the environment from unacceptable risk. This practice is consistent with democratic principles, legal basis, societal values and norms. In the current practice, government's role of controlling the risk of industrial hazardous activities is to delegate this obligation to the industry. There are various modes of how this delegation of government obligation is practiced and these are discussed in the next section.

2.2.2 Modes of Regulation for Prevention of Major Incidents

For several years, there have been vigorous controversies regarding government's rigidity in the application of command-and-control prescription of norms for controlling the risk of hazardous industrial activities and the suitability of alternative modes of regulations. Much of these controversies are well documented in the literature (e.g. Levi-Faur, 2011; May, 2011; Baram & Lindøe, 2014; Kringen, 2014). Various regulatory regimes exist for countries to use to control the risk of hazardous industrial activities. There are three main forms of regulatory regimes. As shown in Figure 2.1, there are three main modes of regulations that vary in terms of regulatory foci, compliance determination and their nature of rules and standards. They are public regulation (prescriptive regulation), co-regulation (performance-based regulation) and the hybrid regulation. The prescriptive regulation develops regimes that provide prescribed actions, inspect that organisations adhere to the prescribed actions and provide particularistic and detailed specific rules and standards to control hazardous industrial activities. The United States reflect this regime type. The co-regulation is a derivative of the collaboration between government and the industry which seeks to fulfil the performance-based regulation. It is a self-regulatory regime that focuses on objective or outcomes, ensure that organisations achieve the desired results and specifies the goal-oriented outcomes. The United Kingdom, Australia and Norway reflect this form of a regulatory regime. The hybrid regulation features aspects of prescribed actions, process and outcomes, considers ensuring compliance with alternative provisions and accepts alternatives or codes of practices. The Canadian regime reflects this form of regulation.

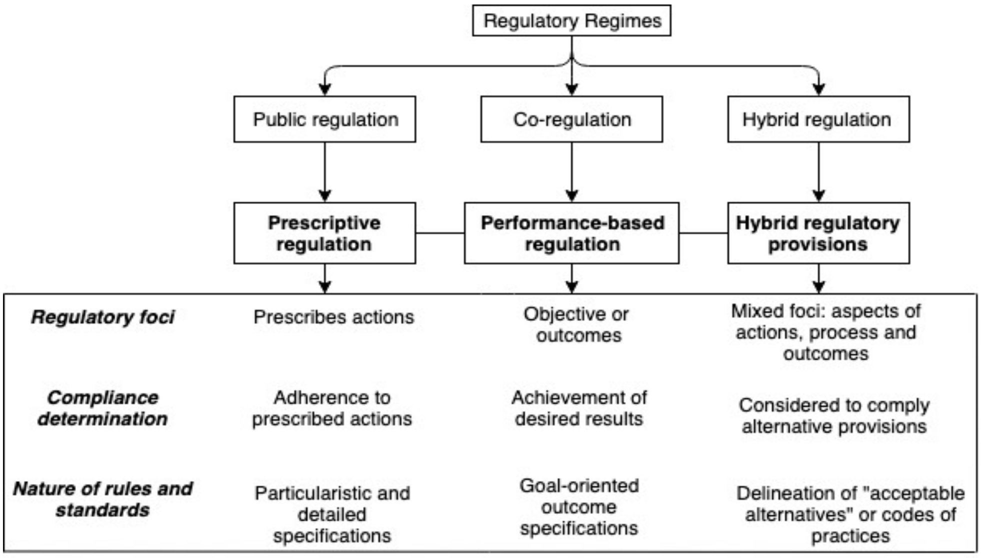


Fig. 2. 1 Modes of regulation for prevention of major incidents

Source: Adapted from May (2011).

The application of the traditional government prescriptive regulatory approach is less attractive to ensure robust control of industrial hazardous activities in these days. Many of the limitations of the government command-and-control approach have been discussed in Baram and Lindøe (2014). It lacks the ability to keep pace with the speedily emerging technologies and incorporate the continuous flowing of new risk information and lessons learnt. Because of the governmental dearth of technical expertise in terms of prescription of suitable designs and operations for ensuring the safety of complex systems, it requires alternative modes of regulation. The strict application of one-way prescriptive rules is not appropriate for organisations with particular operational situations and affect their in-house expertise to provide a more cost-effective superior approaches to safety. Traditional command-and-control prescriptive approach involves costs and resources in developing regulations and monitoring and controlling compliance. The need for deregulation and privatization of government obligation to control the risk of industrial hazardous activities had been more fueled by major accidents in the industry. Several factors have been indicated in support for the development of performance-based regulations. They include the following: the changed values and attitudes from bureaucratic processes that are inherent in the traditional command-and-control prescriptions, the fear of international competitions and the propensity of transferring of industrial market to flexible regulated areas abroad, and accidents have emasculated the confidence in government regulators.

However, the development of alternative modes of regulation which had led to the use of performance-based rules to achieve the safety management functions had failed to bring an end to these controversies. This is because the delegation of self-regulatory responsibility to private companies has raised three main contested issues in the literature: legitimacy, accountability and legality (Baram & Lindøe, 2014; Kringen, 2014). The robustness of safety management would also depend on the following: legitimacy in terms of delegating the state responsibility of safety control to private companies undertaking the hazardous activities, the accountability that ensures that private companies self-regulate in a way that satisfies government's obligations and the legality of implementing the decision made by the regime.

This study argues that to address the knowledge of uncertainty, which is inherent in the risk governance, the regulatory authority must define the risk acceptance criteria. This argument is based on the societal safety view and the basic economic principles (the expected utility theory). The government has a primary responsibility to protect society from the negative externalities of the hazardous industrial activities. The consequences of accident may not fully be taken to consideration by private organisations (Abrahamsen & Aven, 2012). Therefore, delegating government's full responsibility of controlling risk of hazardous industrial activities to private companies may lead to compromising societal safety. This is because it is noted that private organisations have historically indicated to have gravely compromised societal safety and caused several harms due to their economic interests and opportunism (Baram & Lindøe, 2014). These private companies capitalize the weakness of weak regulatory authorities to fulfil their own economic interest. In the application of the expected utility theory to decision making analysis of risk acceptance criteria (Aven & Kørte, 2003; Abrahamsen 2011; Abrahamsen & Aven, 2012), it clearly underscores that the marginal rate of substitution for society in terms of negative externalities is higher than that of the operating organisations. In other words, investing in self-protection relative to negative externalities is more effective than that for the operating organisations. The hazardous industrial activities undertaken by private companies always will cause risk to society and therefore the regulatory authority must define the risk acceptance criteria.

2.2.3 Assessment of Safety Regulatory Regimes

This section examines studies on evaluation of safety regulatory regimes in the upstream oil and gas industry with a view to explore for the existing approaches for assessment and ascertain whether there is a consensual approach for determination of superiority of a safety regulatory regime. In his review of causes of major accidents in the oil and gas industry, Attwood (2017) emphatically stated that those causes could have been avoided if there had been implementation of an effective regulatory regime. The concept effectiveness has been the basis for such evaluation of regulatory regimes. Windle et al. (2008) defined an effectiveness within the context of safety regulation as the relationship between the regulatory change and trends in respect of the occurrence of incidents. In other words, the effectiveness of safety regulatory regimes is contingent on the trends of occurrence of incidents. Some researchers have employed safety performance indicators to evaluate the efficacy of existing safety regulatory regimes in the oil and gas industry. To investigate such efficacy of existing regulatory regimes, comparative analyses are made on regimes between prescriptive and performance-based regulations.

Barua et al. (2016) conducted a quantitative comparative analysis of regulatory regimes in United Kingdom and United States based on an offshore oil and gas recorded incidents data. They sought to provide some understanding of the effectiveness of the two different matured regulatory regimes. In the United Kingdom, the Health and Safety Executive (HSE) data shown that fatality cases were low (e.g. 2008 - 2011 = 0 fatality; 2012 = 2 fatalities, & 2014 = 1 fatality). Incident cases that resulted in major injuries and hydrocarbon release appeared constant within the period from 2008 to 2014, and the number of dangerous occurrences also declined in the last three years. Whereas in the United States, Bureau of Safety and Environmental Enforcement (BSEE) submitted recordable incidents of the Outer Continental Shelf (OCS) from 2008 to 2014 indicated relatively higher fatality rates (i.e. 2008 to 2010 = 8.7). The average fatality rate declined to 2.75 from 2011 to 2014. Barua et al. analysis indicated that the United Kingdom's regulatory regime appeared successful mainly because fatality rate was relatively lower in the offshore oil and gas production activities. Although they could not directly conclude from their study whether prescriptive regulatory regime was less effective to performance-based regulatory regime, it became apparent that the new regulation which was constituted in November 2010 incorporated some aspects of performance-based regulation that actually improved incidents rates.

Mendes et al. (2014) conducted a comparative analysis of the Brazilian safety regulatory framework for its offshore oil and gas operations to that of other experienced regimes (i.e. United Kingdom, United States & Norway). They adopted both safety performance data from 2010 to 2012 (i.e. major injuries, fatalities, major & minor collisions, & fires) and key regulatory features (i.e. tripartite collaboration, barrier management, safety case, & safety research). The tripartite collaboration is about the three-way corporation among the government, employees and companies. The barrier management is a risk management approach that provides understanding on the critical control systems, and their assessment and monitoring of the regular status of operations (PSA, 2013). The safety case works under the principle that the state establishes the broad safety goals to be achieved and the operator develop specific most suitable means of achieving those stipulated goals. In this case the operator submits a document containing a comprehensive analysis of all the hazards and their risks of the facility in question. Investment in safety research and development forms a key requirement of both the government (regulator) and the industry to make a significant investment in research and development in system safety (see NAENRC, 2012). From the analaysis, each country has its own strengths. Regulatory effectiveness was determined by safety performance indicators and the emphasis was placed on the regulatory features.

Jain et al. (2017) investigated the process safety performance of four countries under regulatory regimes between safety case regimes and government prescriptive regimes. These regulatory regimes were analysed in relation to their effectiveness of preventing process safety events in the oil and gas industry. It became indicative from their analysis, that countries (e.g. United Kingdom, Australia) under safety case had relatively lower incidents cases as against United State regulatory approach. In other words, with respect to safety performance indicators, United States' regulatory approach appeared indicating lower process safety performance. However, it must be pointed out that even these countries under safety case regulatory approach recorded differences in process safety performance as Australia was better than United Kingdom. It can be indicated that there are many differences of process safety incidents performance among countries under the same regulatory approach. It was apparent that no country or region was overwhelmingly better in terms of safety performance indicators. Although there was no conclusive evidence from their analysis to suggest superiority of a regulatory regime, the available safety performance indicators clearly shown that United States performed relatively lower than those countries under safety case regulatory approach. There was paucity of evidence in determination of superiority of a regulatory regime and this was attributed to the lack of publicly available process safety data for the studied countries as well as for the industry for a more detailed quantitative analysis.

Attwood (2017) examined the safety performance indicators of the regulatory regimes under the following countries: Denmark, Nigeria, China, United States, Canada, United Kingdom, Australia, and Norway. The safety performance indicator used for the analysis included the Total Recordable Incident Rate (TRIR). The TRIR was calculated as the summation of fatalities, lost workday cases, restricted workday cases, and medical treatment cases per million hours worked. Attwood argued that the differences in process safety regulatory approaches are not significant as having a justifiably defined and enacted form of regulation. The main assertion is that the root causes of such major incidents could have been avoided if there had been existing effective regulatory regimes with rigorous implementation. It is indicative in Attwood's study that the focus on determination of regulatory effectiveness should be placed on implementation of safety programs.

Acheampong and Akumperigya (2018) presented a comparative analysis of two countries operating under performance-based regulatory regimes (United Kingdom & Norway) and used the benchmarks to determine the strength of Ghana's existing regulatory regime for prevention of major hazard incidents in the offshore oil and gas industry. In contrast to the use of safety performance indicators in determination of the effectiveness of regulatory regimes, they conducted a review analysis based on regulatory features that included: legal framework and structures, regulatory authority, workforce involvement, compliance, cost sharing, and objects covered.

From the above examination of the literature, there appeared to be no consensus on what constituted effectiveness of a regulatory regime and how to determine it. Some researchers used safety performance indicators to determine the effectiveness of exiting safety regulatory regimes. Some also used regulatory properties to form a benchmark framework analysis to determine the effectiveness of safety regulatory regimes. Whereas other used both to evaluate the effectiveness of existing safety regulatory regimes. It must be pointed out that indicator for safety has different meanings and for different purposes (e.g. "safety performance indicator", "safety outcome measures", "safety indicator"). For the purpose of making comparative analysis for changes in level of safety performance, safety performance indicator is preferably used (Blakstad, 2014). Safety performance indicator is defined as an avenue for evaluating the changes in level of safety in terms of major incident prevention, preparedness and response (Skogdalen et al., 2010, cited in Blakstad, 2014). However, using safety performance indicator to evaluate the effectiveness of a regulatory regime between countries is may be associated with several difficulties. Much of these difficulties have been discussed in the literature (e.g. Hood et al.,2001; Blakstad, 2011, 2014). As found in the literature, there are differences in scope of oil and gas operation activities among different regulatory regimes that may affect the quality of unified safety indicators for the analysis of the effectiveness of regulatory performance.

Despite a recent attempt by Burton et al. (2017) to provide a benchmark against which comparison of safety performance indicators should be made to determine the effectiveness of existing safety management systems, they failed to establish the link between safety performance indicators and regulatory effectiveness. It must be indicated that good safety performance indicators must have a direct link to *regulatory system status* (with complexity to manipulation), *relate to the future system states and performance*, and *must give real time information* (Fleming, 2010; cited in Blakstad, 2014). Again, in the developing countries, data for safety performance indicators may usually be underreported (Mearn & Yule, 2009; Mendes et al., 2014). Given this practice of underreporting of safety performance indicators, the true reflection of the safety performance in developing countries may not be established. Therefore, a comparative analysis of low incident rates under a regulatory regime of a developing country against higher incident rates under an advanced regulatory regime may possibly results to misleading analysis in determination of effectiveness of a regulatory regime. This is because there are issues associated with underreporting of safety data, differences in definition and reporting of safety indicators. Moreover, national characteristics are noted to influence safety performance indicators that makes comparative analysis difficult to conclude (Blakstad, 2014). Although there is paucity of empirical knowledge on how national culture influence safety performance in the upstream oil and gas industry, the differences in national characteristics (e.g. culture, values, regulatory properties) under the regimes may affect the quality of data for comparative analysis of regulatory performance.

From the literature, there is no empirical evidence suggesting superiority of a safety regulatory regime. It must be pointed that the regulatory characteristics underpinned by the prevailing national cultural influences, disparities in scope of upstream oil and gas activities, differences in definition and reporting of safety data, and differences in regulatory architecture features may contribute to the conclusion that determination of regulatory regime superiority is problematic in comparative analysis. Several regulatory improvements that had taken place in the global upstream oil and gas industry were largely driven by lessons learned from major incident events. Such lessons emerged from scientific studies on retrospective analysis of the link between existing safety regulatory regime and the major incident events which subsequently resulted to the need for incremental modifications within the remit of existing regime's premises, designs, and implementations, or the passage of a new safety regulatory regime (Baram et al., 2014). The way forward is to focus our attention on the issues associated with the governance of risk in the upstream oil and gas industry. This is because the issue of complexity, uncertainty and ambiguity associated with risk are not adequately addressed in existing safety management approach (Marjolein et al., 2011; Renn, 2014). This brings to the essence of risk governance concept which started becoming popular in the last two decades. It describes the structures and processes relating to collective decision making in dealing with risk issues (Marjolein et al., 2011). It relates to how regulations, institutions and processs interact in decision making to address risk issues. Such processes and structures involve government and non-governmental actors. The central ideal of risk governance is how relevant are the involvement of stakeholders in the gathering, assessing, evaluating, managing and communicating the risks knowledge. Given the context of this study, the next section reviews the current risk governance pertained to Ghana's upstream oil and gas industry.

2.3 Risk Governance in Ghana's Upstream Oil and Gas Industry

This section critically reviews existing risk governance related to the upstream oil and gas industry. The purpose of this section is to examine existing safety regulatory and institutional framework as well as the current knowledge gap in Ghana's upstream oil and gas industry. It begins by providing an overview of industrial safety development and practices in Ghana. This is to understand the issues linked to existing safety regulatory and institutional frameworks that preceded the emergence of the new Ghana's upstream oil and gas industry.

2.3.1 An Overview of Industrial Safety Development in Ghana

The development of safety in Ghana can be traced back to the 1930's, a period where there was no existing designated body for the labour administration, and also occupational safety practices were limited to the processing and payment of compensations to workers who were accidentally injured (Asiedu, 2010; Dwumfour-Asare & Asiedu, 2013). In 1938, the British Colonia Administration established a Labour Department and legally empowered it to deal with general labour administration. In 1951, a fully qualified and experienced factory British inspector was appointed to oversee the health, safety and welfare of workers at the various workplaces. During that period, workers in the mining and wood processing industries were protected by the first enactment of the *Factories Ordinance of 1952*, which aimed at providing protection to industrial workers from being harmed at the workplaces (Dadzie, 2013). It must be indicated that prior to Ghana's political independence in 1957 from the British colonial administration, the country's safety laws were inherited from the British legal and institutional framework. The Factories Ordinance of 1952 was the single safety law which only focused on occupational injuries in then mining and wood processing industries until it was replaced by the *Factories, Offices, and Shops Act (Act 328) of 1970*. The Factories, Offices, and Shops Act (Act 328) continues to exist today as a general safety law in Ghana. However, there are other regulations that were subsequently enacted to promote health, safety and environmental protection (e.g. *Mining Regulations of 1970, L.I. 665*; Workmen's *Compensation Law of 1987*; *Ghana Health Services and Teaching Hospital Act 526 of 1999*; *Ghana Atomic Energy Act 204 of 1963*; *Environmental Protection Agency Act of 1994, Act 490*) in some few specific industries in the country. These safety statutes had existed in fragmentation, incoherence and with limited coverage to provide guidance for the provision of safety services in the country (Mustapha et al., 2016; Agyekum & Simons, 2018). This points to several inadequacies of existing safety regulatory framework for the general industrial activities in Ghana.

2.3.1.1 Existing Safety Institutional Framework

The Labour Department had Factories Inspectorate Unit in 1985 and was transformed to an independent body known as the Department of Factories Inspectorate (DFI) with the mandate of promoting health and safety of persons within the purview of the Factories, Offices, and Shops (Act 328) of 1970. The DFI subsequently became a department under the Ministry of Employment and Labour Relations (MoEL) with the following core functions:

- *Inspection of workplaces to ensure maintenance of reasonable standards of health and safety;*
- *Prosecution of offences under the Factories, Offices and Shops (Act 328);*
- *Investigation of reportable occupational accidents and dangerous occurrences*.

The review of the literature as summarised in Table 2.1 clearly points to several weaknesses associated with existing safety institutional framework governing the general industrial activities in Ghana. Existing institutions relevant to the governance of risk in the general industrial activities in the country appeared inffective. There appeared to be no or little effort by government to improve enforcement practices of general safety norms in the country.

2.3.1.2 Existing Industrial Safety Practices

Ghana's industrialization continues to grow with the presence of different types of industries leading to existence of large workforce being exposed to hazardous conditions (Annan et al., 2015). In Ghana, industrial accidents and fire outbreaks data obtained in the past two decades indicate an increasing trend of work-related injuries, fatalities, property damages, process losses and alarming frequency in fire outbreaks across the various workplaces in the country (Norman et al., 2015). In examination of extant literature on safety practices in Ghana as summarised in Table 2.1, the literature clearly points to several gaps in the implementation of safety management system in various industries in the country. The literature also indicates increasing trends in accidents which suggests poor safety performance in the Ghanaian industries. Several studies have linked the causes of these accidents to poor safety culture in the Ghanaian industries. Several of these issues have been summarised as follows:

- Lack of national comprehensive safety policies
- Ineffective safety institutional framework
- Lack of government and industry commitment to safety
- Poor safety culture
- Non-compliance of safety
- Lack of training and supervision

The studies (e.g. Ofosu, et al., 2014; Mustapha et al., 2016; Donkoh & Aboagye-Nimo, 2017; Agyekum et al., 2018) have revealed poor safety practices among the workers and the local construction organisations. Several factors have been identified from these studies that affect risk government in the construction industry in the country which included the following:

- Limited safety communication
- Lack of workers' PPE
- Contractors ignorance of safety due to pressures to meet production deadlines.

- Poor personal attitudes
- Ineffective safety laws and
- lack of safety enforcement
- Poor equipment maintenance
- inadequate safety meetings
- Inadequate evaluation of safety programme
- Lack of emergency response plans
- Lack of safety investment
- Poor incidents or accident data management
- Uncooperative clients
- Inadequate work procedures
- Inefficient training

From the review, existing studies have well documented the issues confronting safety regulation and implementation of safety management systems in the generality of Ghanaian industries. The central issue is the existence of an ineffective risk governance framework governing safety in the country. With the emergence of upstream oil and gas industry, which is more inherently hazardous, the governance of risk becomes critical in dealing with the complexity, uncertainty and ambiguity associated with the upstream oil and gas operations. In this regard, to what extent indicates that safety management in Ghana's upstream oil and gas industry would be robust given the existing experience? The next section examines existing risk governance framework governing Ghana's upstream oil and gas industry.

Table 2. 1 Summary of literature review on Ghanaian industrial safety practices

Study	Industry	Aim	Methods	Findings
Acakpovi & Dzamikumah (2016)	*Energy*	Investigate the level of compliance of OHS management systems and standards set by international and local legislation in power producing companies in Ghana	Questionnaires and interviews interviews of managers, supervisors, safety officers and technician engineers.	Factors influencing workers' safety include: (i) lack of management commitment; (ii) lack of training and supervision; (iii) lack of periodic checks on machines operations (iv) non-observance of safe work procedures
Tulashie et. al. (2016)	*General Industries*	Outline the various applicable exposure assessment strategy and recommend controls and conditions that makes the process work better in Ghana	Quantitative analysis using basic statistics of the sample sizes of the Similar Exposure Group's (SEG's) in the country	(i) workers have little information about national requirements to ensure effective management of workplace safety; (ii) no specific standards on what employers and workers should meet in order to ensure acceptable management of OHS in the country; (iii) it is not unclear to a Ghanaian worker what at is considered safe and unsafe; (iv) no national policy on OHS; (v) the country has not still ratified the ILO convention.
Amponsah-Tawiah & Mensah (2016)	*Transport (Road)*	Explore the impact of safety climate, age and tenure as a driver on safety related behaviours among 290 company drivers in Ghana.	Cross sectional survey design of 350 drivers.	(i) Young drivers in more risky driving behaviours relative to adult drivers; (ii) Tenure of a driver did not significantly affect work related driver behaviours; (iii) Ghana's commitment to safety is lackadaisical because there is no national health and safety policy that stimulates safety behaviour and sanctions for different sectors of the country's economy.
Amponsah-Tawiah et al. (2016)	*Mining*	Examine the relationship between the dimensions of OHS management systems and turnover intention in in the mining sector of	Cross sectional survey design collected quantitative data from 255 mine workers conveniently sampled.	(i) An inverse correlation existed between the dimensions of OHS management (leadership, supervision, safety facilities and equipment, and safety procedures) ad turnover intention of workers; (ii) turnover intension of workers was influenced by the

		Ghana.		commitment of safety leadership to ensure effective formulation of policies and supervision of OHS at the workplace.
Annan et. al. (2015)	*General Industries*	Identify the areas of opportunities for improvement OHS management in Ghana in terms of national legal requirements	Literature review	Ghana's OHS legal requirements are fragmented, under different jurisdictions with unclear responsibilities and accountabilities. No comprehensive national OHS policy
Oppong (2014)	*Oil & Gas*	Explore the literature to identify common occupational injuries, diseases and psychological wellbeing on oil rigs and negative environmental impacts	Literature review	The review shows that: (i) Contusion, cuts and laceration are that commonest occupational injuries suffered by oil rig workers; (ii) The commonest occupational injuries are musculoskeletal disorders, respiratory (iii) Offshore workers experience higher level of stress, burnout, anxiety, depression, low level of job satisfaction and sleep disorder; (iv) The commonest negative environmental impacts are oil spills, leakages, ecosystem disruption, climate change, air pollution, acid rain, environmental degradation and land-use problems.
Amponsah et. al. (2013)	*Mining*	Examine the effects of physical and psychological risk factors on workers' safety experience in the mining industry.	Cross-sectional survey of 307 workers from 5 mining companies.	Mining conditions, equipment, ambient conditions, support and security, and work demands, and control are significant predictors of near misses, disabling injuries, and accidents experienced or witnessed by workers.
Dadzie (2013)	*Construction*	Identify how clauses in the Labour Act 651 address appropriate Health and safety standards used in the construction site and possible challenges facing. adaption of the	Survey questionnaires of 200 workers (architect quantity surveyors, site and structural engineers)	(i) The clauses in the Labour Act 651 addressing the health and safety standards were poorly followed; (ii) Key challenges confronting the adaptation of the Labour Act are: poor risk assessment, inadequate training, poor workers' attitudes towards health and safety, cost, reporting shortfalls, lack of health and safety professionals

		the were used for the study adaption of the requirements of health and safety in the Ghana's Labour Act.		inadequate health and safety policies, data collection shortfalls, and lack of health and safety education.
Achaw & Boateng (2012)	*Oil & Gas*	Investigate safety practices to ascertain if the industry has the wherewithal to safeguard health safety of workers and properties and environment.	Industrial and institutional visits, interviews and questionnaires and desktop workshop were used to investigate designated personnel management.	(i) No national policy of OHS to guide operations of the industry; (ii) Lapses were observed in the way companies practice safety; (iii) Existing regulatory and monitoring institutions were under resourced.
Gyekye et. al. (2012)	*Mining Manufacturing & Wood*	Develop and test a model on the relationship between workers personal characteristics and organisational variables, and safety outcomes.	Questionnaires were used for the study to develop and test a model from a sample of 320 industrial workers.	(i) Workers perceptions of workplace safety shows the strongest impact on accident frequency in the industries. (ii) workplace fatalities are as a human and work environmental factors and therefore managers should pay attention to social factors in order to reduce accident frequency in the workplace.
Amponsah-Tawiah & Dartey-Baah (2011)	*General Industries*	Examine OHS issues in Ghana.	Literature reviews.	(i) Lack of a comprehensive OHS policy; (ii) Poor infrastructure and funding (iii) Insufficient number of qualified OHS practitioners; (iv) General lack of sufficient information to provide OHS services.
Broni-Bediako & Amorin (2010)	Oil & Gas	Identify major areas of drilling fluid exposure and health hazard associated with the use of drilling fluid.	Literature reviews	(i) The setting of pipe at the drill floor, manual handling of the sack at the sack room are major areas of drilling exposure: (ii) Dermatitis, irritation, neorological body are associated with drilling fluid exposure mainly through inhalation, skin contact and oral exposure.

2.3.2 Ghanaian Upstream Oil and Gas Industry Context

This section critically reviews the risk governance pertained to the Ghanaian upstream oil and gas industry. It seeks to identify the risk governance issues that affect safety management in Ghana's upstream oil and gas industry. It covers the following: an overview of Ghana's upstream oil and gas industry, discussion of Ghana's safety case regime, an examination of existing regulatory and institutional framework and existing studies. The literature gap relating to safety management in Ghanaian upstream oil and gas industry is highlighted.

2.3.2.1 An Ovierview of the Upstream Oil and Gas Industry

The history of Ghana's upstream oil and gas industry can be traced back to 1896, where several exploration activities took place in the *Tano* and *Keta fields*, including the *Volta basin*. The *Saltpond field* had been operating since the 1970s with no significant commercial quantity of hydrocarbon resources found. It must be pointed that after 120 years of considerable investment in rigorous exploration of hydrocarbon resources, Ghana eventually discovered its commercial amounts of hydrocarbon resources from the *Jubilee field* in 2007 which was estimated to be 700 million barrels of oil and 800 billion cubic feet of gas (Osei-Tutu, 2013; Skaten, 2018).

The first oil production was made in 2010, which put Ghana on the global map as an oil and gas producing country. There have been two major additional offshore fields developed in the *TEN field* (estimated to be 240 million bbl of oil and 396 billion cf of gas) and the *Sankofa field* (estimated to be 500 MMbbl of oil and 1.45 Tcf of gas) which commenced production in 2016 and 2017 respectively (Skaten, 2018). As shown in Figure 2.2, most of the upstream oil and gas activities are offshore. More discoveries have been reported in both offshore and onshore (Soko, 2018; ENI, 2019) as an aggressive exploration of hydrocarbon resources continues to take place in the country. Moreover, oil production continues to increase since the country's first oil production (Figure 2.3). Given the current expansion of exploration activities coupled with the maximum daily oil production (120000 bbl/d), the government estimated Ghana's oil production to reach 500,0000 barrels per day by 2024 (Ministry of Finance, 2019).

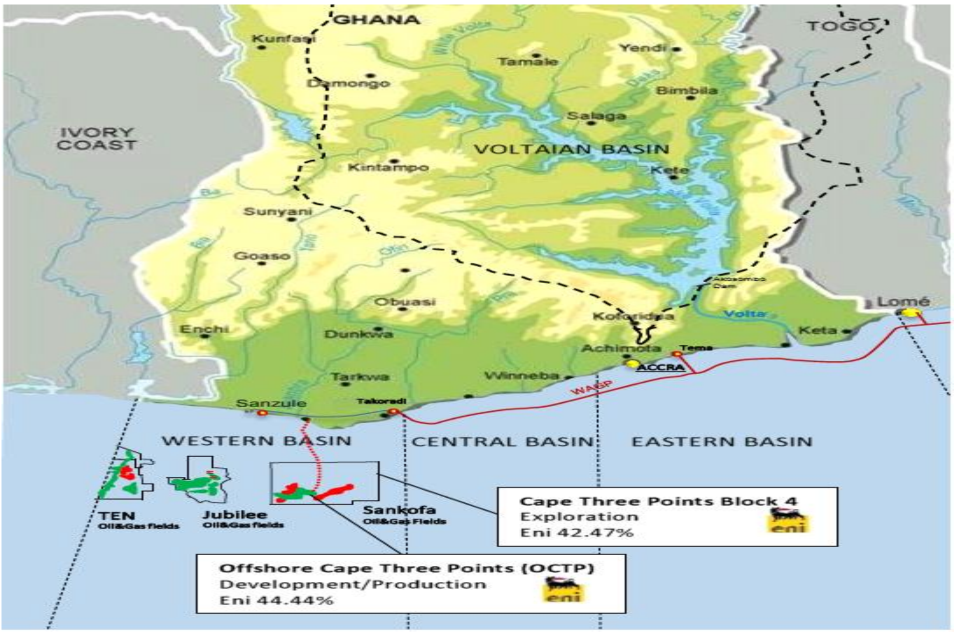


Fig. 2. 2 Jubilee, TEN and Sankofa oil fields at the Cape Three Points

Source: Eni (2018, cited in Skaten, 2018)

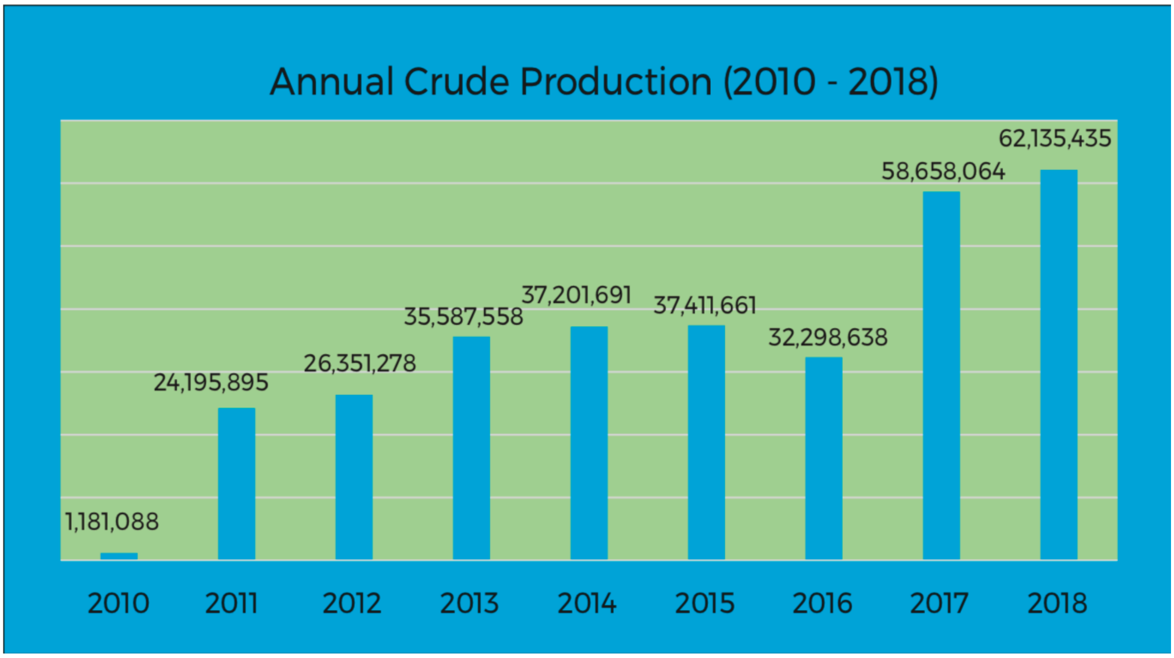


Fig. 2. 3 Ghana annual oil production from 2010 to 2018

Source: PIAC (2018)

Despite the steady growth of Ghana's upstream oil and gas industry, there have been several challenges in terms of partisan political polarisation, corruption investigations and the maritime border dispute with Côte d'Ivoire (Skaten, 2018). It is indicated that this partisan political polarisation may likely have an impact on institutional stability as well as the limit of a sustained potential for state-owned organisations in the oil and gas industry. It pointed out that corruption speculation remains in the industry may have an influence on institutional effectiveness. The three-year-long border dispute at International Tribunal for the Law of the Sea (ITLOS) had been resolved in favour of Ghana but demonstrated the initial rush of development of the industry, lack of readiness and technical expertise in existing institutions in the country.

At the beginning of the country's first oil and gas production, various legislations (such as legislations on revenue management, and exploration and production) were enacted to ensure that the state derives maximum benefits from the new oil and gas resources. However, safety regulations were not part of the initial enactments. In the absence of industry-specific safety regulations, Ghana's Jubilee Field operators agreed with the state participating agencies such as the Ghana National Petroleum Corporation (GNPC), the Environmental Protection Agency (EPA) and the Ministry of Energy to adopt, where applicable these international Environmental Health and Safety (EHS) Standards: *Safety Case Regulation of the UK*; *World/IFC Standards/ MARPOL*; *US Coast Guard Regulations*; *International Association of Oil and Gas Producers (IOGP)*; and *American Bureau of Shipping Classing Standards (ABSCS)*. Ghana developed its regulatory and institutional framework six years after its first oil pour. The country adopted the safety case approach to regulate its upstream oil and gas industry.

2.3.2.2 Ghana's Safety Case Regime

Paterson (2014) defined a safety case as a living document designed to ensure the ongoing safe operation of an installation. Safety case is seen as a form of a structured argument that is supported by evidence which seeks to justify that a system is acceptably safer for a specific operating environment. This structured argument is made to the regulator, which can be accepted or rejected. A safety case regime requires organisations to identify all major hazards and develop plans in terms of how these hazards could be managed (Hopkins, 2012b). Hopkins stated that a safety case regime must require the adoption of a systematic hazard management framework, ensure workers' participation, and a competent, independent and well-resourced regulator.

Before the passage of the *Petroleum (Exploration and Production) Act* in 2016, the safety regulatory regime was more of a prescriptive regulation. The current safety regulatory regime for Ghana's upstream oil and gas industry is based on performance-based or goal-setting shaped by a safety case approach. It requires all oil and gas organisations to show that they can take measures to reduce risk as low as possible. Ghana safety case regime is defined in clause 73 and regulations 10 of the *Petroleum (Exploration and Production) Act* and the Petroleum (*Exploration and Production*) HSE Regulations, respectively. C*lause 74* requires organisations to perform a risk assessment to identify the hazards and evaluate the risks associated with their oil and gas activities. Article 10 of the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations* requires the operators, contractors, sub-contractors and the state entity to submit a *Safety Case* to the regulator for approval in not less than six months before beginning upstream oil and gas operation and decommissioning. The *Safety Case* must indicate the following:

- description of the facility, technical and control measures, risk analysis, emergency preparedness analysis including emergency preparedness plan, and information on the management systems that are in compliance with existing safety legislation and regulations.
- It requires the duty holder to identify hazards, evaluate risks, and demonstrate that measures will be or have been taken to control the risks in such a way that the residual risk level is 'as low as reasonably practicable' (ALARP).

However, the effectiveness of Ghana's safety case regime has not received adequate research attention yet. An earlier study by Acheampong and Akumperigya (2018) noted that its effectiveness is unconvinced because it lacks robustness. But it had been argued that there is no existence of evidence to suggest the effectiveness of a regulatory regime. This is because there are considerable difficulties in terms of acquisition of empirical data on the effectiveness of the safety case regimes generally (Hopkins, 2012b). The literature recognised the importance of human and organisational factors as critical issues that go beyond the safety regulations, which must be given attention. In this regard, risk governance issues are worth examining. The existing regulatory and institutional frameworks are discussed.

2.3.2.2.1 Existing Safety Regulatory Framework

The power to control the risk of industrial activities in Ghana is inherent in the state's sovereignty which is exercised through enactment of laws and and establishment of regulatory authorities. The safety for the complex upstream oil and gas operations is governed by different statutes and regulations in different sectors. Table 2.2 presents the existing HSE statutes and regulations that are to some extent applicable to Ghana's upstream oil and gas industry. These statutes and regulations are examined.

Table 2. 2 Safety regulatory framework governing Ghana's upstream oil and gas industry

Safety Statutes and Regulations	Industry
Factories, Shops and Offices Act	General
Labour Act	General
Petroleum (Exploration and Production) Act	Oil & Gas
The Environmental Protection Act	Environment
The Petroleum Commission Act	Oil & Gas
Ghana Shipping (Protection of Offshore Operations and Assets) Regulations,	Marine Transport
Petroleum (Exploration and Production) HSE Regulations	Oil & Gas

2.3.2.2.1.1 The Factories, Offices, and Shops Act

This statute (Act 328) provides the main onshore regime as far as registration of factories, and the welfare, health and safety of employees are concerned. In terms of orientation, the Act is highly prescriptive in its content, as are the regulations expected to be made by the Minister responsible for labour. Additionally, its implementation is characterized by high-level bureaucracy, which calls into question its effectiveness in emergencies. However, it has hardly been tested given that the regulatory support and the inspectors envisaged under the Act have not so far been put in place. This law is highly limited in terms of its regulatory content coverage to deal with major hazard risks in the upstream oil and gas industry.

2.3.2.2.1.2 The Labour Act

The *Labour Act* (Act 651) provides a general statutory duty to all industries in Ghana in terms of imposing on all employers to ensure that every worker under his or her employment works under satisfactory, safe and healthy conditions. The Act imposes specific obligations on employers in very exacting and unattainable standards by providing that every employer must provide and maintain at his workplace, plant and system of work that is safe and 'without risk to health systems of work that are safe and without risk to the health of employees. Employers also have a duty to provide necessary information, training and supervision of employees with regards to health and safety. Act 651 equally imposes responsibility on employees by requiring them to use the safety equipment provided by their employers in compliance with the employers' instructions. Given this provision, the Act limits the liability of employers to the extent that an employer shall not be liable for injury suffered by a worker who contravenes his duty to use safety equipment and who suffers injury solely by his non-compliance of the Act. The scope of the health and safety needs in this Labour Act, particularly its applicability to the oil and gas industry is limited and incoherent.

2.3.2.2.1.3 Petroleum (Exploration and Production) Act

This Act (Act 919) was passed in 2016 to regulate the upstream oil and gas activities in Ghana. It is a legislation that was enacted by an act of Parliament to replace an earlier statute known as the *Petroleum (Exploration and Production) Law (P.N.D.C.L. 84)*. Although this Act mainly regulates the exploration and production activities, it makes provision to address some limited safety needs as contained in *Clauses 73-80*. The relevant safety needs covered the following areas: safety requirements and standards, safety precautions, emergency preparedness, safety zones, suspension of petroleum activities in case of a safety issue, measures to ensure safety, and safety training. The Act requires in *Clause 73* that the safety of upstream operations should be conducted in accordance with technological development, international best practices and applicable laws relating to health, safety and labour. It defines the regulatory regime approach that must be used to regulate the safety of the upstream oil and gas industry. Thus, it requires the application of *the Safety Case* approach for the conduct of all the upstream oil and gas activities. The requirement for the safety case approach is clearly defined in *Clause 73(2-3).*

The provisions in *Clause 74* require a licensee, contractor, sub-contractor and the state to perform a risk assessment to identify the hazards and evaluate the risks associated with their oil and gas activities. This regulatory provision only defines one dimension of risk for in offshore petroleum activities. It must be indicated that the preparation of a Safety Case requires the duty holder to identify hazards, evaluate risks, and demonstrate that measures will be or have been taken to control the risks in such a way that the residual risk level is '*as low as reasonably practicable*' (ALARP). According to Vinnem (2007), when an accident occurs in offshore petroleum facility, the consequences are related to personnel, to the environment, and assets and production capacity. These are referred to as the dimensions of risk. The dimensions of risk for offshore petroleum accidents include personnel risk (include fatality and impairment risks), environmental risk and asset risk (include material damage and production delay risks).

However, this Act does not contain the requirements of a Safety Case to demonstrate that the operator or the contractor has in place HSE management systems which must be sufficient to ensure compliance with all the safety regulatory requirements. A management system includes the necessary organisational structures, resources, accountabilities, policies, and procedures to achieve that objective. Carefully designed and well-implemented management systems are essential to keep people safe and protect the environment. Although this statute contains legal Clauses (e.g. clauses 73-80) for safety needs, it is succinctly prescriptive in content which also does not address in detail how safety should be regulated in the oil and gas industry. These requlatory gaps have to be covered by the new safety regulations to address the critical safety operational needs in Ghana's upstream oil and gas industry.

2.3.2.2.1.4 The Petroleum Commission Act

The Petroleum Commission Act (Act 821) was passed in 2011 to set up a regulator to regulate and manage the use of oil and gas resources and to co-ordinate the policies to ensure efficient utilisation of these resources in a safety manner. This legislation establishes the Petroleum Commission (PC) as an agency for advisory policy role under the Ministry of Energy to regulate the petroleum activities in the upstream sector. The PC serves as the regulator for both the *licensing* and *safety* of upstream oil and gas activities. This dual role is provided in Clauses 2 and 3 of the Act. It further specifies numerous functions that the PC is required to under which are provided for in Clause 3 of the Act. The only provisions relevant to the safety needs in the upstream activities as stipulated in Clause 3(d) (1). The PC must ensure compliance of HSE standards in accordance with applicable laws, regulations and agreements.

Two main issues warrant further discourse that must be informed by empirical evidence. The issues have to do with the lack of independence of the Petroleum Commission as a regulator; and the inherent contradicting role of the Petroleum Commission in terms of having to manage petroleum resource development as well as regulating safety needs of Ghana's upstream oil and gas sector. This will be established in the empirical analysis of the current study.

2.3.2.2.1.5 The Environmental Protection Act

The *Environmental Protection Act* (Act 490) was set up to provide the regulatory authority specifically on the formulation of general environmental policies, issuance of environmental permits, regulation of pollution and prescription of environmental standards in the country. Under the auspices of this Act, environmental regulations and several guidelines have been made to ensure adequate general environmental protection in Ghana. The *Environmental Assessment Regulations (L.I. 1652*) amended in 2002 requires every activity that has the likelihood to cause adverse effects on the environment to be subjected to environmental assessment. The Act requires the following process to be made: Preliminary Environmental Reports (PER) on the activity, Environmental Impact Assessment (EIA) which is a mandatory requirement to be conducted on the activity, Environmental Impact Statements (EISs) must be produced, production of Environmental Management Plan (EMPs), Environmental certification and Environmental Permitting. These processes have to be completed before a permit is issued for the commencement of the activity. Several environmental guidelines have also been produced including the *Environmental Assessment Procedures* (1995) which guides the conduct of EIA, the *Environmental Quality Guidelines for Ambient Air* which indicates the permissible level of air pollution and other general guidelines for industrial or facility effluents including noise levels and air quality. The EPA law ensures that upstream oil and gas activities are conducted in an environmentally friendly manner. However, Achaw and Danso-Boateng (2013) studies revealed several gaps in the application of this Act in the oil and gas industry as most organisations failed to adhere to the environmental regulatory and guidelines requirements of this statute.

2.3.2.2.1.6 Petroleum (*Exploration and Production*) HSE Regulations

The Petroleum (*Exploration and Production*) HSE Regulations (L.I. 2258) was developed in 2017 to specifically prevent adverse effects on health, safety and environment in the upstream oil and gas activities in Ghana. That is, it was established under the authority of the *Petroleum (Exploration and Production) Act* to provide the minimum health, safety, environmental requirements applicable to operating, contracting and sub-contracting organisations in the upstream oil and gas industry. These regulations are related to the design and operation of facilities in both onshore and offshore, drilling and well systems, load-bearing structures, management systems, risk analysis, maintenance of facilities, decommissioning and emergency preparedness and reporting systems. In terms of the prevention of human lives and facilities from unacceptable risks, the recurrent regulations are much improved over the previous regulatory regimes. In terms of its scope of environmental protection, it provides for emissions and discharges. Articles 81 to 84 provide for environmental principles and protection, environmental impact assessment, liability for pollution damage and compensation for pollution damage in upstream oil and gas operations. However, it has a limited scope of environmental protection of the upstream oil and gas activities. These regulations have to be supported by a new development of HSE guidelines.

2.3.2.2.2 Existing Institutional Framework

There are various institutions whose roles are essential for managing safety in Ghana's upstream oil and gas industry. As pointed at the beginning of this chapter, safety management is a matter for both the state and the industry. Through the enactment of various safety legislations in the country, these safety laws have established various regulatory authorities to control the risk of industrial activities in Ghana. In the context of the Ghanaian upstream oil and gas activities, various regulatory agencies have been established through different legislations. It must be indicated that the DFI and PC constitute the main regulatory authorities relevant to safety management in Ghana's upstream oil and gas industry, respectively.

DFI was established by the *Factories, Offices, and Shops Act* with its primary responsibility to ensure that industries comply with the best safety standards in the country. Dwumfour-Asare and Asiedu (2013) and Atombo et al. (2017) investigated the effectiveness of this regulatory authority. The research findings indicated that DFI had not been effective in its core role of compliance monitoring of safety standards in the general industries in Ghana. Among many challenges confronting the DFI, resource constraints and knowledge gap continue to be the key issues affecting this regulatory authority. Though DFI appeared to be the only independent safety supervisory authority for all industries, its activities are not much extended to the upstream oil and gas operations.

The PC is established by the *Petroleum Commission Act* as the regulatory authority with dual roles in licensing and safety compliance monitoring in upstream oil and gas industry. Two critical concerns have been raised on its core mandates: *who regulates the safety of the upstream oil and gas industry* and *the independence of the PC*. Few studies have examined the role of the PC in Ghana's upstream oil and gas industry. Akumperigya (2015) and Abdulai (2016) examined the role of the PC. These studies indicated that PC has conflicting roles and lack independence in safety compliance monitoring in the upstream oil and gas upstream. It was noted that the PC appeared to be more of coordinating agency that a regulator as several agencies in the industry also contributes to preventing human lives, facilities and the environment from unacceptable risks.

Other regulatory authorities have a role to play so far as the safety of the upstream oil and gas activities is concerned. The Ghana Maritime Authority (GMA) is responsible for monitoring, regulating and coordinating the activities taking place in the marine environment. The offshore oil and gas operations and assets are covered as mobile offshore mobile drilling unit must have to take place with prior approval of the GMA. The EPA is another regulatory authority responsible for environmental protection which in its activities, develop environmental policies and regulations, prescribe standards and guidelines for the EIA. In this regard, there is a mandatory requirement of all upstream oil and gas exploration, field development, production, and decommissioning activities to be submitted for prior approval by the EPA. However, such multiple agency regulations may conflict with the PC's mandate of HSE compliance monitoring.

The independence of the PC can be critically examined from three key areas that include *legitimacy*, *accountability* and *legality*. According to Baram and Lindoe (2014), the societal concerns for these three areas play a critical role in determining the matter of independence of a regulator. The legitimacy in this context is about delegation of government safety responsibility to a private organisation in undertaking hazardous activities. The accountability contextually means ensuring that companies self-regulate in a way that fulfils their obligations.

The legality aspect refers to the authority of decisions made by the regulatory regime for the implementation of safety needs.

On the concern for legitimacy, the power to control any industrial activities is the sovereignty of Ghana, and this sovereignty is protected by the 1992 Constitution of the Republic of Ghana. This Constitution, in Article 73 vests the legislative powers to Parliament to enact laws, regulations and adoption or acceptance of rules and practices developed by professional, industrial and international organisations. This legislative power is delegated to the government agencies to create a regulatory regime that delineates the mode of regulating hazardous activities. In this sense, the issue of legitimacy is rarely raised, and furtherly the independence of the regulator is not established. The legitimacy issue cab is raised when regulatory authority is delegated to private entities (Baram & Lindoe, 2014). According to Rosness and Forseth (2014), in seeking a more complex answer to who regulate, it is crucial to consider patterned network actors or constellation of actors who contribute to the effect that may call for "regulation of risks". On could understand the Ghanaian democratic political settings which there could be obnoxious tendencies of compromising the legitimacy in terms of government agencies engaging in corruptions. The concern is about the accountability of the regulator. It has been a good practice to separate the regulatory role of managing petroleum resource development from safety regulatory function. An example is UK where Health and Safety Executive is separated from the Department of Energy and Climate Change (DECC) whose role is to regulate the energy business enterprises and climate change. An independent safety regulatory will promote transparency and accountability, and legality of regulating hazardous activities in the self-industrial regulation environment and delineate the authority of decision to allow the industry to implement safety needs respectively. In this regard, the safety regulatory authority for Ghana's upstream oil and gas industry must be established separately and independently from the current arrangement.

2.3.2.2.3 Extant Studies on Risk Governance in the Industry

Earlier literature review summarised in Table 2.1 focused on the safety of the general industries. This section examines the existing literature relevant to risk governance in Ghana's upstream oil and gas industry.

Dadzie (2013) examined Ghana's *Labour Act* concerning safety in the construction industry. The study aimed at identifying how the clauses in the Labour Act (Act 651) address appropriate safety issues in the construction industry and the adaptation to the requirements of safety. His research findings indicated that the safety requirements in the Labour Act (Act 651) were poorly complied by contractors. The results further reported the following as the main challenges confronting the adaptation of the health and safety requirements in the Labour Act (Act 651): *inadequate training communication shortfalls, lack of safety professionals*, *poor risk assessment*, *lack of safety policies* and *poor attitude of workers towards safety*. Although the empirical findings of Dadzie's study are worth considering for further research in safety compliance and enforcement in Ghana, it is important to point out that the scope of the study was only limited to clauses of safety found in the Labour Act. Other safety legislation applicable to the construction industry were not examined. Importantly, it must be indicated that Dadzie's research sample was only limited to experts' opinions about contractors' compliance with the safety requirements in the labour Act. The views of the workers and managers in the construction industry were not considered in the study as these views are important to strengthen further the empirical knowledge about the contractors' poor compliance of the safety requirements in the Labour Act. In light of the increasing proliferation of local contents regulations required in the extractive industries in developing countries, local contractors play a significant role in the oil and gas operation activities (Daher, 2015; Ackah & Mohammed, 2018). In Ghana's upstream oil and gas industry, there are several kinds of local contractors which included contractors from the construction industry. Dadzie's empirical findings have potential implications for the quality of contractors' safety knowledge and safety behavior in the country's upstream oil and gas industry. When there is a prima facie empirical indication of poor compliance of safety requirements by contractors in the construction industry, it points to the need for research in contactor safety management in the country's upstream oil and gas industry.

Annan et al. (2015) examined the existing legal requirements for safety in Ghana. The objective of their study was to identify and understand the key issues on safety practices in the country and their legal requirements for Ghanaian industries. Their findings indicated that there exist fragmented safety laws in Ghana under different jurisdictions with unclear responsibilities and accountabilities. In their study, what is conspicuously missing is the examination of existing safety regulatory requirements that are relevant to the high-hazard industry like the oil and gas industry.

Akumperigye (2015) examined the inherent conflicting regulatory roles and the absence of independence of the PC. The study argued that the current arrangement in terms of the dual roles of the PC made it not adequately competent to oversee robust safety regulation of Ghana's upstream oil and gas industry. The regulatory conflict was examined from the view that the desire to attain revenue and profit target particularly as stimulated by a rising price of oil products, could undermine its role in safety compliance monitoring. It was also analysesed from *regulatory capture* concept. The capture was exaplined as the persisitent failure of the regulatory agencies to enforce the law against regulatory organisations which may be manifested in three forms: the sysmpathy with the issues confronting the regulated organisations in fulfilling the standards, association with the industry and the stiffness of the regulated organisations. The current arrangement exposes the PC into the risk of these three mechanisms of regulatory capture. The discussion of the mechanisms of regulatory capture is well documented in Mitnick (2011). The absence of independence of the PC was analyses from the ground that the law that established it conferred discretionary powers on the executive (the minister) which does not provide a formal requirement. Again, the lack of independence was also analysed from the general sense of the Constitutional source of the PC as it is inherently subjected to political and external controls. However, it must be indicated that in advancing robust regulation in the upstream oil and gas industry, it requires dialogue and collaboration as discussed in the literature (e.g. Renn, 2014; Aven &Ylönen, 2018). Independence of the regulatory agencies can also be examined in the context of self-regulatory perspective where it does not require 'policing' of compliance monitoring of safety standards.

Addulai (2016) examined existing safety regulatory regime in Ghana's upstream oil and gas industry. His analysis focused on the regulatory architecture and orientation of safety regulation. In terms of regulatory architecture, it was mainly characterised by fragmented agencies under piecemeal legislation. He pointed out that existing regulatory authorities lack decision making independence as independence and visibility is needed for a robust safety regime. In the analaysis of the regulatory orientation, it found that Ghana's safety regime was self-regulatory and further recommended Ghana to adopt the United Kingdom's safety case region shaped by management-based approach. However, it must be indicated that the main elements that characterised robustness of a regulatory regime were not captured in the analysis. This robustness concept is well documented in the literature (van Oss & van't Hek, 2011; Hale, 2014). The robustness of a regulatory regime must capture all the steps in the Renn's (2014) model.

Kotey (2016) examined the operational safety lessons from the Jubilee and TEN field after five years of oil production in Ghana. The author focused on the challenges that confronted the Jubilee oil field development stage. Some few incidents were recorded, which included near-misses, injuries, process safety events and environmental events. The main issue attributed to these incidents was the lack of 'operational discipline' or 'management deficiencies'. The study offered a prima facie impression about the weakness of existing safety management in the industry after five years of oil production. However, the author failed to adduce adequate empirical support on the causes of these incidents. Moreover, exploration and production-related activities were not covered by the study.

Acheampong and Akumperigya (2018) examined existing safety laws pertaining to Ghana's upstream oil and gas industry. Their research attempted to contribute to the discourse on the emerging controversy surrounding the offshore risk regulation in new oil and gas producing countries. The findings of their comparative analysis show several weaknesses of existing safety regulatory regime. However, it was not clearly indicated what constituted robustness of a safety regulatory regime. In view of the hazardous nature of the oil and gas industry coupled with the existing weak safety regulatory regime in the country, Ghana needs a robust safety regulatory regime to proactively manage safety to avoid major hazard-incident risks in the upstream oil and gas industry.

From the above examination of the literature, there appears to be inadequate research on robustness of safety regulatory regime for Ghana's upstream oil and gas industry. The extant literature predominantly focused on safety issues in general industries such as the construction, transport, agriculture and manufacturing. There are few studies that are relevant to risk governance in Ghana's upstream oil and gas industry. However, these studies were not empirically based and also their scope did not cover defining what constitute criteria for evaluation of the robustness of existing safety regulatory regime for Ghana's upstream oil and gas industry. Empiricism is important because it provides evidence of experience (direct or indirect) and observation. Empirical evidence in legal research are both pragmatic and policy driven, and theoretical or critical (Bell, 2016). The empirical impulse is to measure the gap between formal law and practical reality. Assessing the robustness of existing safety regulatory regime for Ghana's upstream oil and gas industry would help to identify the issues to proactively address them to prevent major hazard-incident risks. The inadequate research on defined criteria in the extant literature on Ghana's upstream oil and gas industry also point to one basic thing, which is the vagueness of the regulatory gap found in the literature. If gaps are identified through defined reviewed criteria would easily help in improving existing safety regulatory regimes towards its robustness.

2.3.2.3 The Gap

From the literature review on risk governance in Ghana's upstream oil and gas industry, it emerged that few studies have examined the current safety regime. The existing literature focused mainly on examining the safety regulatory architecture and orientation. The current modes of safety regulatory style for the prevention of major accidents in Ghana's upstream oil and gas industry is self-regulation shaped by the safety case regime. This safety case regime is mainly rooted in the engineering risk assessment, which is associated with knowledge uncertainty and potential surprises. Although there have been few studies that focused on the safety, there is no adequate empirical research has been provided to define and the safety management problem in the upstream oil and gas industry in Ghana. Existing safety performance indicators in the industry have not been sufficiently examined yet. In short, not much has been contributed toward how safety should be managed to avoid major hazard incidents in the country's oil and gas industry. Importantly, existing studies have limited knowledge on how to address the complexity, uncertainty and ambiguity of risk associated with Ghana's upstream oil and gas industry. The present study seeks to fill this gap. The next sections examine the literature on the most appropriate approach to address the risk governance issues in the industry.

2.4 Approaches to Address the Risk Governance Issues

Given the search for a better approach in addressing the issues associated with the risk governance in the upstream oil and gas industry, the resilience thinking has become more popular in the safety literature as one of the ways to approach safety. Generally, current actions towards driving improvement in the industry have followed resilience thinking. These advances were mainly introduced after major incidents or accidents have occurred in the industry. However, uncertainties of knowledge and potential surprises continue to be associated with the complexity of the upstream oil and gas operations. Some researchers have considered robustness thinking as an alternative approach to deal with these issues. Currently, these two concepts have increasingly dominated the risk governance literature as the '*official* *solutions*' for addressing the risk governance issues in the industry. These two concepts vary in foundation and practice.

The purpose of this section is to critically review the literature on these two approaches with the view to adopt the robustness perspective as a suitable approach that must be applied to manage safety in the upstream oil and gas industry. In other words, it reinforces the argument that robustness thinking is a more appropriate approach to address the complexity, uncertainty and ambiguity risk-related issues in the upstream oil and gas industry. In fulfilling the purpose of this section, this study begins with examining the meaning of these two concepts and their implications to risk governance.

2.4.1 Resilience versus Robustness Thinking in Risk Governance

Since the last three decades, the concepts of resilience and robustness have received increasing interests among researchers of risk governance. Several of these researchers had been interested in the design of policies to deal with uncertainties particularly in the areas of environmental policy (e.g. Funke & Paetz, 2011; Yang et al., 2018), climate change (e.g. Ruhl, 2011; Bhave et al., 2016) and risk management (e.g. Herwig, & Simoncini, 2016; Hoffman & Hancock, 2017). The reason for such growing interest stems from the fact that these two metaphors have been actualized as *'official solutions'* for dealing with potential policy issues (Capano & Woo, 2017). Similarly, in the oil and gas industry, these two concepts are also continuing to gain more traction in the risk management literature (e.g. Lindøe et al., 2012; Hale, 2014; Lindøe, 2016; Aven & Ylönen, 2018b). In response to the history of the oil and gas industry that had been blemished by the sporadic occurrence of major hazard incidents, there is a growing global discourse on how to regulate the oil and gas operations in a safe way to avoid these sporadic major events. Following the trends of safety regulatory reforms that had taken place in the global oil and gas industry since the last four decades, there still appeared to be paucity of adequate approaches for provision of proactive measures in dealing with the emerging hazard incident risks that are associated with the undergoing organisational change, technological development, and organizational business management in view of gaining competitive market advantage. It is indicated that imbuing the concepts of resilience or robustness into existing safety management that had been shaped under different safety regulatory design modes is associated with several challenges (Lindøe, 2016). This section clarifies the distinction between resilience and robustness concepts and discusses the implication of these concepts to risk governance.

2.4.1.1 The Meaning of Resilience and Robustness

The mentioning of these two metaphors, *resilience* and *robustness* seems to appear cognate on the impression that they are used to substitute for each other. According to Capano and Woo (2017), these two metaphors seems to unveil interconnection, but the link between them is not inevitably positive. The former comes from the Latin word, *"resilire"* that means 'leaping back'. Whereas latter comes from the Latin word "*robustus"* that means 'firm and hard'. The Oxford Dictionary meaning of resilience is linked to the ability to recover quickly from difficulties. Whereas robustness relates to the ability to withstand or be strong and healthy to adverse conditions. From the etymological perspective, these two words have different meanings: the former strongly express recovery of weaknesses, while the latter clearly expresses vigorousness and healthy to endure attacks.

Some researchers have attempted to differentiate these two concepts in different discipline. Hale (2014) conceived resilience as connoting to 'bending' or 'adapting' and 'bouncing back'. Whereas the robustness connotes to 'standing up to' or 'resisting attack' and 'weathering storms unchanged'. Capano and Woo (2017) conceived resilience as the action of 'returning' or 'bouncing back' to some extent of equilibrium from the confrontation of external perturbations or shocks. This relates to the understanding that stems from disciplines such as ecology (Folke, 2006), engineering (Hollnagel et al., 2006), socio-ecological systems (Folke, 2006; Schoon et al., 2015) and disaster management (Mack, 2014). The key elements that characterize resilience performance include the ability to respond, monitor, learn, and anticipate (Hollnagel, 2017). Resilience is a 'borrowed' metaphor to the social sciences because of its systemic ontological application to policy design. On the other hand, robustness is broadly conceived as the ability to "withstand" or "survive" perturbations of external shocks. The emphasis here is the capacity of a complex system to maintain its functionality in the confrontation of disturbance or shocks. Two main elements must characterize robust performance across all different disciplines: the *ability to withstand shocks* and *systemic functioning*. From the literature, the two concepts expressed different meanings as well as offering different implications to risk governance.

2.4.1.2 Resilience versus Robustness Concepts

Hale (2014) examined the concept of robustness about risk governance and further made a comparative analysis of the United Kingdom, the United States and Norway regulatory regimes. Although Hale’s comparative analysis was only limited to the concept of robustness, earlier studies (e.g. Hollnagel et al., 2006; Wreathall, 2006) illuminated some challenges associated with the adoption of resilience thinking in risk management. Some of the challenges may include the following:

- *Lack of flexibility* in terms of decision-making in the organisation which can lead to several failures for the systems to respond swiftly in augmenting protection as against the pressure of production;
- *opacity* where information about safety concerns are confined to a few individuals;
- ‘*just culture*’ where there is a limited extent for permitting and encouraging people to report safety concerns and problems (the fear for penalisation or victimisation for raising safety concerns and issues in the organization;
- *Lack of real leadership commitment* where management is not able to invest in safety consistently and also allocate resources to improve safety timely in the balance of the ‘chronic’ pressures for production.

Hale's comparative analysis was only limited to the Norwegian regulatory regime as against other regimes that operated under different modes of regulation.

Capano and Woo (2017) examined the concepts of resilience and robustness in the context of risk governance. The authors presented the fundamental empirical challenges associated with these two concepts given a contribution to their thinking development towards policy process and policy design. They indicated that the direct application of the resilience concept might not be useful to address policy complexity. This is because social systems have inherent complexity and dynamism feature. The complexity concept affects different dimensions of the making of social policy and implementation processes (Özer & Şeker, 2013). The systemic ontological application of resilience between ecology and social systems are different in terms of policy complexity as the presence of the human agency through various ways may cause several and unpredictable possibilities of social adaptation to shocks. There are three critical dimensions (i.e. *structure/agency*, *policy change*, and *manipulability*) examined based on dealing with the complexity and changes of public policy. In these dimensions, it became indicative that resilience concepts may not be useful and also could be misleading in dealing with complexities and changes in public policy whereas the idea of robustness appeared to strongly demonstrate high potential for proactiveness in policy structure and implementation.

Aven and Ylönen (2018) discussed resilience and robustness thinking within the context of a sociotechnical systems perspective to risk management. They conceived the resilience concept as the capacity of a system to restore its fundamental functionality in response to shocks. They pointed out several weaknesses in the literature (e.g. Groth et al., 2010; Luxhøj et al., 2017) that are associated with the current risk management framework used in the oil and gas industry that is mainly rooted in engineering risk assessment perspective (probability risk estimates). The current risk management approach is unable to capture knowledge uncertainties and potential surprises. Because of the inherent complexity associated with the upstream oil and gas operations, they considered the robustness - sociotechnical system linked perspective as the most appropriate approach to safety management in the industry. They emphasised an opinion that resilience management can be conducted without necessarily identifying the hazards and threats and estimating their probabilities because the literature (e.g. Park et al., 2013; Linkov et al., 2016; Aven, 2017) acknowledged resilience management and risk management as supplementary instruments. The weaknesses associated with probability-based risk management are well documented in the literature (see, e.g. Le Coze et al. 2017; Capano & Woo, 2017; Ylönen et al., 2017) that indicated that such an approach is limited in terms of its proactiveness in addressing the complex emerging situations.

Amir and Kant (2018) examined the concept of resilience from a socio-technical perspective to conceptualise resilience as an inherent attribute of a sociotechnical system. They acknowledged the earlier definition of resilience as the ability of a system to return or bounce back to disturbances or shocks. The authors argued that the application of the concept of resilience in the sociotechnical perspective is fundamentally dependent on its transformability that is anchored by three constituents: *informational relations* (Information organisation and management give to support operation), *socio-material structures* (reciprocal entanglement of human organization and material structures), and *anticipatory practices* (construction of daily operations for anticipation of occurrence of shocks). Thus, the ability of the sociotechnical systems to cope with disturbances or shocks is articulated in its transformability. Transformability was defined as *"how quickly and robustly a sociotechnical system transforms from one state to another"* (p. 11). Informational relations offer an awareness of how the dynamic vulnerabilities emerge and breed throughout the system. They indicated that this required the following: *effective design of information network*, *implementation of cross-scale information couplers*, *control the flow of information* and *proactive dissemination of information to the targeted audience*. It recognised that every sociotechnical system has socio-material structures that underscored the concurrent hybrid fashion of social realities of the stakeholders (i.e. individuals, groups, institutions, & government) and the material realm of machines (i.e. electronic-mechanical networks). They identified two key aspects of socio-material: the hybridity and interpretation of flexibility along with the interaction between human and machines; the design for correct functioning and resistance to disturbance or shocks. As a result, to obtain knowledge of a resilient sociotechnical system, these two aspects of socio-material that have to be concurrently taken into consideration. In their view, the human-machine interaction creates socio-material modes that offer control and governance for risk reduction and prevention of incidents. Due to the gradual emergence of incidents (see Reason,1997; 2016), anticipatory practices are required so that culture is developed where stakeholders drive coordinating actions at faster and slower temporal scales towards the anticipation of the possibilities of occurrence of disturbance or shocks. Much discussions of this sociotechnical resilience concept coupled with the analysis of its strengths and weaknesses are also well documented in Amir (2018).

From the above examination of the literature on resilience versus robustness concepts, it is clear that the two metaphors have different meanings as well as offer different theoretical implications to safety management. This study argues that robustness concept tends to offer more proactive measures in dealing with complexity, uncertainty and ambiguity of risk. This argument follows the next discussion.

2.4.1.3 The Researcher's Argument for Robustness Thinking

In the theoretical context, this study relates resilience thinking development to what Holgnall (2016) describes as *Safety-I* that reflects reactiveness in safety improvement. Whereas, robustness refers to *Safety-II* that reflects proactiveness in safety improvement. The current safety regulatory regime is underpinned by the reactive strategies where it commences from the manifestation of the absence of safety. Thus, safety is appraised by counting the number of cases where it fails. However, there is a need to shift to where there is the capacity to succeed under changed conditions. Safety must be appraised by counting the number of cases that goes right.

One important thing that has to be explicitly made clear in both the research and professional literature is that the reliance on the current approach in managing safety in the upstream oil and gas operation is inadequate in dealing with complexity, uncertainty and ambiguity. The current safety management approach in the upstream oil and gas industry is mostly underpinned by an engineering risk assessment perspective (Aven & Ylönen, 2018). This approach aims at providing system understanding by employing simple linear models. The knowledge gained through the application of these linear models is quantified and used to compare with predefined criteria which resultantly serves as inputs to the decision-making process. This risk-based approach focuses on following: the risk reduction strategy mainly defined as the ALARP, the application of risk assessment (probability-based) and the risk acceptance criteria. Today, most existing safety regulations for the upstream oil and gas industry explicitly requires the operating companies and regulatory agencies to use the risk acceptance criteria. Despite the relevance of the current risk assessment approach in providing both logical framework and systematic procedures to improve "consequence-driven" decision making, there are several limitations, skepticism, disillusionment and dissatisfaction with the existing probability-based risk assessment that have been well documented in the literature (Cox, 2009; Villa et al., 2016; Aven & Ylönen, 2018). Some of these issues are summarized as follows:

- the omission of relevant social, political and cultural realities;
- failure to capture emotional responses that significantly influence individuals' perceptions, judgments, and behaviours in response to risks;
- failure to adequately deal with the realistic uncertainties, complexities, and value judgments;
- it can be easily manipulated politically for a hidden agenda.

However, the current approach is not adequate to deal with the system complexity related issues. The problem is that the linear models do not identify hazards and threats in a complex system as causal links to systems that provide a complicated understanding of their boundaries against a single chain (Jensen & Aven, 2018). The use of these linear model techniques, for examples, HAZOPS, HAZIDS, Event Trees, Fault Tree used in the oil and gas industry are not adequate to capture the threats and hazards associated with the upstream oil and gas operations. There is a need for the application of a sociotechnical system thinking to safety regulation and industrial safety management. It must be established primarily that the integrated upstream oil and gas activities are more sociotechnical characterised (Rasmussen, 1997; Liyanage et al., 2006; Le Coze et al., 2017) with inherent complex interactions (Bento, 2018; Jensen & Aven, 2018). Fundamentally, every sociotechnical system has an emergent property in which there exist complex interactions between technology, humans, and organization components (Baxter & Sommerville, 2011; Reiman & Rollenhagen 2014; Carayon et al., 2015) with the general goal of fulfilling social functions (Geels, 2004). The fundamental problem with the sociotechnical systems is its inherent complexity (Leveson, 2017; Aven & Ylönen, 2018). The complex interaction of a sociotechnical system has implication for human performance as the capacity to capture adequate knowledge of threats and hazards in this complex interaction is the current fundamental challenge (Klinke & Renn, 2012; Hale, 2014; Kyriakidis et al., 2018). This complexity emanates from the several networks of relationships, interactions and interconnectedness of the components of the systems. Consequently, the boundaries of these systems become not clear in term of their understanding (Dekker et al., 2011). Therefore, relying on only engineering linear model techniques will always produce uncertainty of knowledge and potential surprises.

In linking the resilience and robustness concepts to system complexity within the context of sociotechnical perspective for addressing uncertainties, there is limited research attention that has been given to the area. Amir and Kant (2018) discussion of resilience concepts as an inherent attribute of a sociotechnical system was fundamentally based on its reliance on transformability. This means that the ability of the sociotechnical systems to cope with disturbances or shocks is articulated in its transformability. The human-machine interaction creates socio-material modes that offer control and governance for risk reduction and prevention of incidents. In contrast, robustness is a crucial quality of complexity, in which complexity is a process that orients towards the *General System Theory*, a concept developed by Von Bertalanffy (1969). Safety is an emergent phenomenon made up of several interacting components which cannot be detached from the other core functions of an organization. Robustness concept is an essential specific characteristic of a system that can retain its fundamental functional features, albeit its confrontation of uncertainties. The review study by Capano and Woo (2017) points to the relevance of the robustness concept in the provision of conceptual and empirical room in policy and institutional design. Robustness thinking is mainly associated with the policy process (Capano & Woo, 2017) and policy design (Howlett et al., 2018; Capano & Woo, 2018). It is an essential concept for a policy process because it has a significant influence on the dimensions that characterized policy process (structure and agency, policy change, and manipulability) in the confrontation of uncertainties or potential shocks. Again, robustness thinking contributes significantly to policy design (design process and output).

From a public perspective, institutions are key concepts because their structures and rules influence the state and political actors (Knill & Tosun, 2012). The social structure functions through the action of the agents in the form of allotment of roles and meanings. Social structure and its agency constitute a vital part of every sociotechnical system as Upham et al. (2018) pointed out, strong structuration stimulates the actors' situated knowledge that may have a potential influence on technological reformation or correction. The understanding of the characteristics and processes of the agency relative to the general structural features will have potential relevance in capturing the knowledge that contributes to manipulating the agent-level processes. Resilience and robustness are associated with structure and agency in influencing policy process but in different ways. Resilience thinking in safety regulation has its challenge due to the inherent complexity and dynamism of the sociotechnical system (Patriarca et al., 2018) as its holistic dimension (e.g. structure/agency, policy change, manipulability) is challenging to grasp and unpack (Capano &Woo, 2017). Owing to its reactiveness nature where there are always inherent biases of bouncing back to an earlier equilibrium state (Davoudi et al., 2012; Bond et al. 2014), it is noted that, in terms of *structure and agency*, such return to systemic stability may ironically lead to counterproductive in response to shocks because it impedes organizational flexibility (Pidgeon, 2010; de Walle, 2014; Capano & Woo, 2017). Therefore, resilience thinking does not permit a significant role for the agency. Robustness provides an inherent proactive capacity for the system to prevent the consequences of shocks due to its ability to offer means to control and manage bureaucratic institutional and actors' behaviours specifically.

Notwithstanding in view of policy change the two concepts may have the propensity to sustain the status quo or drive an incremental change, it must be indicated that a major or radical change seem highly impossible for a policy that is driven by robustness thinking. This is because the concept of robustness has the capacity to always retain the principal function of the policy in confrontation to disturbance or shock either internally or externally. Therefore, the two concepts offer different implications in policy to regulate uncertainties. Due to the reactiveness nature of resilience thinking, it fundamentally focuses on anticipatory practices where there is always a construction of operations for the anticipation of possibilities of occurrence of shocks with concurrent exploitation of the experiences through learning to adapt to the changed situation (Amir & Kant, 2018; Amir, 2018). On other hands, robustness thinking is naturally more "*proactive and design-centric*" (Capano & Woo, 2017, p. 414) because it influences the development of rigidity and resistance to change, and at the same time providing avenues for the development of policy to adapt to change towards the confrontation of disturbances or shocks. In terms of policy manipulability (flexibility), resilience thinking is characteristically noted as having structural rigidity and drives growth in change. Studies (e.g. Hollnagel et al., 2006; Wreathall, 2006) have pointed out that resilience application has flexibility limitation in terms of decision-making in the organisation which may contribute to several failures for the systems to respond swiftly in augmenting protection as against the pressure of production.

Therefore, it can be established that robustness thinking can maintain the functions of a sociotechnical system (policy, political system, institution/organisation) with concurrent continuity in adaptation to details of priorities and changing situations. This requires the government's capacity to demonstrate satisfactory policy analytical and managerial competence in the safety policy process and policy design (Wu et al., 2015). Resilience thinking emerges less promising in terms of policy application with a primary focus on developing anticipatory cultural practices towards constructing daily operations for the anticipation of possibilities of occurrence of disturbances or shocks. Contrarily, robustness emerges more promising in two ways: improvement in understanding of policymaking and also improvement in policy designs. Robustness thinking is a crucial proactive strategy in the application of a sociotechnical system perspective to the regulation of hazards and threats in the oil and gas industry. This is because its potential capacity of adaptability provides continuous room for improvement in technological, human and organizational policy designs without experiencing adverse occurrence before adapting. Despite its associated challenges (i.e. diversity of issues, modularity and redundancy) in application to policy design, research (e.g. Capano & Woo, 2018) has indicated that elements such as *institutionalisation of polycentric decision process*, and *provision of political and technical capacities* would help to ensure robustness of the performance of policy design in confrontation of disturbances or shocks. Currently, there appears to be limited research on how robustness thinking has been applied to develop a framework to manage safety in the upstream oil and gas industry. To what extent can safety regulatory regime reflect the characteristics of robustness concept? The next section discusses the conceptualisation of robustness safety regulatory regime.

2.4.2 A conceptualisation of Robustness of Safety Regime

The previous section reinforces the need to adopt robustness thinking in addressing the threats and hazards associated with the upstream oil and gas operations. The design of the safety regulatory regime must reflect the characteristics of the robustness concept.

Robustness of safety regime is defined as "a *regime that has survived for a considerable period with its principles intact, but with adaptation in its detail to changing situations and priorities*" (Hale, 2014: p. 421). This definition relates to an earlier definition of robustness from organizational theory by van Oss and van't Hek (2011, p. 34) as, "*capacity of an organization to retain its fundamental pattern at core characteristics under changing conditions*". This definition underscores two critical elements: *the capacity to sustain the core functions of the system* and the *adaptability to changed situations*. What it means is that the regime must incorporate the measures to ensure the sustainability of the functionality of the sociotechnical system while adjusting to changed situations. In looking for a way to drive the required capacity to retain the functionality of the system, Hale extended his definition to include all the steps of Renn's (2014) model for adaptive and integrative risk governance as key characteristics underpinning a robust regulatory regime. He stated emphatically, that for one to call a regulatory regime a robust, one "*must have dealt with all of the steps in that model explicitly and achieved a stable balance in each*" (p. 420). As presented in Figure 2.4, Renn's model is based on five key steps: pre-estimation of the risk, interdisciplinary estimation of risks, risk evaluation, monitoring and controlling, and communication.

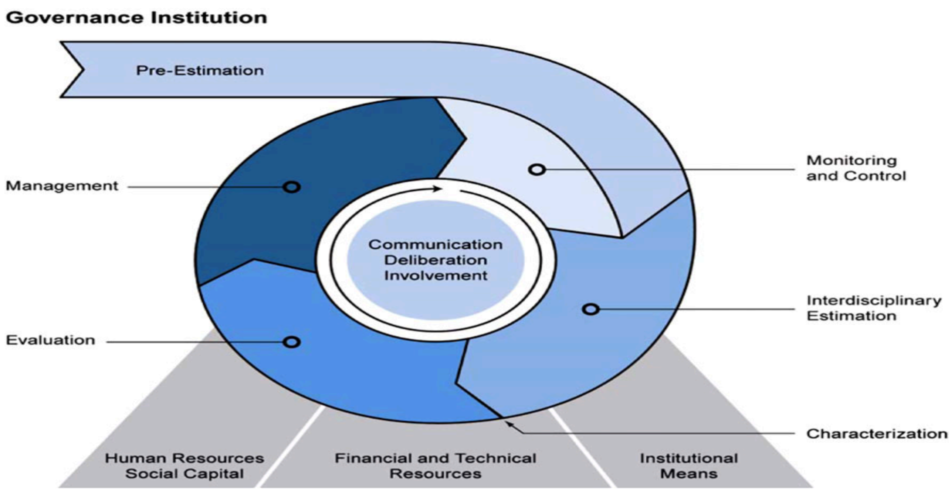


Fig. 2. 4 Renn's model for adaptive and integrative risk governance

Source: Klinke & Renn (2012).

2.4.2.1 A Synthesis of Renn's Model

The link between the Renn's model for adaptive and integrative risk governance and the characteristics of the upstream oil and gas industry have not received sufficient discussions in the literature. There are two essential characteristics associated with the upstream oil and gas industry: *multi-layered in structure* and *multi-playered in actors* (Rasmussen, 1997; Hale, 2014). Several layers are constituting the structure (both vertical and horizontal) for the management of the upstream oil and gas operations. These layers are managed by several industry players involved in the upstream oil and gas operations. Each element in the model emphasises its requirements for improvement in risk governance. These requirements include the following:

- A suitable frame to capture all the hazards and threats from the multi-layered structure of the industry.
- Interdisciplinary assessment of hazards and threats as well as other issues of individuals and societies that relate to a particular risk.
- Institutionalisation of transparency on the judgement of risk acceptability or tolerability.
- Monitoring and controlling of high-level safety.
- Effective risk information sharing.

These requirements are discussed in the next section.

2.4.2.1.1 Framing of Risk Emphasising Multiple Actor-Network Involvement

Risk is only comprehended through mental constructions that originates from people's perception of uncertain phenomena which is dependent on the presumption that human agency can prevent them (Rosa et al., 2013). Those perceptions, interpretations and responses are influenced by political, economic, social and cultural factors (IRGC, 2005 cited in Renn, 2014). Those mental constructions are shaped by people's experience and knowledge about the events and developments that are associated with real consequences. Therefore, comprehending risk as a construct has an implication on how it is considered. This implies that given the previous vast experience and knowledge gained on incidents or accidents, it is only required that screening is made to consider those experiences and knowledge that are relevant to the risk candidates. This points to the criticality of the framing process in risk governance.

According to Bengtsson (2011, p.14), "*to frame means to select some aspects of a perceived reality and make them more salient in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and treatment recommendation for the item described*". Framing implies screening to select from an extensive collection of actions and problems that constitute the risk candidates. Given the critical features of the upstream oil and gas industry as *multi-layered in structure* and *multi-playered in actors*, it is only necessary that the framing process is linked to these features. According to Lindøe (2016), a risk regulatory system must fit into those elements and dimensions that characterise a production system. In the production system, these dimensions may include the following level of actors: government (state agencies), industry (operating organisations), contractors (contracting, sub-contracting and service organisations), labour unions, public (communities whose activities shape the risk candidates) and media. The framing process must be linked to the "multi-actor and multi-objective governance structure whereby the actors are all involved in the selection of the suitable frame for the conceptualisation of the problem. However, there are some critical issues identified by Klinke and Renn (2012) that affect the upstream oil and gas operations as far as the frame analysis is concerned:

- The legitimacy of trading off the value between societal risks and economic benefits.
- The relative weight allotted to each of the values upon the need for a balanced judgement is accepted.
- The treatment of remaining uncertainties as to the effort in balancing risk and benefits always varies significantly.

It must be indicated that the establishment of a framing process towards upstream oil and gas operations is critical in terms of the understanding of the risk nature. What is essential in this case is that safety regulatory regime must incorporate the aspects of setting up institutions and procedures that will be able to capture all issues emanating from the complex actor-network involved in the upstream oil and gas operations. Any safety regulatory regime that ignores the essence of framing emphasising actor-network involvement will find it challenging to design risk assessment management strategies that will be supported and accepted by all the major stakeholders in the industry. It is therefore vital that a safety regulatory regime must make provision for a frame structure that indicates the establishment of institutions and procedures to collect all the risk candidates that captures the hazards and threats emanating from the complex sociotechnical system.

2.4.2.1.2 Interdisciplinary Risk Estimation

Interdisciplinary estimation of risk forms the second step of Renn model. This step requires risk estimation to be conducted in a multidisciplinary approach. This interdisciplinary approach emphasises a *risk assessment* (i.e. reviewing all scenarios that makes the facilities vulnerable to hazard risks) and *concern assessment* (i.e. identification and analysis of issues of individuals or society that are linked to the risk). In other words, the interdisciplinary risk estimation requires the incorporation of human and organizational factors into the risk assessment.

This risk assessment, as referred in Renn's model, is understood and described along with the perspective of purely probabilistic-based expression of uncertainty of events and consequences. This perspective has been a long tradition of the oil and gas industry. Existing risk assessment in the oil and gas industry mainly relies on the probability-based estimation that is limited in terms of its capacity to establish the causal links to those quantitative estimates. This risk assessment is not able to capture the adequacy of the risk issues from the complex sociotechnical system (Flage et al., 2014; Amundrud & Aven, 2015; Aven & Ylönen, 2018b; Jensen & Aven, 2018). There is the need to look beyond the numbers. Therefore, to understand the concerns of the stakeholders, risk perception plays a critical role.

There is always the knowledge of uncertainties and potential surprises in the complexity of the sociotechnical system. This is because the state and the quality of the available knowledge about the hazards and risk are not usually known (Renn, 2008). The emphasis here is how to obtain all the knowledge of human and organizational issues embedded in the complex sociotechnical system. According to Amundrud and Aven (2015), the risk assessment must be conducted to obtain risk understanding within the *sense of knowledge - justified beliefs*. The concern assessment relates to those evaluations of organisational and human influences that shape the hazard risks. This refers to safety culture or better state the safety climate perceptions, which are much discussed in the subsequent section 2.6. The main point in these two types of risk estimation is the ability of the existing assessment to capture the risk understanding in sense-making within the context of decision-making. These assessments of knowledge must be obtained through scientific investigation. Renn et al. (2011) identified several scientific methods to assess the concerns that may include survey, focus groups and interviews of the stakeholders.

Linking this feature of Renn's model to the upstream oil and gas operations, the industry is a sociotechnical system that recognises the human agency and social institutions as a critical part of the technical systems. This implies that the actualisation of organisational safety goal cannot only be optimized by the technical systems but largely inclusion of the human agency and social institutions. However, the interdisciplinary risk estimation step in Renn's model has several limitations. The conceptual distinction between threats, vulnerabilities, hazards, and risk are not adequately dealt with in Renn's model. Noy and Yonson (2018) have made these conceptual distinctions as *vulnerability* relates to conditions that are predetermined by physical, social, economic and environmental factors or process with the possibility of augmenting the susceptibility of a person, assets and community to the impacts of the hazards. *Hazard* relates to a process, human activity or phenomenon that may cause loss of life, injury including other health-related issues, destroy or damage asset, socio-economic disruption and pollution of the environment. *Risk* relates to potential loss of injury, life, destroyed or damaged assets, and community within a specific time. Risk perception plays an essential role in bringing to light some of these vulnerabilities, hazard and risk-related issues. However, Aven and Ylönen (2018) noted that its application to decision making must be consciously considered.

This study asserts that risk estimation in the upstream oil and gas industry must cover both aspects of the assessments. Risk perception application in various working groups in the working environment may contribute to exposing several issues that are linked to human and organizational influences. The human and organisational factors remain critical issues because they continue to contribute to many of these hazard incidents and process failures in the industry today. This requires that interdisciplinary estimation of risk must be carried out to expose vulnerabilities and hazards that will have potential consequences to the risk of human fatalities and injuries, destruction of assets in systems and pollution of the environment.

2.4.2.1.3 Risk Acceptability or Tolerability Criteria

One important heavily debated issue in both the academic and professional literature has to do with the approach in which risk is evaluated. The classical approach of risk evaluation is focused on the rank and prioritisation of risk based on a combination of probability and consequences (Renn et al., 2011; Renn, 2014). Most of the existing safety regulations explicitly have been built on this classical approach to risk evaluation. Thus, the safety regulations are shaped by a risk assessment method linked to the RAC. It is often referred to in safety regulations or standards as ALARP which are usually expressed mathematically by comparing the calculated values of the probabilities derived from the risk analysis with the predefined acceptable limit and drawing the conclusion for decision making.

However, Renn's model underscored the need for the legitimisation of an open and democratic process regarding the judgement on risk acceptability or tolerability. This view is based on the fact that the judgement on the RAC is a political decision that had to be taken in the interest of the public. Kringen (2014) identified two main problems relating to the legitimisation of the risk acceptability or tolerability criteria: (1) the legitimisation of the regulatory goals relative to how much risk is the regulatory regime ready to tolerate; (2) the legitimisation of the regulatory means and instruments contrived for actualising these goals. Kringen stated that the issue relating to tolerance is usually found embedded and hidden in legal decision making, even though the existence of a defined value judgement is at stake. Obfuscating the value judgement often results in the consequences relating to delegitimization since there is no information regarding the trade-offs.

It can be argued that the classical risk evaluation approach itself is associated with inadequate knowledge about risk that are inherent in the complex sociotechnical system. The current practice of risk assessment is characterised by a high level of arbitrariness and wrong focus for decision making. The calculation of probabilities that is derived from the risk analysis must be based on background knowledge. The values of the probability that must be linked to the strength of the knowledge are not adequate captured in the current classical risk assessment approach applied in the upstream oil and gas industry. In practice, the industry (i.e. operating companies) focuses mainly on meeting the risk acceptance or tolerance criteria. Many of the application of the risk appraisal tools are mechanistic as they seek to fulfil a regulatory requirement. These criteria are the minimum requirements that are required to be met by the industry. The critical issue is that the industry mainly focuses on satisfying the minimum requirements for risk acceptability or tolerability criteria.

However, experience indicated that it is challenging to actualise significant improvement in safety so far as there is the existence of such minimum criteria (Aven & Ylönen, 2016). This challenge becomes exacerbated when existing regulatory style requires the industry to set the Risk Acceptance Criteria (RAC). Despite the long heavily disputed issue on risk acceptability or tolerability, not much attention has been made in terms of offering the best strategies to deal with these issues related to the classical approach that shaped the current safety regulatory regime. Two strategies have been suggested by Aven & Ylönen (2016):

- Adjusting the current safety regulations to deal with the hazards and threats inherent in the sociotehncial system (i.e. moving in line with the new risk perspective).
- Removing the use of (ALARP) provided in the current safety regulatory regime.

These two strategies are essential for dealing with knowledge of uncertainties and potential surprises. However, practically, such challenges may take time to be dealt with because of the complexity in reaching consensus. Given these challenges, this study argues that in a government-enforced self-regulatory regime, the government must set the RAC to limit the complete freedom granted to non-state actors in terms of privatisation of the state obligation to protect the public interest. If the probability risk-based approach is the way forward, then the safety regulation must be made to explicitly provide for method and processes to assess the knowledge in which these probabilities are based including the strength of the background knowledge of the hazards. These processes must be legitimised to provide transparent, accountability, trust and democratic process on the judgement of risk evaluation.

2.4.2.1.4 Management - Monitoring and Controlling of Risk

There are two essential elements involved in safety management: the prescription of safety norms and the control that makes these safety norms being complied. Among other players, the state and the industry form the two main players for this safety management. Safety management is based on different regulatory regimes as these regimes establish the rules and standards that must govern how risks are dealt with within a specific regulatory context. The goals of these regimes are to achieve regulatory outcomes (Renn, 2014). According to Renn (2008), this robustness of a regime is mainly determined by how the regulatory agencies and the industry manage the issues of complexity, uncertainties and ambiguity. There are two main emphases in managing risk-related issues: safety culture or safety climate and the monitoring and controlling of risk. Safety culture or safety climate is much discussed in the subsequent section 2.6. The monitoring and controlling of risk play a critical role in the sustainability of high-level safety in the industry. Renn (2014) discussed that relaxation of inspections, overconfidence with staff and incomplete and inadequate monitoring could trigger negative influence on safety performance. This is because incidents or accidents are also caused by lack of oversight. It is stated that "*normalisation of deviations*" (e.g. reduction of cost, convenience, etc.) in safety regulatory program or safety management systems can cause or trigger major incidents or accidents. From the Swiss-cheese model (see Reason, 1997) such deviations form norms in the organisation which gradually create conditions for major incidents or accident occurrence. Two main contested issues in the literature are based on monitoring and controlling of risk: *How* and *Who* to monitor and control risk. Thus, what kind of monitoring and controlling mechanisms should be adopted for different regulatory regimes, and who should be responsible for monitoring and controlling risk? These issues are important for improving safety oversight role of the state.

It must be indicated that in term of the *How* (mechanisms) to monitor and control risk, Addulai (2016) examined two main strategies: *Deterrence* and *Compliance*. The deterrence strategy premises on the sanctioning of the violators in an adversarial and confrontational way. It seeks to deter violations, establish guilt and penalise violators for wrongdoing. This deterrence strategy mainly works under an extreme detailed prescriptive regulatory requirement within the command-control regime style. Given the several limitations of the prescriptive regulatory approach, as highlighted in Baram et al. (2014), the deterrence strategy cannot survive well in *Self-regulatory* and *Co-regulatory regimes*. However, most of the existing regimes continue to rely on the '*Compliance monitoring tool*' as the primary enforcement strategy in the upstream oil and gas industry that characterised detailed prescription rules. Achieving the compliance requirements may mislead safety performance. The traditional compliance monitoring tools used by regulators lack adequate technical competence as was noted in the investigation of the *Deepwater Horizon disaster*, that compliance monitoring turned into 'rituals' that obscures the industry from the knowledge of uncertainties and potential surprises (Hopkins, 2007, 2012). There is the need to move away from the mere compliance monitoring practice to more of cooperation of parties (regulators and actors). As the literature indicated, there is lack of judgement, experience, professionalism, leadership, and competence in both the public and private sector (Hopkins, 2012; Hayes, 2014). This affects the quality of oversight role required by the industry internal safety controls and the state control mechanisms. Hopkins (2007) provided the following strategies that can help to move beyond compliance monitoring:

- *Auditing the auditors*.
- *Proactive investigation*.
- *Supporting organisation safety staff*.
- *Advising on organisational design*.
- *Exposing performance*.
- *Promoting regulatory crisis.*

The usual safety auditing is increasingly reducing into '*tick-a-box* exercise as there is a limited effort by auditors to ask more probing questions regarding the effectiveness of existing safety management systems. It is revealed that the usual checklist questions are not adequate, which had led to weak responses resulting in major incidents (Hopkins, 2007). The auditors need to be technically trained and competent to probe challenging questions that will elicit responses on hidden system failures. There is a need for proactive investigation of the system to identify failures so that it can be corrected. The investigation needs not to be conducted reactively. All incidents or accidents whether minor or major are preceded with early warnings (Reason, 1997), and if they had attended to them, they would have been prevented. It is also indicated that large organisations may have internal staff with specific safety responsibility. Such internal safety staff are to ensure compliance with regulations in their organisations. Given the degree of 'clout' the internal safety compliance staff wield, regulatory agencies can support the organisations' internal compliance staff. The regulators advise on companies' organisational design in terms of locating safety staff to several points of the organisational hierarchy where they report to the line manager. Regulators needs to also pay much attention to exposing process safety performance indicators. Researchers have indicated that when regulatory crisis are promoted it helps to strengthen the intimate link between public opinion and enforcement towards the motivation of compliance. This is because the poor reputation of the companies may fuel the public demand for strict enforcement of safety (Gunningham et al., 2004). However, this must be strategically created with extreme carefulness. In all these strategies as discussed, what can drive their implementation is availability of adequate resources. When safety prioritisation is truly driven by the regulators' values and actions, adequate resources would be available for implementation of these strategies.

In terms of *Who* monitors and controls risk, it has been contested in the literature that is between the operators of the technical facilities (or closely observed) and the public regulatory agencies. Renn (2014) stated that this role is now assumed in the form of '*Joint Responsibility*' (public-private partnership). However, it must be noted that such a decision is contingent on the modes of regulatory regime. For examples, the Safety Case regime of United Kingdom and Australia puts the task of monitoring and control of risk in between the state and the industry but with the emphasis on the industry (operating companies). Norway has government enforced self-regulation regime that is based on internal control. United States has detailed prescriptive regulatory regime with the emphasis on government. It had been suggested that given the limitations of the public sector safety compliance performance, government's compliance responsibility should be delegated to private organisations. However, the literature has indicated evidence of mismanagement of the privatisation of the government's safety control role by the private organisations. This study argues that a great emphasis on *public oversight* and *check and balance* are essential for the public interest in whether self-regulation or co-regulation approaches underpin the choice of the regime style.

Moreover, what is of more critical is the independence of the regulator in improving safety performance and not necessarily ensuring compliance. Satisfying compliance requirements cannot guarantee sustainable safety performance. In sustaining regulatory oversight performance, some researchers (e.g. Mendes et al., 2014; Renn, 2014) have linked the following measures as important factors: high wages, investment in safety training, research and development. There must be an independent and competent regulator that will seek to improve regulatory culture under a joint responsibility approach as it required trust and dialogues with the industry actors that will help to enhance risk governance in the upstream oil and gas industry.

2.4.2.1.5 Risk Information Sharing

One key challenge facing risk governance is lack of effective communication among all relevant stakeholders (Renn, 2014). Effective communication is critical to any successful risk governance. A meaningful exchange of knowledge, interpretations, experiences, concerns and views about risks among all the relevant stakeholders defines the communication concept (Lofstedt, 2003). Renn (2014) identified several purposes of communication that may include: sharing information about risk and dealing with it, supporting the development and sustainability of trust among several stakeholders in dealing with uncertainty, engagement of several actors in risk-related decisions with the view of gain ownership of the process. This is not a simple task of having an accurate risk assessment, bring people together, having just effective communication, but requires more than these. It principally involves establishing procedures to facilitate discourses on uncertainties that involve multiple actors in interactions emanating from a different background (Rosa et al., 2013). In risk governance, effective communication accentuates featuring multiple actors. In the context of risk governance, the critical challenge is the *inclusion of stakeholders* in the participation in risk deliberations. The literature defined inclusion concept to mean the important role the actors play in the framing of the risk. Several forms of inclusiveness have been suggested including open forums for discussion on risk, mediation, negotiated rule-making exercises and advisory committees involving amalgamation of stakeholders and scientists.

The basis for the inclusion of all relevant stakeholders in risk governance has been discussed in the literature to including the following:

- It serves as a means to an end. This stems from the requirement for exploration of various sources of information about risks and identification of several perspectives on them. It seeks to establish procedures for integrating all relevant knowledge as well as the concerns.
- It serves as an end in itself. Stakeholders affected by the risk, within their democratic right, ought to participate in the decision making of the risk. They need to involve these stakeholders in the designing of principles and rules that must be accpeted in the processes and structures of the collective decision making about the risk
- It provides checks and balances between the stakeholders and the society as more actors are involved in the evaluation of the risk, the more socially robust outcome of safety. The inclusion of actors will help in the co-production of the knowledge of risk, coordination of risk assessment and the collective design of the risk management.

The modes of safety regulatory regime define the style of communication and inclusion. This is because the degree and types of inclusion may vary in respect of the governance level and the risk context. Renn (2014) indicated that such variation might stem from the nature of conciliatory, educational, insistent, accommodative, legalistic and persuasive enforcement practices. However, each style requires a specific approach to deal with internal and external communication and involvement of actors in safety management. Therefore, every safety regulatory regime must provide for a procedure for communication and inclusion of actors in the deliberation of hazards, threats and other issues that may affect the personnel, facilities and the environment. This requires incorporation of procedures in the existing regulatory regime to facilitate discourses among the various stakeholders that emanate from different background to promoting meaningful interactions towards the confrontation of uncertainties.

2.4.2.2 Critique of Renn's Model

This study recognises the significance of Renn's model as an approach to improve risk governance in different fields of study. It contributes to the risk research and provides a highly interdisciplinary scope of the risk governance field. However, there appeared to be some limitations associated with the model of which the present study will seek to address in its application to the upstream oil and gas industry.

Firstly, the model of risk governance is over-simplified relative to the body of knowledge required in managing safety in the complex upstream oil and gas operations. It must be indicated that safety is not a system component failure (Leveson, 2011). An accident is viewed as an emergent property that must take into consideration its whole parts. Safety is a control problem which means that the hierarchical safety control structure must be explicitly identified (Rasmussen, 1997; Leveson, 2017). There are hierarchical safety control levels in upstream oil and gas industry that include the government, regulatory agencies, company, management, staff and work. There are interactions between humans, machines and organisational processes in the systems to produce the safety outcomes. Such sociotechnical systems are not explicitly underscored in Renn's model.

Secondly, safety culture was highlighted in the risk management level of the model. However, safety culture was not given much attention in the model. The differences in national characteristics, particularly in regulatory properties underpinned by its style of the regime may limit the adoption of the model. There is limited empirical knowledge of how national culture influence safety performance in the oil and gas industry. It can be suggested that safety climate which is viewed as a manifestation of organisational culture must be emphasised to improve regulatory, organisational and workers' safety performance.

2.4.2.3 Research on Assessment of Robustness of Safety Regulatory Regime

An earlier review (see section 2.2.3) on assessment of regulatory regime found that large body of the literature mainly focused on assessing effectiveness of regimes. Effectiveness in context was defined as the relationship between the regulatory change and trends in respect of the occurrence of accidents. There is no consensus on the criteria for evaluating effectiveness of regulatory regime. Some researchers used safety performance indicators to determine the effectiveness of exiting safety regulatory regimes. Others used regulatory properties to form a benchmark framework analysis to determine the effectiveness of the regimes. However, basing the evaluation of the superiority of regulatory regime on effectiveness may be misleading. There are differences in reporting safety data (safety performance indicators) as well as national characteristics (e.g. culture, values, regulatory properties) among the regimes. The emphasis must be on developing strategies for two important areas: sustainability of the functionality of the safety regulatory regime and learning capability.

Lindøe et al. (2012) identified two main approaches to define the criteria for the assessment of regulatory regime: (1) *the influence of major accidents on the legal and administrative structures*, and (2) *regulatory processes* (i.e. collection of information on risk, establishing the norms and standards, and enforcement strategies). Hale (2014) on other hand, based his asseesment on the following criteria: *framing of the risk*, *interdisciplinary risk assessment* (quantification and cost-benefit), and *management and monitoring*. Hale's analysis reflected the integrative risk giovernance model by Renn (2014). In this study, these two categories of criteria must be considered in other to cover much of the characteristics that reflects regime functionality and adaptability elements. The legal and administrative structures give some impressions about the regulatory culture underpinning the regime. Every regulatory regime is influenced by the prevailing national characteristics of its culture. Therefore, the legal and administrative regulatory structure of the regime must form part of the criteria for the evaluation

However, there appeared to be limited studies that had provided adequate review critera for appraisal of robustness of safety regulatory regime. From the literature, it must be indicated that the comparative analyses were limited to developed countries (i.e. United Kingdom, United States and Norway). These countries had improved their regulatory systems after having gone through several major accidents in the upstream oil and gas industry. These regimes were shaped by the history of their complex differences in technology, political institutions, history, legal systems, culture, industrial structure and management. It appears from the literature that no study had focused on assessing robustness of safety regulatory regime in developing countries. Based on this review, this study presents review criteria for an assessment of robustness of a regulatory regime in a developing country (table 2.3). The review criteria cover four main elements that include: (1) the legal and administrative regulatory framework, (2) the requirements of Renn's model, (3) sustainability of the functionality of the regulatory system and (4) adaptability to changed situations. These review criteria covered 16 elements which can be based to assess the robustness of a safety regulatory regime. The scope of the legal and administrative regulatory framework governing the safety of upstream oil and gas operation covers the following topics: safety and health protection of personnel and facilities, environmental protection, oil spill preparedness (i.e. covering spill preparedness planning, their roles and responsibilities in spill response, and the capacity for response), emergency planning, employment standard and work environment, liability for accidents and management system requirements with clear responsibility. These areas are basically regulated either in the form of a single comprehensive statute and associated regulations or separate statutes that comprehensively deal with the individual areas. In whatever form it may take, in terms of ensuring coordination and effectiveness of these topics in regulations, a single statute can enable an integrated approach that provides a '*single window'* to the regulatory regime. For multiple statutes specific measures can be provided to ensure its effectiveness (Dagg et al., 2011).

Table 2. 3 Review criteria for an assessment of a robust safety regulatory regime

Criterion	Key Elements Assessed on the Criterion	Source(s)
Scope of legislative and administrative regulatory framework governing upstream oil and gas operatins	Existing legislations and regulations must cover the following topics: ➢ Safety and health protection of personnel and facilities; ➢ environmental protection; ➢ employment standards & work environment; ➢ emergency planning; ➢ oil spill response; ➢ liability for accidents. ➢ Existing legislation*s* and regulations must provide for the following: ➢ management system with clear responsibilities; ➢ Regulatory approach	Lindøe et al. (2012), Dagg et al. (2011), Acheampong & Akumperigya (2018), Mendes et al. (2014)

Requirement for integrative risk governance	➢ Provision of procedures for establishment of framing framework that captures all the relevant actors involved in the operations. ➢ Risk asessment must include both quantitative and qualitative approach. ➢ Legitimisation of the methods and processes on the judgement of risk evaluation. ➢ Monitoring and controlling of risk through cooperation, adequate resources and separate competent regulator. ➢ Provision of procedures for communication that emphasises inclusion of all relevant actors in the deliberation of the issues.	Renn (2014)
Sustainability of the functionality of the regulatory Regime	*Sustainability of the functions of the regime type*	Hale (2014)
Learning capability	Requirement for management of change in the facilities	Hale (2014)

2.5 Safety Indicators for the Upstream Oil and Gas Sector

The previous section examined robustnesss concept as a suitable approach to assess safety regulatory regime. Indicators are important to reveal system deficiencies for improvement. This section examines the safety indicators applied to the upstream oil and gas industry. The purpose is to identify the most appropriate dimensions to measure how well safety is managed in the high-hazard industry. One necessary means is to be incessantly vigilant through the use of indicators (Øien et al., 2011a). However, there are issues about offshore safety statistics: data that can capture the essential factors within the regulatory regime, and the development of comparative data across different regulatory context with different culture and history. The lack of scientific knowledge was one of the reasons that had driven the reliance on empirical data of regulatory approach emanating from the various regulatory regime (Blakstad, 2014). The industry had developed its own indicators. Safety performance data is indicated to be a challenge for the regulatory authorities in the oil and gas industry. Regulatory bodies need safety performance data for many reasons including notification of actions for improvement, resource decisions and determination of successes or failures (Walker, 2010, cited in Blakstad, 2014). There are several perspectives and dimensions when applying indicators. This section discusses those perspectives and aspects that are more applicable to exposing weaknesses and gaps in system control within upstream oil and gas operations.

2.5.1 Meaning and Purpose of Indicators

The term indicator is used in several ways and therefore has varied meanings. Øien (2001b; cited in Øien, 2011a, p.149) defined it as *"a measurable/operational variable that can be used to describe the condition of a broader phenomenon or aspect of reality"*. The literature identified two meanings here: (1) as a measurable/operational definition that reflects theoretical foundation; and (2) as an extent to describe the condition of a broader phenomenon or aspect of reality. An indicator must have a theoretical foundation and represents an aspect of reality. Research on indicator development had been taking place within the fields of social and natural sciences. However, an indicator is a new concept in the safety domain, but before the 1980s, safety assessment took the forms of indexes, rates and measurements (Øien et al., 2011a). There are different indicators in safety as discussed in Blakstad (2014) such as 'safety outcome measure', 'safety performance measure' as well as 'safety performance indicator', are occasionally used interchangeably. Safety indicators are developed to monitor the level of safety in a system mainly, to motivate action, and to provide the relevant information for decision-makers about where and how to act (Skogdalen et al., 2011). Harms-Ringdahl (2009) indicated that the demand for safety indicators varies considerably, and one approach is by beginning to look at it from the purpose and application. The real use of indicators is to assess the effectiveness of a system of risk controls (Hopkins, 2009a). Different safety indicators have different purposes and focus of attention. In this study, a safety performance indicator is applied.

2.5.1.1 Safety Performance Indicators

Safety performance is defined by two categories: *safety outcomes* and *safety behaviours* (Christian et al., 2009). Safety outcomes relate to historical information or statistical data on indicators of incidents, accidents, injuries and fatalities. Safety behaviour has two aspects: safety compliance and safety participation. These two components of safety behaviour are examined in the section (section 2.6.3.2.14). A safety performance indicator is defined as "*observable measures that provide insights into a concept – safety – that is difficult to measure directly* (OECD, 2008, p. 5). Skogdalen et al. (2010, p. 109) defined it as "*a means for measuring the changes in the level of safety as a result of actions taken*". According to Kjellén, (2009), it is the metric employed to measure the ability of an organisation to control the risk of incidents occurring. It measures either directly or indirectly, the level of incident risks and how it develops over time. Safety performance indicator reflects the changes that had taken place at the safety level. According to Hopkins (2009a), a description of the safety level of an organisation constitutes the critical function of a measure of safety performance. Safety performance indicator can be used to indicate an early warning of significant accidents (Øien et al., 2011a). These measures provide indicators that are proactive to deal with major hazard incidents before an accident occur.

The main emphasis of safety performance indicators is its ability to monitor system performance. The literature has used safety performance indicators to measure early warnings of system performance. Monitoring system performance requires both reactive and proactive indicators. The former relates to the identification and report on incidents to check the adequacy of existing controls. It indicates the safety outcomes of the control systems. The later is more related to active monitoring of risk control systems to provide feedback on performance before an incident occurs. Much of these are safety climate measures that provide early warning indicators on the performance of the system. In the context of this study, safety performance indicators are applied to only measure reactive or safety outcomes that identify and report the incidents. Safety climate measurement will be used to indicate the active monitoring on the system performance. Given the challenges associated with measuring system performances, there is the propensity to put 'everything' under the umbrella of indicators (Blakstad, 2014). An indicator must reflect the safety domain of the industry, its perspectives and the focus of attention.

2.5.1.1.1 The Safety Domains of the Upstream Oil and Gas Industry

Personal safety and process safety constitute the domains for the oil and gas safety (Swuste et al., 2016). Both the professional and research literatures have recognised the critical relevance of these domains in developing indicators to measure safety performance in the oil and gas industry. Each domain has its hazards and potential consequences. Their differences and issues form the next discussion.

2.5.1.1.1.1 Personal Safety

Hopkins (2007, 2009a) discussed the distinction between personal safety and process safety as the safety domains in a hazard industry like the oil and gas industry. He pointed out that the difference constituting these two safety domains is simply the different types of hazard that emerged from them. These different types of hazard have implications for managing safety in high hazard industry. Several studies (e.g. Horbah et al., 2017; Tang et al., 2018a, 2018b) have differentiated these two safety domains in terms of the hazards they constitute. Personal safety, also known as occupational safety, seeks to protect the health and safety of individual worker at the workplace. It relates to exposure of workers to noise, vibration, chemicals, mechanical, electrical hazards and among other hazards that lead to injuries and fatalities of an individual at the workplace. Such exposures have been examined by Broni-Bediako and Amorin (2010) in terms of the areas of upstream oil and gas operations that are associated with workers' exposure to drilling fluid. From their discussion, the health consequences emanating from the drilling fluids are triggered by the hazardous components of the fluids, additives and workers' exposure to those components. They indicated that skin irritation and contact dermatitis constitute the most common occupational health consequences that are observed from drilling fluids exposure to workers, with eye irritation, headache, coughing, and nausea appeared infrequently. These consequences are instigated by the physico-chemical properties of the drilling fluid and the inherent properties associated with the drilling fluid additives. They are all contingent on the route of exposure to inhalation, oral, dermal, and others. Hopkins (2007) indicated hazard incidents associated with personal safety to include falls, trips, electrocution crushing, and vehicle accidents. The report of the IOGP (see IOGP, 2019a) captured the common personal safety performance indicators commonly used may include *Fatal accident rate, Lost time injury frequency, and Total recordable injury rate, Number of restricted workday cases*, *Number of medical treatment cases*. These safety performance indicators represent the outcomes of safety performance.

2.5.1.1.1.1 Process Safety

Process safety relates to major hazards that could cause major incidents. Amyotte et al. (2016, p.1) defined major incidents as "*adverse events such as major leaks/releases, fires, explosions or loss of structural integrity, leading to multiple deaths and major damage to the environment or property*". In the upstream oil and gas industry, major hazards (see section 2.6.4.2) that included: hydrocarbon releases, explosion, fire, blowout, and just to mention a few, may cause major incident that have potential multiple consequences to the workers' fatalities and injuries, asset loss or damage and environmental pollutions. Horbah et al. (2017) examined the literature on the common characteristics associated with major incidents which included the following:

- they have relatively low frequencies but extremely severe consequences;
- their occurrences were not due to unknown physical or chemical process hazards, but in all cases, the hazards were known for a long time;
- why they continue to occur are mainly characterised by management quality, organisational and human factors;
- They are caused by a multiplicity of flaws, lacks and deficiencies.

The long assumption of personal safety indicators as relevant measures for process safety management is indubitably shown to be misleading. The reason is that evidence of past major incidents in the oil and gas industry such as Shell's chemical Company Plant Explosion in Texas in 1997, BP Texas City refinery disaster in 2005 and Deepwater Horizon accident in 2010 have pointed otherwise. The lessons from these major incidents in the oil and gas industry have indicated that more emphasis should be put on process safety indicators. How is process safety linked to asset integrity?

Tang et al. (2018a) notably linked process safety to asset integrity. They understood the latter as the management of people, systems, process and resources to reduce operation hazard risks that have many consequences to the workers, assert, and the environment. Managing process safety hazards is to safeguard systems assert integrity. Assert integrity and process safety hazards management seeks to achieve the same purpose – safeguarding systems' major hazard incidents. An occupational accident is associated with personal safety defects, whereas major events related to process safety defects. The management of safety hazards cannot guarantee system process safety. However, the management of process safety hazards can help to improve personal safety performance as much of its defects, or latent conditions are associated with safety culture. Although the two safety domains are essential for safety performance in the upstream oil and gas industry, process safety hazards need more attention to improve the control the system operations. From this discussion, the distinction between personal safety and process safety is made which safety performance indicators must reflect these. The debate about the use of safety performance indicators needs to be looked around their difference in perspective and focus of attention.

2.5.1.1.2 The Perspectives and Focus of Attention

Researchers (Øien et al., 2011a; Blakstad, 2014) have examined the development of safety indicators and their utilisation by regulatory authorities in the oil and gas industry. They pointed out that the development and use of safety indicators should be discussed along with the difference in perspectives and focus of attention. The perspectives are categorised into lagging versus leading perspective and technical-human-organisational perspective. The focus of attention of indicators must be related to the difference in aspects of health, safety and environment.

2.5.1.1.2.1 The Lagging versus Leading Perspective

The *lagging* and *leading* indicators are terminologies borrowed from the field of economics and adopted in the field of safety to describe the safety level of a system (Lingard et al., 2017; Oswald et al., 2018). Kjellén (2009) asserted that these terminologies were introduced to the field of safety without consideration of their full meaning relating to safety performance. Because of this, researchers have used these terminologies inconsistently which appeared unhelpful sometimes. In the industry, the use of lagging and leading safety performance indicators to evaluate safety level continues to receive increasing attention among the professional and research communities. However, the distinction between these two safety performance indicators and their practical implication to safety management in the prevention of major hazard incidents have become contentious in the safety literature.

The original Hopkins' (2007) paper (i.e. *working paper 53*) presented at the Oil and Gas Conference in Manchester ignited the controversy characterising safety indicators measurement involving whether managing indicators for occupational accidents the same way as managing indicators for major disasters and how these safety indicators are measured (*lagging versus leading*). As pointed in earlier in this section that the distinction between personal safety and process safety indicators are well understood in the literature — the essentiality in the understanding of the distinction between lagging and leading indicators. The main thrust of this difference is made between the indicators to determine the causes or contributing factors in the post-incident or near-misses evaluation and the indicators to predict possible major incident occurrence. The distinction between lagging and leading safety performance perspective is well documented in the safety literature (e.g. Hopkins, 2009a, 2009b; Hale, 2009a, 2009b; Vinnem, 2010). However, this distinction of safety performance indicators has not been a clear-cut issue in the safety literature.

Lagging safety performance indicators measure safety outcomes (Hopkins, 2009a). They are reactive indicators that measure the potential contributing factors after incidents or accidents occurrence using retrospective analysis. In Guo and Yiu (2015) conceptual framework of developing safety performance indicators, they defined safety outcome to broadly included: incidents, near misses, accidents and safety. Examples of such lagging safety performance indicators can be found in offshore safety statistics (HSE, 2010), Outer Continental Shelf Performance Measures (OCSPM), Petroleum Safety Authority (PSA, 2009b) and International Association of Oil and Gas Producers (IOGP, 2019). Review of these lagging indicators indicated no unified reporting system by regulatory authorities. However, some organisations have established their safety performance indicators for its member countries. For example, IOGP provides a set of safety outcome reporting criteria, including incidents classification, is defined for its member countries. The essence of these lagging safety performance indicators is that they measure the direct outcomes of incidents or accidents. The measure of lagging safety performance indicators is easier to be conducted simply because previous event data are available (Oswald et al., 2018) and provide valuable information about how the system has performed in the past. However, these lagging safety performance indicators are limited in terms of the ability to capture the knowledge of the causal links to these safety outcomes.

In contrast, leading safety performance indicators are predictive indicators that seek to measure potential contributing factors involving active monitoring to achieve organisational safety outcomes. However, there are several other definitions of leading safety performance indicators in the safety literature. For instance, a list of such explanations is documented in Guo and Yiu (2015). Guo and Yiu (2015) and Lingard et al. (2017) examined two different categorisations associated with leading safety performance indicators in the safety literature:

- Leading safety performance indicators that measure the direct aspects of safety management systems;
- Leading safety performance indicators of abstract safety constructs.

Safety management systems relate to a rationalisation of procedures that takes the form of management systems defining the safety policies, procedures and practices. The concept of safety management systems is examined in subsequent section 2.7. Safety performance indicators for safety management systems only measure safety practices and activities as well as offering information about the safety management system implementation. Given this, its central relevance lies in its compatibility with the safety management processes that enable remedial actions to be readily proffered. However, it is pointed out that such indicators do not establish why a worker did not do what he or she is supposed to do in improving system safety performance (Guo & Yiu, 2015). In other words, it does not establish the theoretical and empirical causal link to safety deviations.

The leading safety performance indicators of abstract safety constructs serve as precursors to harm that provides early warning signs of potential failure of the system. Guo and Yiu (2015) examined this type of leading safety performance indicators and pointed out that its causal link to safety outcomes is relatively robust and precise. They defined safety constructs as explanatory tools employed by safety researchers to understand the safety world, whereby several measurement scales are developed to measure safety constructs. They further stated that this type of leading safety performance indicators provides a more rigorous scientific understanding of the safety phenomena. Example of such leading safety performance indicator is the safety climate measures (Zohar, 2010) which are a snapshot of organisational safety culture.

It is clear from the discussion that the distinction between lagging and leading safety performance indicators is not a straightforward task. Some researchers (e.g. Hopkins, 2099; Hale, 2009; Manuele, 2009) argued that the distinction between the two different types of safety performance indicators is not all that relevant, but they should be used as a continuum. Manuele (2009) criticised the applicability of lagging and leading safety indicators as these terms do not provide value to safety practices. Other researchers are of the view that (e.g. Reiman, & Pietikäinen, 2012; Guo & Yiu, 2015) safety performance indicators should be explicitly distinguished as they create confusion for safety management.

However, much of the discussion of this distinction between lagging and leading safety performance indicators in the safety literature is driven by the epidemiological perspective of safety that underscores the relevance of the Swiss-cheese model (Reason, 1997) where latent failures create the condition for incidents occurrence. In this study, both lagging and leading safety performance indicators are for safety management. The reason is that safety performance indicators that reflect safety outcomes that are reactive and objective that cannot be ignored as they provide valuable information about the past safety performance of the system. However, leading safety performance indicators give information on safety management deficiencies as they specify the avenues for detection and resolution of safety deviations to be made before incidents occur. Given the aim of the present study, robustness thinking driven by a sociotechnical perspective requires the establishment of the background knowledge that links to risks. The measure of safety culture (i.e. safety climate) provides early warning indicators to improve system weaknesses. It provides background knowledge of the threat, which helps to minimise risks. However, from the safety literature, two different meanings appeared to characterise leading safety performance indicators. They include leading safety performance indicators that reflect management activities (safety management systems) and early warning signs (safety climate constructs).

The categorisation of these leading safety indicators appeared to have been driven by the epidemiological perspective of safety. This perspective on safety performance indicators is insufficient to improve safety management as they seek to correct individual safety behaviour without considering the whole system. Such safety performance indicators are mostly associated with knowledge uncertainties and potential surprises as they do not view safety as system control. This study argues that safety performance indicators must be developed along with a sociotechnical perspective where safety is understood as an emergent property which has technical, human and organisational components that interact to fulfil a corporate goal. Given this sociotechnical perspective of developing safety performance indicators, the most appropriate approach of measuring safety performance is to employ robustness strategies. Robustness thinking in developing safety performance indicators emphases background knowledge on which the consequences and the uncertainties are based on (see Aven & Ylönen, 2018b; Jensen & Aven, 2018). As safety evaluation seeks to gain an understanding of system vulnerabilities in the sense of knowledge – justified beliefs, they must be obtained through the application of scientific investigation process (Amundrud & Aven, 2015). What is of relevance is to explore the causal links to the safety outcomes under a robustness strategy underpinned by sociotechnical perspective. Since safety is conceived as a control problem that involves decision-making at a different hierarchical system level, the concerns of all the relevant stakeholders as well as the information of their risk perceptions is essential and must be captured. Therefore, leading safety performance indicators must reflect the background knowledge that links to the risks. Several studies (e.g. Zohar, 2010; Horbah et al., 2017; Guo & Yui, 2017) found safety climate constructs as major hazard risk predictors. According to Guo and Yui (2017), the link between safety climate constructs and safety outcomes is relatively robust and precise.

In linking the ideas of Rasmussen's model to leading indicators, the following broadly constitute the decision-making hierarchical levels in safety management: the government, regulators, industry and workforce. Leading safety performance indicators should be designed to capture the knowledge from these hierarchical levels to deal with the knowledge of uncertainties and potential surprises. In terms of using leading safety performance indicators to measure the deficiencies associated with companies' safety management systems, Guo and Yui (2015) pointed out two main limitations. The first limitation has to do with the existence of the knowledge gap regarding the effectiveness of the safety management systems. Due to the fact the safety management systems only accentuate its processes and procedures without emphasising the factors (i.e. the knowledge about the human element and cultural factors) that drive the implementation of the safety management systems. The second limitation is that leading safety performance indicators have weakness in analytical soundness and predictability in measuring safety management systems' intrinsic deficiencies. In empirical support of this limitation, Hopkins' (2007) analysis of Gretley mine disaster shown that the development of safety management systems is inadequate for incident prevention. In this study, qualitative risk assessment is essential to capture the issues that drive the implementation of safety management systems in line with the Rasmussen's hierarchical level of decision making in safety management. Because of this, more attention is required to be directed towards developing leading safety performance indicators that practically contribute towards improving the functionality of the safety system

2.5.1.1.2.2 The Technical-Human-Organisational Perspective

Safety performance indicators can also be looked at within the technical, human and organisational perspective. Blakstad (2014) examined this perspective and linked the safety investigation in the nuclear industry to it. This perspective is about developing safety performance indicators to capture the technical, human and organisational factors influencing incidents risks. Blakstad stated that assessment of plant safety is conducted in two levels: by evaluating the physical system designs and performance, and the operating system designs and performance. The former is linked to the technical system deviations. Whereas, the latter denotes the human and organisational contributing factors that cover human performance, operational safety and safety culture. However, in several investigative reports (e.g. Cullen, 1990; Baker, 2007; CSB, 2014) and scientific studies on the analysis of hydrocarbon leaks (Sklet, 2006; 2010; Vinnem et al, 2007a; Okstad et al. 2009; Haugen et al, 2010) have pointed out that human and organisational factors constitute the main causal factors. Therefore, safety performance indicators should also focus on capturing the human and organisational factors.

2.5.1.1.2.3 Aspects of Health, Safety and Environment

Blakstad (2014) discussed the different aspects of health, safety and environment that safety performance indicators should be directed towards. She identified several issues of health, safety and environment in the oil and gas industry: personal hazards and illnesses, helicopter transportation hazards, major hazards, physical and psychosocial working environment hazards, risk perception as well as workers' behaviours, attitudes and safety culture. However, Øien et al. (2011b) stated that safety performance indicators differ in terms of the types of damage made to personnel, assets and the environment. Much discussion on the hazard risks associated with each kind of damage (risk dimensions) is made in the previous section 2.6.4. It must be pointed out that safety performance indicators should focus on clarifying the distinction of the type of damages that have effects on personnel, assets and the environment. This is because applying safety performance indicators for one aspect of safety among several aspects is problematic.

In short, this study applies safety performance indicators to measure reactive or safety outcomes that identify and report the incidents in Ghana's upstream oil and gas operations. The safety outcome classifications as shown in table 2.4 are applied in this study to measure the reactive indicators of the industry. Safety climate measure will be used to indicate the active monitoring of the system safety performance of Ghana's upstream oil and gas operations.

Table 2. 4 Safety indicators reported in the industry

Fatalities:
Injuries:
Incidents
Near-misses
Medical treatment cases
Reported diseases
Restricted work cases
First aid cases

Source: IOGP (2019a)

2.6 Safety Climate Influences on Hazard Risks

Having reviewed that safety climate is as an active indicator for monitoring system safety performance in the preceding section, the current section examines the literature on the safety climate measures and hazard incident dimensions relevant to the upstream oil and gas industry. It begins by discussing the conceptual relationship between organisational culture and organisational climate, the antecedents and multi-level measurement of safety climate as well as its potential measures. It examines the link between safety and risk and further identifies the potential measures of the dimensions of hazard incidents risk in the upstream oil and gas industry.

2.6.1 Safety and Culture Relationship

The link between safety and culture was first introduced in the International Nuclear Safety Advisory Group (INSAG) report on the Chernobyl accident in 1986. A fundamental assumption in the safety literature is that workers' safety or unsafe behaviours are a function of the prevailing safety culture of the organisation. Safety culture as a new concept in the safety field at that time had to be given much attention by both safety professionals and researchers because it was a golden opportunity to expand the view on safety to include the intangible aspects of human behaviour (Guldenmund, 2010). Since then, safety culture and safety climate have become essential concepts that had attracted much research interest in the broader concepts of organisational culture and organisational climate. An organisation context has an influence on safety outcomes as several reviews of major accidents consistently identified the elements of organisational management as direct or indirect contributors to incidents (Griffin & Curcuruto, 2016). Several accident enquiry reports related to the upstream oil and gas industry (e.g. Cullen, 1990; DHSG, 2011; CSB, 2016) and scientific studies on hydrocarbon releases (e.g. Sklet et al., 2010; Cox et al., 2016) have established that human and organisational influences are the main important causal factors to major. Various studies have found safety culture as the main driver that shapes organisational safety performance (Flin et al., 2000; Mearns et al., 2003; Mearns & Yule, 2009; Mearns, 2014). However, given the conceptual challenges of measuring safety culture (Guldenmund, 2000; 2007; Glenton & Stantan, 2000), most studies have used the term safety climate to describe the tangible outputs or indicators of an organisation's safety culture. Safety climate' has been established in the literature as an indicator that predicts organisational safety performance. However, many of the existing safety climate assessment relating to the high-risk industries focus on personal safety indicators which have limited scope to capture proactive indicators of major accident risk factors.

Guldenmund (2000), in his review of safety culture, noted that no study of safety climate would be meaningful without a discussion of aspects of organisational culture and climate. Because of this, this section begins by looking at an organisation from the generic culture concept. These concepts of organisational culture and organisational climate have different meanings, particularly when the focus is specifically more on safety. However, neither the research nor the professional literature has provided for an explicit or consistent distinction between organisational culture and organisational climate, which has led to a considerable definitional confusion (Hecker & Goldenhar, 2014). Safety climate has its meaning from organisational climate concept. This review attempts to clarify this seemingly definitional confusion of the distinction between organisational culture and organisational climate. The current section seeks to explore the potential factors (also known as dimensionalities or constructs or determinants) for assessing safety climate. Safety climate is viewed as a multi-dimensional and multi-level concept in organisational culture theory.

2.6.2 Organisational Culture versus Organisational Climate

The link between the concept of culture and organisational study is well documented in both the professional and research literature. This relationship has been triggered by the indication of the symbolic aspect of organised settings (Smircich, 1983). Smircich attempted to clarify the differences in ways many researchers have linked the concept of culture to an organisation. In her review of the literature on the linkage between culture theory and organisational theory, the following five main research themes emerged from the intersection: "*Comparative Management"*, "*Corporate Culture", "Organisational Cognition", "Organisational Symbolism",* and "*Unconscious processes* and *Organization"*. Researchers have advanced these research themes for many different purposes and grounded on many different assumptions. It is indicated that a cultural framework for analysis is required to help to stimulate organisational researchers and managers to question the ends its serves than to appreciate organisation as a value. However, it noted that it is difficult for researchers and professionals to live within their cultural context and also question their assumptions and value. Whatever the challenges that would emanate, a cultural framework of analysis for researchers and managers requires such questioning.

The term organisational culture was firstly introduced in the academic literature by Andrew M. Pettigrew in 1979, a pioneering paper entitled "*On studying organisational culture"* (see Pettigrew, 1979) published by *Administration Science Quarterly* (Chatman, 2016). Pettigrew's (1979) understood culture as a system of publicly and collectively established meanings that work for a certain group of people at a specific time, He understood the emergence and development of organisational culture from typical concepts in sociology and anthropology. Martin and Siehl (1983) defined organisational culture as shared values, attitudes, beliefs and customs of the members of the organisation. Deshpande et al. (1993) reviewed over 100 studies in organisational culture. They understood organisational culture as a pattern of shared values and beliefs that make individuals of an organisation to understanding the functions of the organisation and offer them the norm in which the individuals behave in the organisation. Cameron and Quinn (1999) conceived organisational culture as what is valued, the procedures and routines, the language and symbols, the dominant leadership styles as well as what defines success to make an organisation unique. Schein (1985) explains organisational culture from three dimensions: *assumptions*, *values* and *artefacts*. Ramachandran et al. (2011) noted from their review work on organisational culture that research on culture focused on organisational values. Zammuto and Krakower (1991) see organisational values to be more visible representation of culture. From the literature, shared values are more reliably accessible in measuring organisational culture than assumptions and artefacts. This study adopts the perspective that organisational culture is a pattern of shared values and beliefs that offer members of an organisation an understanding of the organisational functions that informs their behaviour.

Organisational climate is defined as the workers' perception of work environment events and the expectations that the organisation has of workplace behaviour, attitudes, and norms (Ostroff, 1993). According to Schneider (2017), organisation climate is made up of shared perceptions among employees regarding the procedures, practices and the kind of behaviour that is rewarded and supported relating to the specific environment in question. From these definitions, the key attribute of the organisational climate is the *shared* employees' perceptions regarding the work environment. Zohar (2000) argued that this attribute emerges as a group-level property, which actually develops from individual members' experiences and perceptions of the work environment and progressively become *socially shared*. Organisational climate arises through individual perceptions of order in the workplace. It is a multidimensional construct that is made up of individual evaluation of the work environment.

Several scholars have conceived the debates on the difference or link between organisational culture and climate. Denison (1996) argued that the seeming difference between organisational culture and climate stems from their respective theoretical foundation as the former emerged from the social constructionism and the latter emerged from the Lewinian field theory. Climate depicts the situation and its relationship to thoughts, feelings, and behaviours of the organisational members. Whereas, culture denotes an evolved context within which a situation may be embedded with an entrenched history, collectively held, and sufficiently complex to withstand manipulation. According to Schein (1992, p. 230), "*climate will be a reflection and manifestation of cultural assumptions*". Several studies (e.g. Guldenmund, 2000; Schein 2010;

Schneider et al. 2013; Schneider et al. 2017) have conceived climate as the tangibles on which are focused to produce or shape behaviour, whereas culture offers the intangibles (abstracts) that are possibly accrued to provide a deeper psychological understanding of people in a given organisational setting. In the review work on safety climate by Hecker and Goldenhar (2014), they recognised climate as a "snapshot" of culture. There is still no clear demarcated boundary between the two concepts in the research literature. However, in terms of their connection, the two concepts offer metaphors that describe the complex social systems that are organisations which address the meaning people assign to their values, attitudes and experiences of that setting. Organisational climate is the shared meaning organisational employees attach to their experience and behaviours relating to events, policies, practices and procedures, and are being rewarded, supported and expected. This key attribute of shared employees' perception of the work environment has been relevant to safety studies. Organisational climate provides the context in which specific individual evaluation of the values of safety is made. This implies that the organisational climate can predict a particular safety climate.

2.6.3 Safety Climate as a Robust Predictor of Safety Performance

Safety Climate is defined as "*shared employee perceptions about the relative importance of safe conduct in their occupational behaviour*" (Zohar, 1980, p. 96). It is viewed as a specific facet of the social climate in an organisation relative to employees' perceptions of the priority of policies, procedures and practices of safety (Kvalheim & Dahl, 2018; Bergman & Payne, 2018). It is described as the "*molar and unified set of recognition*" that is held by the workers of the organisation relating to their safety in the organisation (Zohar, 1980, p. 101). Safety climate is mainly identified as social consensual or shared cognition in an organisation. Safety climate emerged from organisational climate concept. The general view that emerged from the understanding of organisational climate as discussed in the preceding section is that it is a collective phenomenon explicated by shared meanings workers give to their experience and behaviours regarding organisation's policies, procedures and practices that are rewarded and supported towards a specific goal of the organisation.

To review the development of safety climate as a construct, Griffin and Curcuruto (2016) highlighted two key features of perception that explains the constitutionality of safety climate. The first feature is that the emergence of perception is shared across individuals. The term sharedness points to the understanding that climate is a collective characteristic of groups.

Linking the sharedness nature of perception to distinguish the difference between psychological climate (i.e. the individual perception of the workplace) and safety climate (i.e. shared perception by individuals within a group or an organisation), the understanding is that perception serves as a collective frame of reference for workers that give indications of or cues about the expected behaviour and outcome of organisational safety. The second feature of perception that explicates safety climate is that it is characterised as inherently descriptive and cognitive. Their inherent descriptive and cognitive nature is recognised with reference to observable characteristics of the safety of the organisation experienced by the workers in their day-to-day interactions.

2.6.3.1 Antecedents of Safety Climate

One pertinent theoretical issue regarding how perception becomes shared and gradually emerged as climate. This can be explained from these antecedents: symbolic social interactionism (Schneider & Reichers, 1983; Gonzalez-Roma et al., 2002; Ostroff et al., 2003; Weick, 2005) and supervisory leadership (Lewin et al., 1939; Dragoni, 2005; Zohar, 2010). This symbolic interactionism also labelled as a social sense-making process is explained from a philosophical view that meaning of things and interpretation of events emanating from cognitive exchanges among people seeking to understand their environment (Zohar, 2010). Sense-making processes develop the emergence of climate. It is a process through which experiences of an individual accumulate to form the collective phenomenon. During this process of cognitive exchanges, individual perception is being checked and also modified in view of the observation and assessment of others. In such a situation, an attempt would be made to reach a consensual interpretation of the meaning of events, procedures and practices at the work environment, leading to a process of convergence of group members' perceptions and resembling of newcomer socialisation (Schneider & Reichers, 1983; Zohar, 2010). In this process, the members of the group come to share the meaning of their work environment, and this promotes the emergence of climate.

Leadership had been identified as one of the antecedents that explain climate emergence. This mechanism originally had its conceptualisation from the earlier publication by Lewin et. (1939) that "leaders create a climate". Dragoni (2005) explains this climate –leadership relationship as a social learning process in which group members severally observe and exchange information with their leader in the way of interpreting their work environment. Zohar (2010) explains further that, supervisor practices or group leaders are relatively easy to observe as a result of the leader's proximity and availability, they routinely inform their group members as to relative priorities. With such shared perception arising from the commonality of the leader's instructions and practices, they form the core meaning of domain-specific climate.

Given these antecedents explaining how climate emerges, the use of safety climate as an indicator to assess workers' perception of safety policies, procedures and practices in the work environment is essential in the oil and gas industry. In today's world, which is driven by competition and decreasing earning capacity, the process industry like the oil and gas industry puts the emphasises on cost reduction and time-saving. According to Knegtering and Pasman (2009), this can produce conditions in which risk awareness fades away. The typical characteristic of the oil and gas industry is that frontline leaders are assigned to workgroups for operational activities. The effects of such social interactionism and leader's supervisory practices with the group members would inform the relative priority of safety with other competing operational demands at the work environment.

Nevertheless, the literature has established the influence of safety climate in organisational safety performance. Given the multi-dimensionality of the safety climate measure, several constructs have been applied in a safety-critical organisation such as the oil and gas industry. Much of these constructs reflect personal safety related indicators. It must be indicated that not adequate research attention has been directed to factors that could predict major incidents in the upstream oil and gas industry.

2.6.3.2 Measuring Safety Climate

The main challenge in safety research is to find the factors and process that influences safety climate (Zohar, 2010; Hystad et al., 2014). What climate factors can predict major accidents in high-risk organisations have not received much attention in the scientific literature (Andreas et al., 2016). Some studies (e.g. Kines et al., 2011; Hosny et al., 2017) have developed safety climate measures to be applied in the upstream oil and gas industry. Such measures adopted in their study do not reflect major hazard incident risks. Safety climate measurement must indicate the dimensions of the nature of hazards that characterise the specific industry (Flin 2000). Currently, no consensus has been reached on categories of constructs that are specific to the upstream oil and gas industry. Given this challenge, this study explores the existing literature on potential constructs that can be used to measure safety climate in the upstream oil and gas industry. There are several constructs established by the literature (see table 2.5) that can be used to measure safety climate. They may include the following: safety policies, safety priority, safety training, management commitment, safety rules & procedures, management of change, safety communication, equipment maintenance, safety involvement, safety supervision, supportive environment, safety empowerment, safety motivation and safety behaviour. These constructs are discussed as potential factors that can be applied to measure the predictive influence of safety climate on major hazard risks.

2.6.3.2.1 Safety Policies

A safety policy is defined as *the management's expression of the decisions to be followed in the organization* (Kuusisto, 2001, p. 35). Safety is integrated into the overall organisation's function. Every organisation is required to protect workers from accidents. This requirement means that there must be in place of safety policies. The safety policies commit the management at all levels of the organisation and show which tasks, responsibilities and decisions are to be carried out or made towards fulfilling the requirement that workers, the facilities and the environment are protected from unacceptable risk. The safety policies are in a written statement form that must be succinct, clearly written, signed by the management and indicated primary responsibilities and plans to implement them (Othman, 2010). Safety policies in an organisation become enacted when the safety plans and procedures are implemented by the supervisors and the workers (Petitta et al., 2017). According to Mearns et al. (2003), safety climate influence organisational safety performance in the offshore oil and gas operations environment. They indicated that the knowledge of organisational safety policies must improve a positive safety climate. Mearns et al. suggested the following elements to assess safety policies influences: the ability of workers to read their companies' safety policies, understood them, understand what the policies statements require them to do.

2.6.3.2.2 Safety Priority

The Cambridge English dictionary defined the word priority to mean "*something that is important and must be dealt with before other things*". According to Spicker (2009), the idea of priority is linked to the exercise of judgement between competing demands. He noted that there are many different understandings of the term, which requires a priority setting to be worked out. This is because a system that seeks to establish a priority is not likely to reflect the intended issues and concerns which needed to be resolved. In context, safety priority means management making safety at the workplace more important than production-related activities. This requires a commitment to their safety values and actions. It can be stated that the true meaning of safety priority is when leadership backs the importance of workplace safety improvement by real their efforts. Several studies have found safety priority to influence workplace safety climate (Cox & Lacey, 1998, 1999; Cox & Cheyne, 2000). The literature measured safety priority by ranking adherence to safety over operation cost, production pressures and an indication of actions and not just safety slogans.

2.6.3.2.3 Safety Training

Safety training and competence (herein referred to as safety training) is a critical ingredient for a robust safety management. According to Gao et al. (2019), for safety management practice to devise a well-functioning safety culture in the oil and gas industry is to have an effective safety training. Wright et al. (2003) defined competence in safety to cover three key areas: *(1) underpinning knowledgeability* to understand major accident hazards that are associated with the process, equipment, plants and the understanding of the correct operating procedures and practices; *(2) skill* - ability to demonstrate the interpretation of the process instrumentation readings, identify faults, operate controls, pass a procedure; and *(3) behaviour* – covering the ability to show safety leadership, coach team members of potential hazards, raise their risk awareness and consistent behaviour in terms of following safety procedures at all time. Several studies have reported that organisations that have low accident rate have practically implemented safety training effectively.

Kvalheim and Dahl (2016) found a causal link between safety training and competence and safety compliance in the oil and gas industry. Mearns et al. (2003) investigated the relationship between safety management practices and accident rates in 13 offshore oil and gas installations which established safety competence as a causal link to accident rates. Dahl and Olsen (2013) found safety training (workers' competence) as one of the key characteristics for an important investigation of hazard incidents in the offshore oil and gas industry. Alruqi et al. (2018) found safety training significantly correlated to workplace injuries. Dahl and Kongsvik (2018) established safety training (safety competence) as a positive predictor of mindful safety practices in the oil and gas industry. From the safety literature, effective implementation of safety training in an organisation may drive a low hazard incident.

However, in terms of a unified itemised factor structure to assess safety training in the oil and gas industry is not clear in the literature. In a reviewed work by Davies et al. (2001) on assessment of safety climate in the oil and gas industry, the following areas were established for organisations to assess their safety training and competence in the industry: *effectiveness of training*, *availability of training*, *competency assessment, training coverage or content,* and *training priorities*. For training to be effective, workers should be able to demonstrate a clear understanding of the aspects of the operations critical to safety. The coverage or content of safety training must indicate all the responsibilities for a worker to ensure safe operations. Safety training is required to be organised for both new and existing workers to have competence for their job. Safety competency must be evaluated on the individual level and the methods of assessment must be indicated.

2.6.3.2.4 Management Commitment

Management commitment to safety is defined as the extent to which a manager puts high priority to workplace safety and how effectively he or her communicates and takes actions in relation to safety issues (Neal & Griffin (2004). Zohar (1980), in his original paper, identified management commitment as part of the seven dimensions for measuring safety climate. Since his paper, meta-analyses have identified several studies indicating a perceived managerial commitment to safety as a critical dimension for measuring safety climate (e.g. Guldenmund, 2000, 2007; Zohar, 2008). A high level perceived managerial commitment to safety is an indicator for a positive organisational safety climate.

Tappura et al. (2017) linked management commitment to leadership behaviour as leadership is key to influence workplace accidents. Studies have examined the relationship between safety leadership and workplace accidents (e.g. Pilbeam et al., 2016; Wu et al., 2016; Mullen, 2017; Willis et al., 2017; Stiles et al., 2018). These studies indicate that leaders' behaviours influence organisational safety performance. There exist several levels of leadership in an organisation. In suggesting criteria for safety excellence, Petersen (2000) indicated that management commitment to safety is reflected at different levels in an organisation such as top management practically demonstrating that safety is valued, middle managers' involvement in supervisory performance (ensuring quality supervisory performance) and safety system enforcement in supervisory performance. However, in a practical sense, workers typically do not have a direct engagement or contact to their top executive managers, rather their middle managers and supervisors of the organisation (Tappura et al., 2017). In the industry, operations are mostly executed in work-groups led by a leader or supervisor. What is important here is the manifestation of the real commitment from leaders to safety at each level of the organisation. The safety attitudes and values of leaders must be demonstrated in actions at each level of the organisation. Actions must drive leaders' commitment to safety.

Few studies (O'Dea & Flin, 2001; Wu et al., 2011; Kilaparthi, 2014; Zuofa & Ocheing, 2017) have examined the influence of safety leadership behaviour on organisational safety performance in the oil and gas industry. O'Dea and Flin (2001) investigated the link between the level of experience of managers and leadership style to safety attitude and behaviour in the oil and gas industry. They found that managers' experience level was not a key factor in the determination of leadership style or attitude to organisational safety performance. Wu et al. (2011) examined the relationship between safety leadership, safety climate and safety performance in the oil and gas industry. Their results indicated that safety climate mediated the link between safety leadership and safety performance. Kilaparthi (2014) identified effective leadership as a key factor to drive safety culture in the oil and gas industry. This leadership drive the workforce to participate in safety initiatives of the organisation. Zuofa and Ocheing (2017) examined senior managers' perception of the role of safety leadership on safety performance in the oil and gas industry. They found that leadership style influences the effective implementation of safety management systems in offshore oil and gas construction operations. Although these studies have examined management commitment as an essential factor in promoting a positive safety climate, in terms of assessing what defines management commitment from the leadership perspective has received limited research focus. What actions define leaders' (e.g. managers, supervisors, work-group leaders) commitment to safety at all levels of an organisation has not been adequately addressed in previous studies focusing on the oil and gas industry.

Davies et al. (2001) identified the following areas to measure management commitment to safety: resource availability, manager willingness to act and swift implementation, trust and support, managers' attitude towards rules breaking, and encouraging workers participation. Fruhen et al. (2019) provided a systematic review to identify the following six components that demonstrate real management commitment to safety: communication, resource allocation, managerial participation, support and guidance, and policies and decision making, workers' involvement. This study adopts the following areas to define management commitment to safety: *communication, resource availability, managerial participation, policies and decision making, support and guide, managers' attitude towards rules breaking* and workers' involvement. These areas are essential elements that can drive active management commitment to safety.

2.6.3.2.5 Safety Rules and Procedures

Safety rules and procedures are essential terms often used in the workplace. The two terms are not used the same; differences exist between them. In general sense, safety rules are defined as all rules with the objective of, among other things, keeping people safe from the risk of being injured and damaged (Hale et al., 2012). There are several objectives that these rules are linked to, such as efficiency, production, quality, health, environmental protection or sustainability. However, this study supports the view to integrate these objectives into rule sets that must relate to the organisational process and activities. Procedures are defined as plans that establish a routine method of undertaking future activities (Marume et al., 2016). Procedures guide actions and provide details of the exact way in which a particular activity should be accomplished. The essence of procedures is to provide a chronological sequence of needed actions. Safety procedures refer to the approved step-by-step sequence of instructions that must be followed to accomplish safe operations. Safety rules and procedures have become key concepts in both the research and professional literature as indispensable elements of safety management, particularly for high-risk industries.

From the research literature, Hale et al. (2012) review of the literature from 1986 relating to the management of safety rules and procedures in organisations ignited the debate on two contrasting models of safety rules and procedures. The first model is rooted in *Scientific Management principles* developed from the rationalisation idea mainly associated with top-down classical approach (Taylor, 1911). The main idea underpinning the designing of safety rules and procedures is the assumption that work tasks must be designed and controlled in a top-down fashion that requires an organisational control to identify and eliminate safety risks (Weichbrodt, 2015). This model viewed safety rules and procedures as static, strict limitation of freedom of choice, and violations considered as negative behaviour that ought to be curbed (Hale & Borys, 2013; Vidal-Gomel, 2017). Studies have established that workers adherence to safety rules and procedures helps to improve workplace safety climate (Hale & Boris, 2013a, 2013b; Weichbrodt, 2015; Vidal-Gomel, 2017). The literature indicated that safety rules and procedures must be useful, adequate to prevent the occurrence of incidents and must be enforced by the supervisors or line managers at the workplace.

2.6.3.2.6 Management of Change

Management of change is a subset of organisational influence (Theophilus et al., 2017) which forms one of the elements of safety management systems (see Levovnik, & Gerbec, 2018). Within the context of the high-hazard industries, U.S. Department of Labour Occupational Safety and Health Administration (OSHA) defined management of change as "*modifications to chemical processes, technology, equipment, procedures and changes to a facility that affect a covered process*" (OSHA, 2000, p. 22; cited in Theophilus et al., 2017). Daily changes in technology and organisational business management have become rampant in recent high-hazard industries to gain competitive market advantage. However, several studies have indicated that such changes increase the complexity of the processes and systems operations as well as contributing to the changes in hazards which may have significant potential consequences to the risk of major industrial incidents (Yang & Mannan, 2010; Gerbec, 2017; O Johnsen et al., 2017; Zio, 2018; Jain et al., 2018). Management of change has been reported to be a significant cause of many of the catastrophic incidents that have occurred in the history of the oil and gas industry. The essence of the implementation of management of change is to ensure that the changes process does not deliberately bring new hazards or increase the risk of existing hazards at the workplace.

Bell and Healey (2006) conducted a review of the causes of major hazard incidents to identify relevant control measures and behaviours to prevent the incident occurring in the high-hazard industries. The oil and gas industry was a key part of these high-hazard industries that were understudied. The results of the study indicated circumstantial evidence from case studies that link management of change issues to major hazard incidents. Singh et al. (2010) reviewed some of the critical safety lessons from the North Sea Piper Alpha disaster that occurred in 1988. The Piper Alpha disaster was reported as the world's worst offshore oil and gas industry which resulted in 167 dead, dozens severely injured and worst environmental pollution. Management of change was identified as the main issue that contributes to the cause of that catastrophic event. They suggested that the industry disassociation between, urgency to build, knowledge transfer, and management of change, were the key lessons that have to receive much attention. Theophilus et al. (2017) carried out a study to propose an improved framework of Human

Factors Analysis and Classification System (HFACS) for use in investigating incidents in the oil and gas industry. Management of change was indicated as a critical organizational deficiency that influences the occurrence of major hazard incidents resulting from the failure to plan, communicate, and coordinate the changes process effectively. As acknowledged by Theophilus et al., several studies (e.g. SPE, 2014; Hayes, 2012) have indicated that when decision-making on changes are not adequately communicated to employees and also managed effectively, it could lead to hazard incident occurrence. The study showed that management of change in the oil and gas industry must cover the following areas; process hardware and software modifications, temporary process changes, operating procedures changes, and organizational process changes. Gerbec (2017) indicated that the daily changes in the industry have a potential influence on major hazard incidents. The changes that occur in the facilities or operations are complex and involve technical and organisational influences which must be managed effectively to avoid incident occurrence.

Although management of change is one of the elements of safety management systems in many of the existing safety management standards used in the industry, there are limited scientific studies that have investigated it as part of safety management (Gerbec, 2017). Moreover, there appears to be limited empirical research on how employees' perception of management of change deficiencies influences hazard risks. It must be indicated that the circumstance employees find themselves to have potential implications for the quality of their decision making. Operations in the industry are tightly coupled and involve complex processes which require effective communication of the changes processes to the workers. As indicated by SPE (2014), mostly certain factors such as time pressure, poor information presentation, the ambiguity of information and conflicting goals lead to poor decisions. The quality of decision making can affect the effectiveness of organisational safety management of change at the workplace. According to Theophilus et al. (2017), measures to address management of change deficiencies require the following: an effective organisational safety management of change must have robust safety procedures that specify the roles and responsibilities of workers during operations; the changes in working procedures that must be effectively communicated to workers; the changes in the facilities must be effectively communicated to the workers; there must be effective process to continue, resource, and control outsourced arrangement at the workplace; and there must be efficient management of the implementation of the changes at the workplace. Therefore, effective implementation of management of change will reduce the workers' perception of hazard incident risk at the workplace.

2.6.3.2.7 Safety Communication

Communication is defined as "*the process of sharing information, thoughts and feelings between people through speaking, writing and body language*" (Velentzas, 2014: p. 130). Velentzas indicated the goals of communication to include the creation of a common perception, changing behaviours and the acquisition of information. Velentzas' discussion of communication mainly based on the sharing of information between people. It must be indicated that communication must not only be limited to the exchange of information but importantly, a precondition for learning, and for new, innovative ideas to emerge (Kines, 2011). Communication can have a great influence on the quality of relationship emergence in the workplace through the Social Exchange Theory (Blau, 1964). The principles of the Social Exchange Theory have been used to explore the development of a relationship between an individual and organization (see, e.g. Eisenberger et al., 1990). The quality of communication practices can create inherent social interaction which eventually may lead to the creation of social construct like organizational climate. Reporting culture is one of the sub-climates (Reason, 1997). The critical importance of communication practices in workplace safety is well documented in the safety literature (e.g. Wold & Laumann, 2015; Nixon, 2018; Newnam & Goode, 2019). According to Vinodkumar and Bhasi (2011), the frequency of communicating safety issues between workforce, supervisors and management indicates effective management practice for safety improvement at the work environment. An effective safety communication practices in the workplace help to reduce incidents occurrence.

Many of the oil and gas operations are executed in workgroups led by supervisors or group leaders. These supervisors or group leaders play an essential role in conveying relevant safety working practices in the form of encouragement of participation, compliance and motivation in safety management among the members of the team (Newnam & Goode, 2019). Several studies on the review of major incidents in the oil and gas industry have highlighted safety communication as a critical contributory factor to many of the catastrophes (Bell & Healey, 2006; Baker et al., 2007; Christou & Konstantinidou, 2012). Poor communication among personnel is found to contribute to incidents of occurrence in the oil and gas industry (Veland & Aven, 2015). They found a huge difference in terms of workers' understanding of the hazard risks due to lack of information. When there is a lack of knowledge, usually it leads to poor communication at the workplace. The measure of safety communication issues in the oil and gas industry had been mainly conducted through safety climate-related research due to its link to organisational climate construct. In what approaches are safety communication measured to promote a positive workplace safety performance?

Bell and Healey (2006) identified a two-way safety communication approach to improve safety performance: top-down communication and horizontal communication approach. The top-down communication involves communication (i.e. visible safety policy statement, stressing safety issues and procedures, sharing information on major incident risks, feedbacks to respond to reporter) from the top management to the workers. The horizontal communication involves the provision of a system that effectively transfers information between workers and departments. Given the importance of supervisor-worker relationship in safety promotion at the workplace, Newnam and Goode (2019) defined communication in the area of supervisor-worker relationships. Given this, communication was measured along with the following: *task-related communication* (focusing on productivity and efficiency aspects) and *safety-related communication* (focusing on interaction relating to compliance activities required to actualize safety performance at the workplace), safety-related communication is a more appropriate approach. Workplace safety behaviour requires active participation and compliance of safety activities (Griffin & Neal, 2000). While the literature has documented the issues related to poor safety communication, approaches and interventions required to be adopted by workers and supervisors to drive an effective communication among workers appeared to have received limited research attention. Davies et al. (2001) identified six elements to measure safety communication for a positive organisational safety climate: *effective communication in the workplace*, *communication with superiors*, *communication between employee groups*, *communication at shift handover and crew change*, *communication in terms of near-misses/incidents/accidents*, and *communication systems*. Given the nature of the upstream operations, which involves work-groups, work-shifts, temporal contractors and the complexity of the processes, these elements are essential to define the effectiveness of safety communication in the oil and gas industry. Given this, most studies have not considered these elements in determining safety communication as a dimension for measuring safety climate in the oil and gas industry. In this study, these elements are adapted to measure safety communication.

2.6.3.2.8 Equipment Maintenance

The frequency of maintenance is an essential activity that must be conducted to keep equipment and work environment safe and reliable. Equipment maintenance is a high-risk task with associated hazards and risks. The analysis of World Offshore Accident Database in terms of the distribution of events shows that equipment malfunction constituted the main accident cause for the event (34%) in the oil and gas industry (Christou & Konstantinidou, 2012). Maintenance activities may involve inspection, testing, measurements, replacement, adjustment, repairs and upkeeping. The human element in maintenance operations is critical as workers get contact with the processes. Other studies (e.g. Dhillon & Liu, 2006; Sheikhalishahi et al., 2016) have indicated that the human factor in maintenance activities is a pressing problem in industries. ILO (2015) reported that causes related to safety systems (technical factor) rarely triggered the occurrence of incidents or accidents in the offshore oil and gas industry. However, it is the human and organisational factors that have to be addressed to improve the safety of equipment and facilities in the oil and gas industry. This is because most of the occurrence of the events were attributed to the absence of unsafe rules and procedures followed by workers.

Several studies have highlighted the lack of adequate equipment maintenance as the cause of industrial incidents. Skroumpelos (2010) conducted a study in industry operations that experienced incidents and revealed that these incidents occurred during maintenance activities. The study revealed the following as the cause of the incidents from the workers and supervisors' perspectives. In terms of the workers perspective, the following were the causes: violation of safety rules and procedures, lack of housekeeping, the use of defective hardware, unanticipated start-up, and bantering. The perspective of the supervisors included the following causes: hastiness, inadequate job specifications and familiarisation with dangers. How equipment maintenance factor has specifically contributed to the cause of incidents in the oil and gas industry has also been established by researchers. Okoh and Haugen (2013) examined how maintenance influenced the occurrence of some major hazard incidents high-hazard risk industries. They found that maintenance activity or deferment of maintenance can create barrier vulnerability and deficiency that may contribute to the improper functioning of the safety barriers in terms of risk control.

Despite there is a well-documented evidence linking lack of maintenance to the cause of incidents in the oil and gas industry, how researchers have measured equipment maintenance in safety, climate-related research appeared to have received limited research attention. The measure of perception of equipment maintenance in the oil and gas operations is one of the ways to obtain knowledge on existing organisational safety performance. Most of the existing studies (e.g. Ratnayake, 2012; Christou & Konstantinidou, 2012; Okoh & Haugen, 2013; ILO, 2015) only highlighted the deficiencies or deferments of maintenance practice as a critical cause of the many major incidents in the oil and gas industry. However, how equipment maintenance is defined and measured in safety climate-related studies appears to have received inadequate empirical research attention in the oil and gas industry. For example, Binch et al. (2012) identified equipment maintenance as an essential dimension that has to be used to measure process safety climate research. However, the elements that define the equipment maintenance dimension for safety climate measure was not indicated in their study. In Baker et al. (2007) study that investigated the BP's Texas City refinery explosion in 2005, equipment maintenance was identified and measured in terms of the following elements: *regular testing and maintaining of alarms, interlocks and other process safety-related devices; easy and clearly understanding of the use of checklists and procedures related to maintenance of equipment*; and *prioritisation of regular inspection and maintenance of equipment*. Given the ground that Baker et al. (2007) measure on equipment maintenance was linked to process safety, it is appropriate for this study to adapt these elements to measure the shared workers' perception of the relative importance of equipment maintenance at the workplace.

2.6.3.2.9 Safety Involvement

The essence of workforce involvement in organisational decision making has been advocated in the management literature for several decades. The interest in workforce involvement in safety management in the oil and gas industry became only recognised in the investigative report of the Piper Alpha disaster in 1988 (Cullen, 1990). However, in an earlier review by Bryden and Gibson (2000), indicated a limited application of the principle of workforce involvement in safety management in the industry. The safety literature (e.g. Hart, 2000; Bryden & Gibson, 2000) indicates that the application of the principle of workforce involvement helps in communication, motivation and operational efficiency in the oil and gas industry. Because of its relevance, workforce involvement had been considered as an aspect of organisational climate mostly investigated in safety climate research (e.g. Yule et al., 2007; Ghahramani, & Khalkhali, 2015; Horbah et al., 2017). A positive organisational influence establishes a consultative link between management and the workforce. When there is an existence of such a framework of association, employees will be actively involved in safety management of the organisation, especially where they will always be consulted on the development of safety management systems programs.

Klein and Vaughen (2008) identified workforce involvement as one of the DuPont's four elements that characterised operational discipline. Workforce involvement involves employees' activeness and enthusiasm for safety management practices. They pointed out that an effective workforce involvement at the workplace must exhibit the following features in employees: they must know and share the safety core values and goals of the organisation, volunteer and active in safety activities and workgroup, provide feedback and suggestions for workplace safety improvement, and demonstrate pride in being part of the organization. Yule et al. (2007) investigated the link between the role of managers and supervisors in risk-taking behaviour. They found a negative association between perception of risk-taking behaviour and supervisor involvement and a positive relationship between safety responsibility and management commitment. In other words, the study establishes a negative correlation between organizational climate variables (i.e. management commitment, safety involvement) and risk perception. They also indicate positive relationships among the organizational safety climate variables. A similar link was established between workforce involvement and changes in work procedures (see Nielsena, & Randall, 2012). Kouabenan et al. (2015) examined the relationship between safety climate, risk perception and involvement in safety management. They found that the safety climate appeared mediating the influence of perceived risk. Kvalheim et al. (2016) investigated the strength of safety climate tools to evaluate the major accident risks in the oil and gas industry. Workforce involvement was one of the constructs of their safety climate tool, which measured workers' perception of a communication link between workforce and management. They found a negative association between workforce involvement and major accident risks. Given the benefits of workforce involvement in providing communication, motivation and operational efficiency in the oil and gas industry, research need to measure how the principle of workforce involvement empowers employees to work around process safety concerns rather than reporting: how individual employee can voluntarily carry out tasks or activities to improve process safety, how management involves employees in updating (including revising and reviewing) safety policies, and how employees give feedback on important safety issues at the workplace. Despite the earlier interest in the application of the principles of workforce involvement in the oil and gas industry, much empirical research is still needed to strengthen the inverse relationship between workforce involvement and perception of major hazard risk.

2.6.3.2.10 Safety Supervision

There are several ways researchers have defined the term supervision in the research literature. One popular definition of supervision is given as someone coordinating the work of others which include including planning, scheduling, allocating, instructing and monitoring actions (Mintzberg, 1979; cited in Ward et al., 2004). This implies directing the work of others towards achieving the organisational goal. In establishing the link between supervision and leadership, Ward et al. (2004) examined supervisors as team leaders. Earlier studies have linked supervisory behaviour to organisational safety performance (Mattila et al., 1994; Ward et al., 2004). In Bell and Healey's (2006) review of literature on the causes of major hazard incidents in the oil and gas industry, safety supervision became a key factor in most of the hazard incidents. Several studies have established the importance of safety supervision in promoting a positive organisational safety climate (e.g. Flin et al., 2000; Kouabenan et al., 2015; Haung et al., 2017; Pandit et al., 2019). Despite there is a growing body of research supporting the relevance of safety supervision to organisational safety performance, the factors that drive active supervisory behaviour are under-explored.

Kvalheim and Dahl (2016) investigated the link between safety compliance and safety climate in the oil and gas industry. Safety supervision was identified as part of the four dimensions that measured safety climate. Safety supervision was measured with four items which were assessed on the perception of the extent to which leaders are committed to working with safety, appreciate the effort of raising and discussing safety topics at the workplace. Haung et al. (2017) investigated the predictive influence of safety supervisory communication on safety performance. They found that a supervisor's communication of safety-related information to subordinates helps to reduce work-related incidents. They argued that supervisor communication of safety-related information is a contingency factor as it affects how safety climate is linked to safety outcomes. There are two ways that supervisor safety communication has to take place: workers' perception of how effective their supervisor provides them with the information (i.e. top-down approach safety communication) and the creation of 'free-environment' by supervisors where workers feel free to discuss safety-related issues that can influence the organisation safety performance (i.e. bottom-up approach safety communication). Pandit et al. (2019) evaluated the effect of safety climate on hazard recognition and risk perception. Supervisor support was identified as a key dimension to measure safety climate. The elements that measured supervisor support included: the adequacy of safety knowledge of the supervisor, supervisor's ability to encourage the reporting of safety-related issues for redress, supervisor's ability to ensure that safety-related rules and procedures are followed by the workers and safety prioritisation against production or deadline. Supervisor support was found significantly related to safety climate.

Although the literature confirmed the predictive effect of supervisor safety communication on incidents occurrence, the alacrity to respond to process safety-related issues against others has become a challenge in the oil and gas industry. The review of the causes of major hazard incidents in the oil and gas industry by Bell and Healey's (2006) highlighted this issue. The measure of perception of safety supervisory support must also include the alacrity of safety leaders or supervisors to address reported process safety-related issues. In this study, the following elements measure safety supervision: supervisors taking swift and appropriate action in response to suggestion for improving process safety, the adequacy of supervisor's process safety knowledge, encouragement of safety communication including both information and discussion of safety relates issues, supervisor safety participation, and supervisor ensuring that safety-related rules and procedures are followed by the workers.

2.6.3.2.11 Supportive Environment

The social environment of a workplace may be driven by a supportive environment and involvement of all workers. Supportive environment refers to the nature of the prevailing social environment at the workplace as well as the support derived from it. The supportive environment has become an important factor that promotes a positive safety climate at the workplace (Arghami et al., 2014; Flin et al., 2000). The relationship between supportive environment and workplace safety performance is established in safety climate-related studies. Mohamed (2002) identified a supportive environment as a key dimension for measuring safety climate. Ghahramani and Khalkhali (2015) developed and validated a safety climate scale made up of seven dimensions which included a supportive environment for the manufacturing industry. The supportive environment was empirically measured based on three elements: a workplace that prioritises safety, the existence of adequate rules for workplace safety and effective communication of safety information by managers and supervisors. These elements defining a supportive environment appeared inadequate to capture the essence of involvement and motivation of the co-workers to support the safety promotion at the workplace.

Cox and Cheyne (2000) discussed the joint industry and UK HSE research project that focused on an approach to assess safety culture in offshore oil and gas environment. In the assessment tool, a supportive environment was one of the dimensions to measure safety culture. The elements that define supportive environment included the following: encouragement to report unsafe conditions at the workplace, the ability for a worker to influence safety performance at the workplace, motivation to work safety at the workplace, and communication of safety information particularly how to work safely at the workplace. Several studies have applied this safety climate assessment tool which included Amiri et al. (2015). Amiri et al. (2015) investigated the link between safety climate and demographic factors in the oil and gas industry. The supportive environment was a significant dimension that measured the safety climate. Given the review of the safety literature on the supportive environment as a dimension to measure safety climate, researchers have given limited attention to it in safety climate-related studies. Although supportive environment as one of the important aspects to measure safety climate in the oil and gas industry, the elements that define the measure of a supportive environment in safety climate-related research must include the involvement and motivation of co-workers towards safety performance at the workplace. Because of this, this study adapts Cox and Cheyne's (2000) elements but with greater emphasis on co-worker's involvement and motivation for working safety at the workplace.

2.6.3.2.12 Safety Empowerment

Empowerment of workers to work safety became more relevant in the safety climate research when Nordic Safety Climate Questionnaire (i.e. NOSACQ-50) was developed. This questionnaire model has been applied in safety climate research, including Bergh et al. (2013). Kines et al. (2011) examined safety empowerment as a key dimension for assessing workers' perception of the relative importance of safety at the workplace. They explained that the empowerment of employees is one of the avenues for managers to convey trust to workers. They defined empowerment as a delegation of power such that management trust the ability, judgement of the workers and values their contributions. In a safety context, they viewed that empowerment strengthens social exchanges and also provides conditions where safety is highly valued that encourage reciprocation and reinforcement of safety behaviour in an organisation. Today, safety empowerment has been used in several safety climate studies.

Shannon et al. (1997) examined the link between organisational factors and injury rates. They found that management empowerment of workers and delegation of safety tasks were significantly related to lower injury rates. Törner and Pousette (2009) conducted a qualitative study that involved front-line supervisors and safety representatives in the construction industry. In their opinion, empowerment was identified as one of the main constituents of workplace safety. Larsson et al. (2018) found safety empowerment as an important dimension of safety climate that correlated with personal perception of safety, mental strain and injury rate. Gillen et al. (2013) identified safety empowerment as a key factor (representing the top second and the third choice of the evaluation at the workshop) that constituted organisational safety climate measure. Lee et al. (2019) examined the relationship between safety empowerment in leadership perspective and safety climate. Their study found safety empowerment a pre-requisite for safety behaviour. They asserted that empowering leaders empowers workers' safety behaviour that enhances their willingness for safety participation, safety compliance and knowledge sharing behaviour at the workplace. Probst et al. (2019) measure safety empowerment in their Safety Climate Assessment Tool (S-CAT) from the following elements: the building of trust for workers to work safety, involving workers in safety-related planning and decision-making, and encouraging workers in the discussion of potential hazards that could affect safety performance at the workplace.

Despite the safety literature recognised safety empowerment as one of the critical dimensions for measuring organisational safety climate, not much has been found in the oil and gas industry. In an attempt to advance for the development of leading indicators for effective organisational safety performance, Javad et al. (2017) developed a scale for measuring safety climate in the oil and gas industry which included safety empowerment. However, what defines the actions that drive management's attitude for empowering workers to work safely in the industry has not been well documented in the literature. In this study, the encouragement of workers' participation and compliance in safety, supporting and trusting of workers to work safety. Workers in the industry must be encouraged to participate in hazard reviews and assessment as well as participation in incident and accident investigations. When workers are supported and trusted that they can influence safety positively at the workplace without any victimisation and fear, a high perceived organisational safety performance would be actualised.

2.6.3.2.13 Safety Motivation

Safety motivation became recognised as a key factor in preventing industrial incidents occurrence since the early period of Heinrich's (1930) work that found the motivation of workers to work safely at the workplace as a relevant factor that can prevent incidents at the workplace (Scot, 2016). Safety motivation is commonly defined in the literature as the willingness of an individual to put effort to enact safety behaviours and the valence linked to those behaviours (Neal & Griffin, 2006). Thus, it is the level of effort that an individual is willing to exert to work safety. Safety motivation is one of the important determinants of a good safety climate in an organisation. A motivational mechanism is a way through which safety climate can employ subjective-normative influence on individual behaviour or groups behaviours in an organisation (Zohar, 2010). Safety motivation is linked to a psychological process that is established to provide direction, energy and sustainability of an individual action (Latham & Pinder, 2005; Scott et al., 2014). Safety motivation is a proximal determinant of employee safety behaviours and that safety climate which is a distal factor that has an indirect effect on organisational safety behaviour (Griffin & Neal, 2000). When there is a clear understanding of workers' motivation to work safely in an organisation, it mainly helps in augmentation of workers' participation in safety activities and the reduction of the level of unsafe behaviour at the workplace (Conchie, 2013).

Griffin and Curcuruto (2016) reviewed some theoretical perspectives that underpinned the concept of safety motivation. The derivation of safety motivation can be linked to subjective-normative influence of safety climate (Zohar, 2010; Curcuruto et al., 2013; Scott et al., 2014), self-determination theory (Scott et al., 2014; Zohar et al., 2015), psychological empowerment (Zohar et al., 2014; Curcuruto et al., 2015) and social-exchange theories (Mearns & Reader 2008; Tucker et al., 2008). The conceptual link between safety motivation and subjective-normative influence of safety climate is explained that subjective meaning of safety underscores the safety motivation, which its meaning has relatively emerged through the means of normative influence. Safety climate indicates the normative value of safety relative to other competing demands of the organization. As conceived by Zohar (2010), individual safety behaviour is perceived to be valued and rewarded in the organization. A self-determination theory underpins safety motivation through the two types of motivation: *intrinsic* (engaging in or performing work for its own sake rather than a desire for external rewards) and *extrinsic* (engaging in work behaviours with expected instrumental value for gaining tangible rewards) motivations. Furtherly, Griffin and Curcuruto (2016) argued that because of climate perceptions related to the role of rewarded behaviour, it was reflective to indicate that the substantive safety climate-behaviour link should be elucidated in respect of the motivation for working safety. Psychological empowerment drives safety motivation. Zohar et al. (2014) asserted that particularly in a high-risk environment when prevailing work is psychological meaningful, safety behaviours turn out to intrinsically stimulate investment in self-protection. Other studies (e.g. Zohar, 2008; Curcuruto et al., 2015) have indicated that safety climate stimulates safety behaviours through the feeling of empowerment, personal engagement, psychological ownership and passion for actualising challenging organisational goal. Social-exchange and social reciprocation perspectives explain the link between safety climate and safety motivation. The social-exchange principle explains that the perceived support and investment of the employer breeds an implied obligation in workers that leads to a positive reciprocal effort favouring the organization (DeJoy, 2005). In linking this principle to safety, perception of management commitment and investment in the safety of workers can be reciprocated by the workers through their active commitment to compliance and participation in their discretional activities towards safety promotion at the workplace (Griffin & Curcuruto, 2016). This implies that the extent of managerial style in active support and participation in organisation and workgroups is reciprocally correlated with a more significant commitment by the workers in safety promotion.

Some studies had demonstrated the relationship between safety motivation and safety behaviour. However, there is a limited empirical research on the link between safety motivation and safety performance (Panuwatwanich et al., 2016). Several empirical research findings on the effects of safety motivation on workers safety behaviours appeared inconsistent and lacked a theoretical foundation in the research literature. Earlier safety climate measures (see, e.g. Davies et al., 2001; Mearns et al., 2003) that focused on the oil and gas industry, failed to captured safety motivation as one of the key factors that influence organisational safety performance. Al-Harthy (2008) found motivation as a challenging issue in the oil and gas industry. In recent times, safety motivation has been identified as an essential determinant of safety climate. This has reflected in some few empirical studies identifying safety motivation as a key factor for organisational safety performance in the oil and gas industry. For examples, Hystada et al. (2014) identified safety motivation as one of the key determinants of safety climate that correlated to safety outcome in the Norwegian oil and gas industry. Boughaba et al. (2014) found safety motivation (incentives) as an essential factor that should be emphasized to improve safety culture in the oil and gas in Algeria. Musa et al. (2015) noted safety motivation as one of the factors that influenced the low workers' perception of safety values in the oil and gas industry. It appears there is little research that has empirically investigated the influence of safety motivation on workplace safety performance in the oil and gas industry. Based on the literature on the theoretical perspectives underpinning the link between safety motivation and safety performance, self-discipline theory is recognised as a distinct from other human motivation perspectives because it reckons that the relevance of the type or quality of motivation is the same as the amount or quantity of motivation in understanding and prediction of human behaviour. This makes the self-determination perspective as a useful theoretical framework that must guide researchers seeking to establish the influence of safety motivation on workers' safety behaviours (Scott, 2016). Given this, workers' self-determination can influence organisational safety policies implementation. Workers' self-determination can encourage co-workers to engage in safety practice. Workers' self-determination can drive them to reduce incidents at the workplace. These would drive a positive organisational safety behaviour and safety outcomes.

2.6.3.2.14. Safety Behaviour

Safety behaviour is defined as the actual behaviour enacted by an individual at the workplace (Christian et al., 2009). Given the Borman and Motowidlo's task performance typology (Borman & Motowidlo, 1997), Neal and Griffin (2002) identified two main components that form safety behaviour: *safety compliance* and *safety participation*. Safety compliance denotes those core activities that are required to be conducted by individual workers to maintain safety at the workplace, examples such as having a positive attitude regarding working safety, attending a meeting as well as helping co-workers. Whereas, safety participation denotes behaviours that indirectly yield to an individual worker's safety, but also contribute to the development of workplace environments that support safety, examples such as wearing PPE as well as complying with safety rules and procedures (Neal & Griffin 2004; Lyu et al., 2018). These components have been adopted in safety behaviour related research (e.g. Lu & Yang, 2010; Vinodkumar & Bhasi, 2010; Lyu et al., 2018). Safety behaviour must have a direct link to an individual's compliance with safety rules and procedures as well as active participation in working safety at the workplace.

Some prior studies have found a significant and positive link between safety climate and safety behaviour in the research literature. Lyu et al. (2018) investigated the relationship between safety climate, safety behaviour and safety climate using ethnic minority workers in the construction industry. Their study found a significant positive correlation between safety climate and safety behaviour. Wang et al. (2018) investigated the relationship between safety awareness, safety behaviour and safety climate in the construction industry in China. Their study found that organisational safety climate influenced individual safety behaviour. These studies could not explore other factors that could contribute to establishing the mechanisms underlying workers' safety, as several antecedents could determine the relationship between safety climate and safety behaviour. Examining the relationship between safety behaviour and incidents occurrence in safety climate-related studies in the area of the oil and gas industry, relatively limited empirical research attention has been given in the safety literature. Davies et al. (2001) study on safety climate tools captured safety behaviour as a critical factor for measuring safety behaviour in the oil and gas industry. Mearns et al. (2001) conducted a study to investigate the offshore workers' attitude to safety as well as the feelings of safety and satisfaction with safety in the UK oil and gas industry. The study found that the unsafe behaviour of workers was the "best predictor" of accidents. Although the literature found safety behaviour positively related to safety climate, the factor structure of the safety behaviour measure did not adequately reflect the safety compliance and safety participation components identified by the Neal and Griffin (2002). The measure of safety behaviour in safety climate-related studies must specifically reflect these two components as they define safety behaviour of an individual.

Moreover, it appears there is limited research attention on the mechanisms by which safety behaviour influence safety climate in the industry. In view of Neal and Griffin (2002) defined components of safety behaviour, workplace condition must be designed to promote an individual to comply with safety regulations, discourage an individual worker to take shortcuts involving little or no risk implications, create a working environment to allow an individual to willingly participate in safety-related activities and an individual worker must not be put under pressure for production that could lead to non-adherence to code of practice at the workplace. These address good safety behaviour that promote workplace safety climate.

Table 2. 5 Literature summary of organisational safety climate factors

Safety Climate Factors	Literature Sources
Safety Policies	Kuusisto (2001), Mearns et al. (2003), Othman (2010), Petitta et al. (2017)
Safety Priority	Cox & Cheyne (1999), Cox & Cheyne (2000), Cox & Lacey (1998)
Safety Training	Davies et al. (2001), Mearns et al. (2003), Wright et al. (2003), Kvalheim & Dahl (2016), Alruqi et al. (2018), Dahl & Kongsvik (2018)
Management Commitment	Davies et al. (2001), O'Dea & Flin (2001), Wu et al. (2011), Zuofa & Ocheing (2017), Fruhen et al. (2019).
Safety Rules & Procedures	Hale et al. (2012), Hale & Boris (2013a), Hale & Boris (2013b), Weichbrodt (2015), Vidal-Gomel (2017)
Management of Change	Hayes (2012), SPE (2014), Theophilus et al. (2017), Gerbec (2017)
Safety Communication	Davies et al. (2001), Bell & Healey (2006), Kines (2011), Wold & Laumann (2015), Nixon (2018), Newnam & Goode (2019).
Equipment Maintenance	Binch et al., 2012; Ratnayake, 2012; Christou & Konstantinidou, 2012; Baker et al., 2007; Okoh & Haugen, 2013; ILO, 2015)
Safety Involvement	Klein & Vaughen (2008), Nielsena, & Randall (2012), Kouabenan et al. (2015), Kvalheim et al. (2016)
Safety Supervision	Kouabenan et al. (2015), Kvalheim & Dahl (2016), Pandit et al. (2019), Haung et al. (2017).
Supportive Environment	Cox & Cheyne (2000), Mohamed (2000), Amiri et al. (2015), Ghahramani & Khalkhali (2015).
Safety Empowerment	Kines et al. (2011), Bergh et al. (2013), Javad et al. (2017), Larsson et al. (2018), Lee et al. (2019), Probst et al. (2019)
Safety Motivation	Boughaba et al. (2014), Hystada et al. (2014), Griffin & Curcuruto (2016).
Safety Behaviour	Mearns et al. (2001), Davies et al. (2001), Lyu et al., (2018)

2.6.4 The Link Between Safety and Risk

The link between safety and risk has been contentious one in the research literature (see Moller et al., 2006; Aven, 2009; SRA, 2015a). Safety has been looked at in two different thinking: an absolute versus a relative. In terms of expressing the absolute concept of safety, the presence of safety means that there is no risk. This thinking expresses safety as an absence of accident (Tench, 1985; Leveson, 1995; 2004). This thinking is problematic as it is arguably impossible to actualize "no risk" in real life situation (Hansson, 2012). This is because a future accident is associated with uncertainty as it is unknown today. In contrast, the relative concept of safety expresses safety in relation to risk. From the standard theory of safety, safety is defined as an antonym of risk (Aven, 2009; SRA, 2015a). The nature of this inverse relationship implies that safety cannot be referred to as low or high. It is rather a probability or uncertainty of safety that can be expressed as low or high. A lower risk level implies a higher safety level. However, this definition has been challenged by some researchers including Moller et al. (2006) who claimed safety as an antonym of risk, is not an exhaustive one but goes beyond this. This is because epistemic uncertainty was linked to probability on the basis that probability of safety or risk is not known with certainty.

These views are complicated by the convolution of the risk conceptualization. The focus on combination of probability and harm as the understanding of risk is inadequate because it does not address the critical safety issues in complex sociotechnical systems. The issues of unknowledge of uncertainties and potential surprises are inadequately captured by existing applications of probability (Aven and Ylönen, 2016, 2018; Jensen & Aven, 2018). Viewing safety and risk as inversely related point to the need to all always ascertain the background knowledge of these probabilities. In the risk understanding and decision-making context, the knowledge from justified beliefs is mainly applied. To a large extent, risk assessment seeks to "*gaining risk understanding in the sense of knowledge – justified beliefs*" (Amundrud & Aven, 2015, p. 44). By application, ascertaining the background knowledge of hazard risks is a critical way to improve safety performance in the upstream oil and gas industry.

2.6.4.1 Risk Perception

Risk perception is also known as a subjective risk assessment. Mearns and Flin (1995, p. 300) defined risk perception as "*the study of people's beliefs, attitudes, judgements and feelings about hazards, danger and risk-taking, within the wider context of social and cultural value*".

Subjective risk assessment goes beyond as a simple intuitive estimation of probability or magnitude of the loss. Risk perception is intimately linked to human decision making. The basic assumption underpinning the risk perception research is that individuals' knowledge and certainty about risk lie on how they perceived risk. According to Dong et al. (2018), an adequate information reduces the perception of higher risk of hazards. When an individual is possessed with enough information about a particular hazard, he or she is more likely to be well-informed of its negative consequences. Workers remain critical factors in high-hazard industries because their unsafe behaviour affects incident risks in the work environment. These hazard risks have potential consequences to the individual workers, facilities and the environment.

However, research has shown that cognitive biases can influence individual risk-taken behaviour in human decision-making, the psychological factors and organisational conditions (Rundmo, 2000). The technical report of Society of Petroleum Engineers (SPE) has indicated that the application of rational decision-making in a point where there are adequate time and information becomes problematic in highly safety-critical situations (SPE, 2013). It indicated that decision-making process in the oil and gas industry involves the process of situational awareness (i.e. the perception of a potential hazard or failing to recognise hazard), projecting the consequences, planning the possible course of remedies, and choosing what to do. The rational decision making involves applications of models in which humans are assumed systematically in the risk analysis. Individuals make quality decisions in response to situations in the workplace when there are adequate time and information.

There are well-documented evidences in the literature that have established the link between risk perception and safety. These can be found in the following: workforce trust in safety management was associated with workers' risk perception (Kivimaki et al., 1995), workers' safety experience was linked to risk perception (Marek et al., 1985), offshore workers 'safety behaviour was associated with perception of accident risks (Flin et al., 1996; Rundmo, & Sjöberg, 1998), organisational safety influencing factors were found linked to perceived nuclear risk (Kivimaki et al., 1995), safety behaviour was found associated with employees' risk perception (Arezes & Miguel, 2008) and safety climate influences on hazard risks (Pandit et al., 2019). From these studies, it was established that risk perception at workplaces can influence workforce safety behaviour. How workers' safety behaviours influence subjective perception of hazard risk dimensions in the oil and gas industry have not received adequate empirical contribution in the extant literature. The present study provides empirical support to strengthen this link. The risk dimensions in the oil and gas industry have various hazard sources which have implications for incidents occurrence.

2.6.4.2 Risk Dimensions Applicable to the Upstream Oil and Gas Industry

The risk literature has indicated that the hazards associated with upstream oil and gas operations have potential consequences to three main areas: injuries and fatality to the workers (*Human risk*), damage or loss of facilities (*Equipment risk*) and environmental pollutions (*Environmental risk).* These areas are known as the '*Risk dimensions*' (Vinnen, 2007). These dimensions of risk can be assessed in both objective and subjective ways. The various hazards found in the literature that have potential consequences to these risk dimensions are summarised in Table 2.6.

2.6.4.2.1 Human risk

Human risk is defined only to include the risk to workers which is often known as the 'first party' in the upstream oil and gas industry (Vinnem, 2007). It is stated that when assessing the risk to workers in offshore operations, the risk to the public is not taken into consideration (Vinnem, 2014a). Human risk assessment is usually subjected to impairment and fatality hazards analysis. Employees performing upstream activities may be susceptible to impairment and fatality risks. The literature defined four main elements that constitute the hazards to human risks: *occupational accidents*, *major accidents*, *transportation accidents* and *diving accidents*.

The occupational accidents that may occur to individuals are summarised to include the following: trips, slips, strains, falls from height or dropped object, cut, puncture, scrape, caught in or under or between, overexertion, struck by or impact, electric exposure and confined space (Skogdalen et al., 2011; Vinnem, 2014a; Vinnem, 2014b; Hauge & Øien, 2016; IOGP, 2019a; IOGP, 2019a). These accidents have relatively high frequency but low consequence events at the workplace. Major accidents are defined as the potential to cause five fatalities or more Vinnem (2014a). In the event of the probability of major accidents, workers may be exposed to fatality risk, which usually occurs relatively in low frequency but has great consequent events. Occupational disease refers to any disease that is contracted from exposure to factors emanating from the workplace (Naafs, 2018). Niven and McLeod (2009) found five groups of potential hazards in terms of health risks associated with the activities of the industry: physical hazards (e.g. hearing noise), chemical hazards (e.g. haematopoietic cancers), biological hazards (e.g. food-poisoning), ergonomic hazards (e.g. musculoskeletal disorders), and psychological hazards (e.g. job stress). Health risks such as medical malaria, gastric and food poisoning are more prevalent in the developing countries' offshore oil and gas operations (IOGP, 2019b). Transportation accidents relate to the risks to fatality when transporting employees to or from shore for operational activities. The literature captures air transport (helicopter). Diving accidents are mainly required in offshore operations, particularly in the aspect of drilling, construction, production and decommissioning activities. Divers are exposed to lifting/slinging, power tools, noise and vibration, underwater explosions resulting from burning or cutting, high-pressure water jetting, and among other hazardous risks (HSE, 2018). It is important to indicate that workers performing diving activities are usually exposed to several fatality risks in offshore oil and gas operations.

2.6.4.2.2 Equipment Risk

It is established that hazard risks may have potential consequences to the equipment of the organisation in the upstream oil and gas industry (Vinnem, 2007; 2014a; 2014b, Hauge & Øien, 2016; IOGP, 2019a). The risk to the facilities is expressed in the following: possible damage to structures and equipment, possible duration of the production delay, and frequency of incidents that may have similar consequences (i.e. either in the magnitude of damage or duration of production delay). In other words, the risk to asset of the organisation is made up of potential damage to equipment, structures and disruption of production. Hydrocarbon releases were found to be the root causes of major hazard precursors on offshore installations (Sklet, 2006; Vinnem et al., 2007; Vinnem et al., 2010; Vinnem, 2012). Explosions were found as key hazard elements that caused damage to many facilities in the oil and gas industry (Dadashzadeh et al., 2013; Puskar, 2015; Blair et al., 2017). From the literature, gases, vapours and dust explosions constitute the real hazards that continue to be a serious threat to upstream oil and gas operations and that require an adequate assessment to control their risk.

Given the past experiences of major incidents and accidents in the oil and gas industry, the literature found that sources of hazards emanating from offshore production operations are flammable materials usually in the risers, separators, slug catchers and also high-speed rotating equipment (e.g. compressors, turbines, export pumps). The frequency of fire cannot occur without the emergence of ignition event in the situation of a flammable oil or gas or other liquids leaks (Paik et al., 2011). In other words, ignition of hydrocarbon oil or gas leaks plays a key role in fires occurrence. Blowout hazard is explained as the uncontrolled flow of subterranean formation of fluids (e.g. oil, saline, natural gases, water) or well fluids into the atmosphere or an underground formation. The resultant consequence of the Loss of Well Control (LWC) is the blowout. The occurrence of LWC is explained as when formation pressure exceeds the pressure, which applies to it by a column of the fluid (API, 2010). The fluid could be cement spacer fluid, cement slurry, brine completion fluid, drilling fluid, or a combination of any of the column of fluid. A typical example of a blowout hazard incident was the Deepwater Horizon event (*Macondo blowout*) that occurred as a result of the consequence of not maintaining sufficient well integrity (Skogdalen et al. 2011). Nivolianitou et al. (2006) found equipment failure as one of the hazards that cause a major accident in the oil and gas industry. Such accidents may lead to damage to the facilities. In the analysis of lessons learnt from the offshore oil and gas incidents, Necci et al. (2019) found evidence of a collision between platforms and supply vessels. Pengfei1 et al. (2016) noted in their study that the consequences of any collisions with the offshore platform may be costly relative to human safety, cost of facility damage and environmental pollution. Weather and wind conditions have been indicated to cause consequences to upstream oil and gas operations such as a helicopter crash as well as damaging offshore facilities (Kaiser, 2008). Research has found that unsafe act like sabotage by workers may negatively affect the systems, processes or production at the workplace (Theophilus, 2017). The term sabotage act refers to an intentional act to negatively influence the system, work or production, a process that may result in serious damage or accident in a reaction to a challene identified as an organisational factor (Reinach & Viale (2006). For example, Kalelkar and Little (1988) linked the Bhopal disaster to possible of sabotage acts.

2.6.4.2.3 Environmental risk

The environmental risks from upstream oil and gas activities are dominated by substantial volumes of spill which could come from process leaks, pipeline leaks, storage leaks and blowout events (Vinnem, 2007; 2014a; 2014b, Hauge & Øien, 2016). This was indicated that despite the frequency of process leaks during upstream oil and gas operations, they could not cause extensive damage to the environment. However, spills from pipeline leaks, storage leaks and blowout events may result in a large spilled amount or the frequency of it and cause pollution to the environment.

Table 2. 6 Literature summary of hazards

Risk Dimensions	Hazards	Sources
Human	Trips, slips, strains, falls from height/dropped object, confined space, cut/puncture/scrape, caught in/ under/between, overexertion, struckby/impact, electric exposure, Exposure noise/chemical, biological/vibration, medical malaria, gastric or food poisoning, diving accidents.	Vinnem (2007), Niven & McLeod (2009), Vinnem (2014a), Skogdalen et al. (2011), Hauge & Øien (2016). HSE (2018), IOGP (2019a), IOGP (2019b).
Equipment	Hydrocarbon releases, explosion and fire, blowout, equipment failure, vessel collision interruptions, weather and wind conditions, sobotage acts,	Kalelkar &Little (1988), Sklet (2006), Vinnem et al. (2007), (Kaiser, 2008), Vinnem et al. (2010), Vinnem (2012), Paik et al. (2011), Skogdalen et al. (2011), Nivolianitou et al. (2006), Pengfei1 et al. (2016), Necci et al. (2019), Hauge & Øien (2016), IOGP (2019a)
Environment	Oil spills	Vinnem (2007), Vinnem, (2014a), Vinnem (2014b), Hauge & Øien (2016).

2.7 Safety Management Systems in Upstream Oil and Gas Industry

The previous section examined the concept of safety climate as a leading indicator for improving safety performance, and common hazards applicable to the upstream oil and gas industry. However, in improving safety performance, safety management needs to have a structured control system. This structured conrol is termed as the safety management system. This concept has become a critical requlatory requirement for oil and gas organisations to implement. This section critical review the concept of safety management systems, purposes, dimensionality and potential drivers and barriers related to its implementation in the upstream oil and gas industry.

2.7.1 Safety Management System defined

According to Fernández-Muñiz, et al. (2007), the concept of safety management system has not yet been defined. Several defintions have been given to this concept in both the professional and research literature. It has been related to a formalised way of dealing with practices, roles, policies and procedures for achieving the safety functions (ICAO, 2009; Wold & Laumann; 2015; Yorio et al., 2015). Some scholars conceived it as a planned documented and vierified approach for managing risks (Thomas, 2012). In Li and Guldenmund (2018) review work, it is either employed to manage and control safety or as a management system that specifically aims at safety. Three perspectives have been identified from their review that are linked to the safety management systems: *safety*, *management,* and *systems*. Safety related to the states or conditions of being free from negative consequences. This could be accident, risk, or loss. Management generally involves plan, organise and control functions. This could be a prevention and control fashion. System is basically the input-and output functions. This relates to approach, model, framework, technique and assessment.

However, there is a lack of consensus on the definition of safety management systems and how it can be differentiated from other safety programs in an organisation. In other words, there is no a universal agreement on what constitutes safety management systems and its scope. To differentiate safety management system from other safety programs, Fu and Chan (2014) reckoned that safety management system has a broader scope, while other safety programs are usually a core constituted part of a contractor's safety management systems. Effective safety programs involve proactive processes or safety management systems which are more than a program but a ‘philosophy’ (Watson, 1993). This philosophy is referred to as “*a method of management made up of common concepts and improvement*” (Watson, 1993: p.1). However, this distinction appears vague and requires an explicit meaning of safety management systems.

From the literature, several definitions have been given to the meaning of safety management systems. In a critical glance of these definitions, safety management systems are characterised as part of an organisational overall ‘*management systems’* and that the organization has an integrated set of interacting elements. Management system is seen as an attempt to systematise (Wold & Laumann, 2015). Management being systemic means that it assumes an emergent property which considers its entire constituted parts as more useful or functional than some constituted parts. The integrated set of interacting elements of the organization involves elements or components that interact to give meanings to its defined goal and objectives. These elements are broadly defined and therefore making it challenging to constitute a specific set of elements to other organizations with varied management practices. Safety management system is more seen operating as a system due to its key features of *interdependence* and *interrelatedness* which seek to achieve a common goal (Haight, et al., 2013, 2014). If safety management system is a systemic, then the safety outcomes must emerge from a complex network of causal interactions. Dakker et al. (2011) relate a system approach to sociotechnical complexity as a web of dynamic, evolving relationships and interactions, and not as constituted parts and their interactions. This considers a holistic view of the whole system and their interactions.

However, there is lack of clarity of what constitute the components of the management systems. For instant, Robson et al. (2005) noted some ambiguity in the composition of management system in terms of whether it is made of management components or technical/operational components. They argue that technical/operational components play a critical role in the implementation of safety policy and management of risks. On challenge that is noted from their argument relates to the fact that safety management systems are not well-defined set of management systems and for that matter they lack clear boundaries between safety activities, safety management and safety management systems. This challenge may be attributed to the fact that different organizations have different management practices and different ways of controlling safety hazards, therefore making it difficult to adopt a general set of components of safety management systems as a ‘*one size fits all*’ for all organizations. The prevailing management practices of an organization may be influenced by the difference in the culture of the organizations. This may justify why the components of management systems are not universally well-defined for the management of safety.

It is clear from the literature that the characterization of any safety management system for any organization must have appropriate defined management systems with its constituted interacting components and must be systematic in approach. The management systems must define the safety policies (the safety goals and means for goal attainment), procedures (the tactical guidelines for actions relating to these goals), and practices (implementation of policies and procedures). This understanding of safety management system is applied to the current study. How and why is safety management system a critical tool in managing safety in the upstream oil and gas industry? These questions are answered in the next discussion.

2.7.2 Adoption of Safety Management System in the Oil and Gas industry

The requirement for companies to develop safety management system started to arise after several major accidents had occurred particularly in Europe (e.g. *Flixborough Explosion in 1974*; *Seveso Incident in 1976*; *Piper Alpha disaster in 1987*). The oil and gas industry had always had a long tradition of technical integrity until these major accidents occurred (Hudson, 2007). Flixborough accident in 1974 which occurred at Nypro Ltd's caprolactam production facility led to the first requirement for all oil and gas organisations to present a Safety Case as recommended by Lord Robens Committee. In view of this requirement, the United Kingdom's Health and Safety Executive in 1984 issued the Control of Industrial Major Accident Hazards (CIMAH) regulations requiring the operators to provide to the regulator a written report on the installation which was designated as the Safety Case. Once the report was accepted, it had to be used as a basis for inspection strategy by the regulator. The *Seveso incident* in 1976 eventually, brought about the development of Seveso Directive I (also known as European directive 82/501EEC) and this directive had grown and currently updated to Seveso Directive II (Council Directive 96/82/EC). The aftermath of the *Piper Alpha offshore disaster* in 1987, Lord Cullen Committee made recommendations for the oil and gas companies to "*develop and adopt a Safety Management System*" (Cullen, 1990, p. 387). This was the formal safety assessment which required to be performed by each hazardous installation and frequently updated at regular time interval (*Safety Case*). This became the safety management system. Emerging studies after considering lessons learnt in past accidents in 1980s, focused attention on safety management system as an approach to integrate technology, people and management in response to loss prevention in the process industries in 1995 (Pasman, et al., 1992; Visser, 1994). The oil and gas industry in its mandatory development and adoption of this safety management system, extended further to incorporate occupational health and environmental management system which led to the implementation of integrated health, safety and environmental systems.

2.7.2.1 Purposes of Safety Management Systems

Safety management system is understood to as a rationalised management system that defines the policies, procedures, tactical guidelines and practices for achieving the safety function. As indicated in the literature, the goal of safety management is to protect human beings, machines and the physical environment from unacceptable risks. In view of this, the purposes of safety management systems are driven by two perspectives: control and compliance basis (Li & Guldenmund, 2018; Álvarez-Santos et al., 2018).

2.7.2.1.1 Control Perspective

The main purpose for the development of safety management systems is to control hazards, loss, accidents and risks. Following the several major accidents that characterised the oil and gas industry in 1970s, led to the quest for management approaches to control system performance. It is indicated that the standardisation of work procedures can help an organisationto reduce accidents (Wold & Laumann, 2015). Furtherly, the safety management systems help an organization to identify and manage risk adequately (Santos-Reyes & Beard, 2002; Santos et al., 2013). The PDCA-cycle (e.i. Plan-Do-Check-Act) control process is an example of the control system of organisations' safety management systems.

2.7.2.1.2 Compliance Purpose

Compliance of safety laws, regulations and standards has become another important basis that drive an organisation to develop safety management systems. Cullen (1990) inquiry report of the *Piper Alpha disaster* in 1988 recommended safety management systems to the oil and gas industry. Given this requirement, the industry and countrie started to develop safety laws, regulations, standards and guidelines to reflect these safety management systems. Li and Guldenmund (2018) noted that companies strived to develop and improve safety management systems because they want to obtain certification for their operations. Countries develop safety laws and regulations to explicitly stipulate the norms of safety actions that would underlie the legal framework for which risk is accepted or tolerated. The literature identified three aspects of safety compliance: *understanding*, *comparison* and *integration*. The understansing in this context connotes the explication of clues on how existing organisational management systems can conform to standards. Comparison aspect relates to the general understanding of the strengths and weaknesses of particular standards as several countries or institutions employ different safety standards. This is in the view of realising suitability of the safety standards of certain institutions or organisations. Integration denotes that companies incorporate the needed regulations or standards into their own management systems for specific goals. Safety management systems are developed to contain regulations and standards that may have several goals to accomplish in particular areas.

2.7.2.2 Dimensionality of Safety Management Systems

The dimensionality in this context relates to those elements that characterise the safety management systems. Many elements have been found constituting safety management systems. Usually, the number of elements of safety management systems determines the level of detail of a safety management system. In most elements of safety management systems used in the upstream oil and gas sector are commonly found in many international safety standards. Figure 2.5 presents examples of safety standards comprising many different elements of safety management systems used in the upstream oil and gas industry. Although there may be some elements commonly found in many safety standards (e.g. US OSHA; AICHE/CCPS; RC), some of the elements may be different. Experience has indicated that, sometimes, many organisations fail to implement effective safety management systems (Cambon et al., 2006). It had been cautioned that if due diligence were not considered especially when the safety management systems was designed and formalized, it could potentially result to being quite superficial, disconnected from real work situations, be poorly dynamic and can have the propensity to introduce further limitations to workers or rigidity in terms of the way safety is managed in the organisation.

US OSHA 29 CFR 1910.119 and EPA 40 CFR 68	AIChE/CCPS Risk-Based Process Safety (RBPS) Standard	Responsible Care® Process Safety Code
Management System	***Commitment to Process Safety***	***Management Leadership***
Employee Participation	Process Safety Culture*	Commitment*
Process Safety Information	Compliance with Standards	Accountability*
Process Hazard Analysis*	Process Safety Competency	Performance Measurement
Operating Procedures*	Workforce Involvement*	Incident Investigation
Training*	Stakeholder Outreach	Information Sharing
Contractors	***Understand Hazards and Evaluate Risk***	CAER Integration
Pre-Startup Safety Review	Process Knowledge Management	***Technology***
Mechanical Integrity	Hazard Identification and Risk Analysis	Design Documentation
Hot Work Permit	***Manage Risk***	Process Hazard Information
Management of Change	Operating Procedures*	Process Hazard Analysis
Incident Investigation	Training and Performance*	Management of Change
Emergency Planning and Response	Safe Work Practices	***Facilities***
Compliance Audits	Asset Integrity and Reliability	Siting
Trade Secrets	Contractor Management	Codes and Standards
	Management of Change	Safety Reviews
	Operational Readiness*	Maintenance and Inspection
	Conduct of Operations*	Multiple Safeguards*
	Emergency Management	Emergency Management
	Learn from Experience	***Personnel***
	Incident Investigation	Job Skills*
	Measures and Metrics	Safe Work Practices
	Auditing	Initial Training*
	Management Review & Continuous Improvement	Employee Proficiency
		Fitness for Duty*
	***Addresses some of the 10 Human Factors Categories**	Contractors

Fig. 2. 5 Examples of elements found in safety standards

Source: Bridges and Tew (2010).

Cambon et al. (2006) suggested two dimensions of safety management systems: *structural* and *operational* facets. The former connotes the formal description of all the efforts required by a company to manage safety at the workplace. It involves those safety management processes that are usually found in sections or chapters of safety standards. Such processes may include the definition of safety policy, safety program, implementation of communication or documentation systems, hazard identification, and among others. The later relates to those efforts or actions put in place by the organisation to implement the safety management systems. It implies how those internal processes of the safety management process are implemented by the company. In other words, the efforts that company has to put in place in managing the safety of individual's activities at the workplace. In this categorisation, the emphasis is placed on the operational facets because it requires actions that drive the formal internal processes established by the company.

Li and Guldenmund (2018) indicated that the generic safety management system has two main elements: risk control and the learning systems. The former relates to the management processes that involves business processes that are covered in all life cycle, the risk inventory analysis in all life cycle and the interactions between them, the risk barriers and controls for all the life cycle, and the management systems that provides the entire requirements for effective functioning of the technical or procedural barriers and controls. The latter involves the inspection and monitoring, auditing and management review, and incident and accidents registration and analysis.

The literature provided different ways to view the dimensionality of safety management systems. Those elements explicate the content of safety management systems and their processes in implementation. However, they are more of industry specific with no or limited theoretical drive. They mainly represented a mechanical means in fulfilling the content of the safety management systems. What drive the actions of the dimensionality of the safety management systems must be explicitly accentuated.

2.7.3 Effectiveness, Performance and Robustness Concepts in Safety Management Systems

The terms '*effectiveness*' and '*performance*' are used interchangeably in the safety literature to describe the same phenomenon. The confusion in these two terms relating to their definition, measurement and explanation are virtually identical. Henri (2004) related the concept of performance to output of individual or an organisation. From this meaning, the concept of performance is linked to an action of an individual or organisation. The literature pointed out that when conceptualising performance, the disparities between action (bahaviour) and outcome aspects of performance must be differentiated. This is because not every action is subsumed under the performance concept, but only those actions that are relevant to the organisational goals (Sonnentag & Frese, 2002). The outcome aspect of performance has to do with the consequences or the results of the individual behaviour. This means that the judgmental and evaluative processes do not define performance, rather it is the action.

In contrast, Robbins and Judge (2007) related effectiveness to the extent to which stated goal is achieved. In the actual sense, effectiveness reflects goal attainement. Evaluating the effectiveness of safety management systems from the perspective of goals attainment can have the tendency of obscuring the deficiencies in the safety systems. Usually, organisations' implementation of safety management systems only seeks to address "mechanism elements" such as a structure and system of controls for companies, and establishing competency (knowledge of the structure, control, and norms and ability to perform) for individual workers. Defining effectiveness of safety management systems from the perspective of goal attainment means that it only follows the structural performance of the designed and formalized systems. The structural performance of the safety management systems is defined as "the level of compliance of the internal processes as established by the company with the existing safety management standards. In the literature, some scholars have assessed implementation of safety management systems based on *effectiveness* (e.g. Robson et al., 2007; Thomas, 2012; Bianchini et al., 2015; Ghani et al., 2017). Effective implementation is related to something that is in utilisation or operation (Davies, 2008). However, transformation of safety policies into actions towards achieving the safety function is not just a paperwork. It is far more complex because it requires engagement of stakeholders. Today, the oil and gas industry continues to emphasises on an effective implementation of safety management systems to prevent major accidents. If the indication that the effectiveness of safety management systems is the successful implementation of the structural requirements of the prevailing safety regulations and staandards, then the implementation of safety management systems does not by itself guarantee the improvement in the effectiveness of safety management systems (Ghahramani, 2016). Most of the existing tools developed to-date are purely audit tools that help in determining the degree to which safety management has been implemented, which in the actual sense, is not the same as determining whether safety management systems are effective or not (Brady & Stolzer 2016).

Robson et al. (2007) provided a general systematic analysis of scientific literature on the safety management systems performance carried out by the team of the Canadian Institute for Work and Health (CIWH) which showed that no enough evidence confirmed the effectiveness of safety management systems. In another study by Thomas (2012) which provided a systematic review of scientific literature on the effectiveness of safety management systems, indicated a distinct lack of consistency of findings confirming the effectiveness of safety management systems by its critical components. Pitblado and Bjerager (2015) linked effectiveness of implementation of safety management systems in terms of its ability to improve major hazards occurrence. They stated that its implementation had not improved major hazard risks in the oil and gas industry. Podgórski (2015) reviewed the requirement of safety management systems to prevent major accident in the oil and gas industry. He found that since the implementation of the safety management systems in the industry, no sufficient evidence had been linked to its effectiveness in relation to accident reduction. It must be indicated that over three decades of proliferation of implementation of safety management systems in the industry, no conclusive and clear evidence had been adduced to its effectiveness. The literature indicated that its implementation had helped to improve the general occupational safety performance level. However, the critical concern to the industry is how to improve major hazard incident risks.

The upstream oil and gas operations are characterised with complexity, uncertainty and ambiquity. The literature had failed to view implementation of safety management systems from an integrative approach. An integrative risk governance is a critical requirement to realise a robust safety management. Linking implementation of safety management systems to effectiveness may be inadequate to address the issues of uncertainty of knowledge and potential surpirses that are always the triggers of major accidents. Several companies had implemented their safety management systems along with the traditional safety framework developed by the Health and Safety Executive labelled as the "*Successful Health and Safety Management* (see Figure 2.6). Several researchers including Ahmed (2016) continued to employ this framework to improve safety performance in the upstream oil and gas industry. This framework provides the key features of management concept. The management features include plan, organize, lead and control functions. It is the *plan-do-check-act* fashion espoused by both the professional and research literature. This framework is important as it described the key elements of management. However, it does not address how to deal with complexity, uncertainty and ambiquity associated with managing major hazard risks.

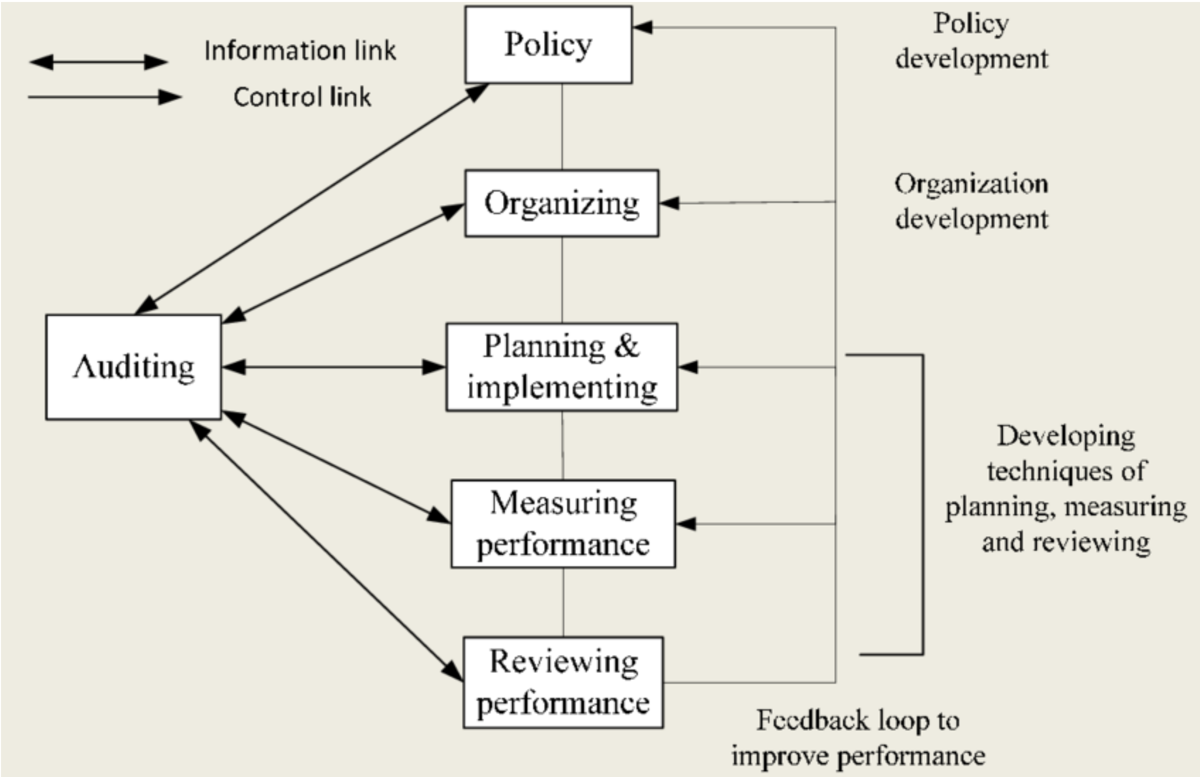


Fig. 2. 6 Successful health and safety management

Source: HSE (1997)

The concept of *Robustness* is linked to system effectiveness. According to Hoffman and Hancock (2017), robustness can be expressed as the capacity of a system to maintain effectiveness through a spectrum of tasks, situations and contexts. Safety management in the oil and gas industry is a control problem. It is not only about achieving the stated safety outcome but addressing complexity, uncertainty and ambiquity issues. This is because the upstream oil and gas industry involves complex exploration and production activities that require coordination of the performance of the industry (drilling rig owners, operators), contractors and the government authorities. The gap associated with the current safety management framework is that it does not address risk governance adequately. To fill this gap, researchers need to base implementation of safety management systems on robustness thinking that emphases integrative risk governance in which the principal features of the systems are always maintained with learning capability towards changed conditions. Implementation of safety management systems under self-regulatory regime benefits all the stakeholders involved that include the drilling owner, operator, contractor and the government agancies (Ghani et al., 2017). Therefore, its implementation equally requires an integrative approach of risk governance that must be driven by safety culture.

2.7.4 Robust Implementation of Safety Management Systems

Robson et al. (2007) identified three main outcome changes in assessing the effectiveness of safety management systems. They include implementation, intermediate outcome and final outcome. Implementation is referred to the course of actions taken to put into the utilisation of an idea, decision, procedure or program (Klein & Sorra, 1996). Othman (2010) characterised implementation with two things: allocating resources and changing the organisational structure. It relates to the act of putting a plan into action to achieve a goal. Implementation of safety management systems can be defined as the act of placing safety policies into action to achieve the safety functions. The primary safety functions are to prevent human beings, property and the physical environment from unacceptable risks. Immediate outcome relates to the initial utilisation of the safety idea. The final outcome is linked to the accident rate. Implementation is regarded as one of the parameters or indicators for assessing safety management systems. The literature established safety climate as a robust indicator of organisational safety performance. Safety climate drives the implementation of organisational safety management systems. In this context, implementation of organisational safety management systems becomes robust when a positive safety climate drives it. There are several drivers and barriers associated with implementing an organisational safety management system. This section discusses those potential drivers and barriers to the implementation of safety management systems.

2.7.4.1 Drivers

Ismail et al. (2012) investigated several factors that could influence the implementation of safety management systems. The factors were categorised into resources, management, personal, incentive and relationship areas. The *resource factor* included both hardware (e.g. PPE and any requirement of the industry) and software. The *management factor* included vision, statement of objectives, leadership, direction, commitment, safety analysis, supervision and prevention planning. The *personal factor* involved good communication, safety awareness, safety culture, individual competence and group positive. The *incentive factor* included promotion, remuneration, campaign, motivation, merit rating, PPE, working conditions, welfare and safety rules. The *relationship factor* comprises two areas: the globalisation and the interfaces with stakeholders, and internal personal relationships at the work environment. However, personal awareness and good communication were found to be the main drivers of implementing safety management systems.

Yiu et al. (2019) examined the literature on the critical factors that drive the implementation of safety management systems. In their review, they categorised the drivers into five areas: safety commitment, competence profile, safety climate, project management, and safety requirement and incentives. They indicated that *safety commitment* must reflect visibility of senior management, investment in safety-related issues, allocation of sufficient manpower and provision of adequate time. *Competence profile* must cover personal quality of safety manager, personal competence of the safety manager, training, education, safety behaviour and leadership of the project manager and the senior manager. The *safety climate* includes elements such as workers' participation in safety, safety awareness, the attitude of the workers and the safety culture of the operation. The *project management* covers the existence of teamwork, effective communication systems, safety organisation indicating responsibility and accountability of the workers, frequency of safety meetings and selection strategy of subcontractors. The *safety requirement and incentives* reflect the incents from both the workers and the organisation, legal requirement in both contractual and certification of standards. However, they found two elements that critically drove the safety management systems implementation in their study: visual senior management commitment to safety and competence of safety managers.

Several other studies have identified drivers of implementation of safety management systems. Othman (2010) identified adequate monitoring of progress and outcomes as critical drivers of implementing safety management systems. It involves active and reactive monitoring. The active monitoring (before things go wrong) establishes that there is the existence of procedures specifically for the activities at the workplace. Reactive monitoring relates to learning from incidents. Several studies found that investment in safety education and training of workers concerning their unsafe behaviour would drive safety management systems implementation (Paul et al., 2007; Whysall et al., 2006; Álvarez-Santos et al., 2018). Stolzer et al. (2018) noted that the active participation of every worker in the organisation is a key driver of safety management systems implementation. Rajaprasad et al. (2015) assessed the factors influencing the implementation of OHSAS 18001 that included continual improvement, safety culture, moral of workers and safety training were considered as the dependable variables. The study found that safety commitment and safety policy were the main drivers of safety management systems implementation. Álvarez-Santos et al. (2018) identified organisational culture as a key driver of safety management implementation. It must reflect on the social domain of labour relations as well as the integration of the technical security that would improve the processes of implementation. Durán and Patiño (2018) found the following factors as key in driving implementation of safety management system in the industry: inappropriate use of PPE by workers, commitment from management and the signing of the policy, collaboration of the heads of the department of the organisation, resources allocation, participation of the workers, safety awareness and trust between workers and their superiors. Kim et al. (2019) investigated the influence of safety climate in the implementation of organisational safety management systems. The authors identified safety motivation, the involvement of sub-contractors in safety meetings and training and safety empowerment as essential drivers of implementing safety management systems. The main drivers found by the literature are summarised in the table 2.7. However, these drivers are more related to safety culture influences.

Table 2. 7 Literature summary of drivers

Potential Drivers	**Literature Source(s)**
Safety policies	Rajaprasad et al. (2015), Durán & Patiño (2018)
Safety incentives	Kim et al. (2019)
Appropriate use of PPE by workers	Durán & Patiño (2018), Yiu et al. (2019)
Adequate monitoring	Othman (2010)
Safety involvement	Kim et al. (2019)
Adequate training and competence	Paul et al. (2007), Whysall et al. (2006), Rajaprasad et al. (2015), Álvarez-Santos et al. (2018), Yiu et al. (2019), Kim et al. (2019)
Organizational safety culture	Rajaprasad et al. (2015)
Sufficient resources allocation	Durán & Patiño (2018)
Safety awareness	Durán & Patiño (2018)
Safety empowerment	Kim et al. (2019)

Favorable working environment for problem-solving	Álvarez-Santos et al. (2018)
Safety awareness	Durán & Patiño (2018)
Satisfaction of stakeholders	Álvarez-Santos et al. (2018)
Trust between workers and superiors	Durán & Patiño (2018)
Adequate communication among stakeholders	Ismail et al. (2012), Yiu et al. (2019), Silva & Amaral (2019)
Learning from incidents	Othman (2010)
Workers' participation	Durán & Patiño (2018), Stolzer et al. (2018),
Management commitment	Rajaprasad et al. (2015), Durán & Patiño (2018), Yiu et al. (2019), Silva & Amaral (2019)
Collaboration among the stakeholders	Durán & Patiño (2018), Silva & Amaral (2019)

2.7.4.2 Barriers

Zeng et al. (2007) investigated the implementation and certification of safety management systems in organisations. The authors found that the factors the negatively affect the implementation of the safety management systems can be categorized in to internal and external. The internal factors involve understanding and perception, human resources, organisational structure and company structure. The external factors are made up of stakeholders and customers, technical guidance, certification bodies and institutional environment. They suggested a multi-level synergy model for the implementation of safety management systems.

Silva and Amaral (2019) conducted a systematic review of the literature on critical success factors and barriers related to the implementation of safety management systems. The authors found the following as critical barriers to implementation of safety management systems: high cost of implementation and management, lack of management commitment, lack of workers' involvement, the challenges relative to the functioning of the safety control and documentation systems, the failure in the process of assessing the risks, challenging of changing the organisational policy and culture, challenge in defining the suitable safety management indicators, and difficulty in integrating different safety standards, attribute compliance to the organisational culture.

Several other studies have identified various factors that constitute barriers to the implementation of safety management systems. Yiu et al. (2019) reviewed the literature to identify barriers to the implementation of safety management systems. The potential barriers were categorised into three areas: *competence profile*, *project management and leadership*, and *project constraint and system limitation*. They noted that poor project management and leadership were the most frequently cited ones from the literature. For examples, Goh and Chua (2013) found insufficient resources and tight project schedule posed challenges to safety management implementation. Yiu et al. (2018) found high turnover rates of labour, lack of financial commitment to safety and high stress for project completion as potential barriers to safety management systems. Agyekum et al. (2018) identified inadequate communication in terms of coordination of work planning and schedules targeting identification and resolution of conflicts could obstruct the implementation of safety management systems. Bianchini et al. (2017) found that the lack of incentives for small companies affects the implementation of safety management systems. Garnicaa and Barrigaa (2018) surveyed to determine the main barriers to the implementation of safety management systems. The authors found that inappropriate behaviour from management, lack of communication and lack of safety prioritisation were the key barriers to implementation of safety management systems. The main potential barriers to the implementation of safety management systems identified in the literature are summarised in the table 2.8. However, it can be stated that all these drivers and barriers are linked to safety climate dimensions. A robust implementation of safety management systems requires a strong safety culture drive. As indicated in an earlier review (sections 2.6.2 & 2.6.3), safety climate is a manifestation of organisational culture. Therefore, an improvement in organisational safety climate would influence a robust implementation of safety management systems.

Table 2. 8 Literature summary of barriers

Potential Barriers	Literature Source (s)
Lack of safety prioritization	Garnicaa & Barrigaa (2018)
Inadequate training and competence	Agyekum et al. (2018)
Insufficient communication	Agyekum et al. (2018), Garnicaa & Barrigaa (2018)
Insufficient resources	Goh & Chua (2013)
High cost of implementation and management	Silva & Amaral (2019)
High turnover rates of labour	Yiu et al. (2018)
Lack of management commentment	Silva & Amaral (2019)
Lack of workers' involvement	Silva & Amaral (2019)
challenges relative to the functioning of the safety control and documentation systems	Silva & Amaral (2019)
Failures in the process of assessing the risks	Silva & Amaral (2019)
Inappropriate management safety behaviour	Garnicaa & Barrigaa (2018)
Challenging of changing the organisational policy and culture	Silva & Amaral (2019)
Challenge in defining the suitable safety management indicators	Silva & Amaral (2019)
Difficulty in integrating different safety standards, attribute compliance to the organisational culture	Silva & Amaral (2019)
Lack of incentives for small companies	Bianchini et al. (2017)
Tight project schedule	Goh & Chua (2013)

2.8 Theoretical Framework of the Study

This section provides the theoretical framework of the research that would help to provide empirical data analysis to achieve the aim of the present study (see figure 2.7). The upstream oil and gas operations represent a complex sociotechnical system as several players are interacting to achieve the production goals. Such interactions always produce complexity, uncertainty and ambiguity of risk (Renn, 2014). The complexity issue associated with the upstream operations relates to the difficulty or the poor knowledge about the consequences of the system, even if there is a strong knowledge about the consequences of its sub-systems. The interactive effects of all the components constituting the operational system are not adequately identified (Jensen & Aven, 2018). Complexity expresses the deficiencies or limitations of the knowledge of the hazards. The uncertainty issue emerges from the insufficient reduction of the complexity in indicating the cause-effect chains. This occurs in the risk assessment stage, where the knowledge of human contribution may not be adequately linked to the probability estimates or the numbers. An ambiguity of risk arises due to the several different contesting views on the justification and severity of the risk. In most cases, many different meanings and interpretations are associated with the risk acceptance criteria. The literature has indicated that there are always uncertainties of knowledge and potential surprises in the application of engineering probability-based risk assessment underpinned the current safety management in the industry. The current practice of obtaining system understanding by the use of simple linear models (e.g. fault trees, event trees, Bayesian networks, etc.) to quantify risk and compare with a predefined criterion for decision-making is inadequate. This is because the underlying assumptions may obscure relevant aspects of risk and uncertainties, and surprises occurrence is relative to probabilities expressions. In this regard, an adequate background knowledge of risk is critical in managing the safety of complex system operations like the oil and gas industry.

The safety management is a control problem. This control problem identified through Rasmussen's (1997) hierarchical model of sociotechnical system. There is interaction between humans, technology and the social and organisational processes which operates in these levels. This model of hierarchical safety control levels is established to address system complexity in decision-making (Carayon, 2015; Leveson, 2017; Jensen & Aven, 2018; Petukhov & Steshina, 2018). The hierarchical safety control levels involved the government, regulatory authorities, company, management, staff and work. These safety control levels influence risk. From control and regulatory purposes, every organisation must implement safety management systems (Li & Guldenmund, 2018; Álvarez-Santos et al., 2018). The safety management systems are characterised by the sociotechnical dimensions of its goal-oriented outocmes (Rasmussen, 1997; Grote & Künzler, 2000). They are rationalised management systems that define the policies, procedures, tactical guidelines and practices for achieving the safety function. The sociotechnical perspective implies that the safety management systems must be developed to value it social relationships. The safety management systems must be implemented with an adaptive and integrative goveranace approach (HSE, 2013, Hale, 2014). In this regard, safety management must require an integrative risk governance.

An integrative risk governance model developed by Renn (2014) is relevant in addressing the complexity, uncertainty and ambiquity associated with system operations. The risk governance must be required in four areas: framing the risk related issues, risk estimation, risk evaluation, monitoring and controlling risk, and risk information sharing. It must be pointed out that an organisational culture that is capable to operate in the social domain of network relations needs to integrate risk governance to improve the processes of implementation and sustainance of its safety management systems. An organisation's safety management system is conceptualised as an "artifact" or "a manifestation" of an organization safety culture (Mearns et al., 2003; Naevestad, 2009; Guldenmund, 2010; Reiman & Rollenhagen, 2014).

The main attribute of a safer organisation is the extent to which it cooperatively optimises the social or organisatonal aspects of the safety of the work environment (Brian et al., 2015). In systemic theory of accident causation, an accident is viewed as an emergent phenomenon that occurs because of the complexity of interactions between its components that cause degradation of the system performance leading to an accident (Qureshi et al., 2007). An accident occurs due to the defective processes involving interactions among people, social and organizational structures, engineering activities, and physical and software system components (Leveson, 2004; 2011). From this view, safety is understood as an emergent property because of its complex relationships and interactions between the components of the system constituting the safety. According to Brian et al. (2015), the main characteristic of the interations of the components parts is the joint optimisation. It is a dynamic state which is continuously subjected to modification and influenced by both organisational internal and external factors. The external factors are mostly beyond the direct control of the organisation. They may include the regulatory environment, market forces, cultural trends and others. The internal factors are more related to organisational climate influences. The literature established that safety climate provides the avenues for assessing the extent of this joint optimisation between the organisation and the technical systems.

The element of this joint optimisation is the performance vulnerability feedback. This safety performance is defined by the safety outcomes and safety behaviours (Christian et al., 2009). Safety outcomes relate to historical information or statistical data on indicators of incidents, accidents, injuries and fatalities. Safety behaviour has two aspects: safety compliance and safety participation. A good safety climate would stremgthen regulatory, organisational and workforce safety culture. The safety indicators and organisational safety climate must be continuously be improved through the hierarchical sociotechnical levels with the incorporation of an integrative risk governance.

From the literature review, it can clearly be stated that over the years, several scientific pieces of knowledge have been provided to support decision-making in safety management. It appeared there is inadequate integrative research that had been contributed in providing a conceptual framework to address the safety control problem. The current study seeks to strengthen integrative research in safety management by a detailed combination of the concepts of sociotechnical, risk governance and safety culture in addressing complexity, uncertainty and ambiguity of risk associated with the upstream oil and gas industry.

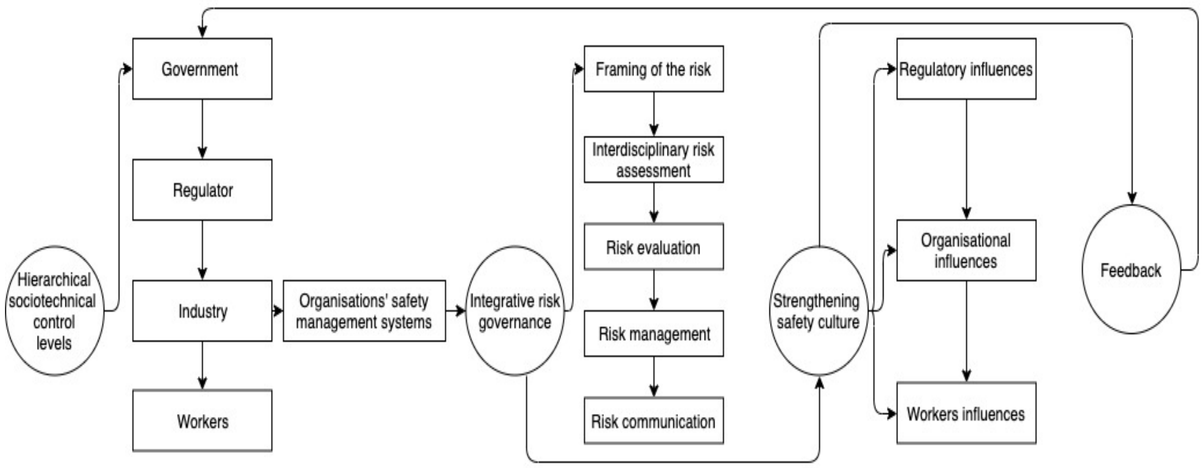


Fig. 2.7 Theoretical framework of the study

2.9 Summary

This chapter commenced by providing an overview of safety management in the upstream oil and gas industry. Safety management involves prescription of safety norms and the activities that would make these norms be duly complied. The study viewed safety as a control problem. The risk governance was discussed as a key concept to address the complexity, uncertainty am ambiquity associated with this control problem. There are modes of regulation to prevent major hazard risks which were discussed along with the prescriptive regulations, performance-based regulations and hybrid regulatory regimes. However, the study reviewed existing literature on evaluation of safety regulatory regimes in the upstream oil and gas industry with a view to explore for the existing approaches for assessment and ascertain whether there is a consensual approach for determining a superior regulatory regime. The study found no literature suggesting superior regulatory regime style because of the differences in prevailing national cultural, definition and reporting of safety data, regulatory architecture and the scope of upstream oil and gas activities.

The risk governance in Ghana's upstream oil and gas industry was reviewed. The review identified some weaknesses in existing regulatory and institutional framework governing the industry. It appeared existing literature focused on examining the safety regulatory architecture and orientation. Ghana's safety regulations are driven by the safety case regime which is mainly rooted in engineering propabilitiy-based risk assessments. The study found inadequate approach to handle the complexity, uncertainty, ambiquity of risk associated with Ghana's upstream oil and gas industry. Given Ghana's past experience of poor industrial hazardous risk management, there is the need to provide an appropriate approach to manage safety in the industry. A review of the resilience versus robustness concepts of risk goverance was carried out to find the most appropriate approach to address the inherent complexity, uncertainty and ambiquity associated with the upstream oil and gas operations. This study argued that robustness concept tends to offer more proactive measures in dealing with the risk governance issues. The review provided review criteria to assess a robust safety regulatory regime in the industry.

Existing indicators for safety management were examined as important to reveal system deficiencies for improvement. Such indicstors must reflect the safety domains and perspectives of the industry. Safety control problem can be exposed by both safety performance indicators (historical safety statisictical data) and safety climate indicators. Safety climate is a robust indicator for hazard incident risks. The study examined the link between safety and risk and further identified the potential measures of safety climate and the dimensions of hazard incidents risk in the upstream oil and gas industry. The concept of safety management systems and its potential drivers and barriers related to implementation were examined. However, it was understood that a robust implementation of safety management systems requires a strong safety culture drive. A theoretical framework of the study was made to provide a guide to the empirical data analysis of the research.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

The preceding chapter reviewed the literature on the risk governance in Ghana's upstream oil and gas industry. This chapter presents the research methodology for the study. It covers the methodological approach, which defined its philosophical position, the design science research as the approach as well as its justification and weaknesses, the research strategy and research methods adopted for the study. This chapter will indicate the extent of the validity and reliability of the data for the analysis. It will show the ethical consideration of the research and summarises the research methodological framework.

3.2 Purpose of the Research

Research is a systematised effort to acquire new knowledge. Every research has the primary purpose of fulfilling or creating reliable and worthwhile knowledge that must be based on evidence and logical argument to solve a societal problem. Generally, it seeks to provide descriptive, explanatory and predictive knowledge of the world. However, another way of solving a societal problem is to provide prescriptive knowledge to solve a practical problem of society through a designed artefact (Kuechler & Vaishnavi, 2014). The context of the current research is the risk governance in Ghana's upstream oil and gas industry. It seeks to understand the risk governance issues and find a more appropriate way to improve the complexity, uncertainty and ambiguity of risk in the industry. Given this, this research seeks to provide prescriptive knowledge to improve safety management in the Ghanaian upstream oil and gas industry. A methodological approach is required to fulfil the purpose of this research. The next section discusses the research methodological approach of this study.

3.3 Research Methodological Approach

A research methodology is a crucial stage in every scientific enquiry. Researchers have defined research methodology in different ways. Kothari et al. (2014) described it as a systematic way of solving a problem. Accroding to Easterby-Smith et al. (2004), it is the combination of techniques applied to enquire into a specific situation. It is also defined as the study of methods by which knowledge is acquired, and which gives the work plan of the research (Rajasekar et al., 2013). Essentially, it is the procedures followed by researchers to obtain knowledge. However, it goes beyond this traditional process of employing a specific research method and includes the rationale and philosophical assumptions that underlie the study (Knight & Ruddock, 2008). Every research must go through procedures to gain knowledge. The indication of assumptions relating to personal values is essential when planning a research study. Therefore, every research methodology must clarify its philosophical stance.

The process of creating knowledge begun with a substantive field of inquiry, known as '*Philosophy*' (Hanid, 2014). According to Dawood and Underwood (2010, p. 178), philosophy means "*love of wisdom* or *love of Knowledge*". Knowledge is a crucial aspect of inquiry to solve a societal problem. It elucidates the view of the researcher's understanding of knowledge, processes and phenomenon of the study area. It concerns with the establishment of rigorous, regulation, and improvement of the methods of knowledge creation in all fields of intellectual endeavour (Partington, 2002). Researchers recognise that the choice of a research methodology ('*how research*') requires something far more in-depth than practicalities. It requires rational solutions to the 'why research'. Understanding of philosophical issues in an intellectual endeavour is essential in knowledge acquisition. Crossan (2016) stated that due to its 'indirectness' and 'circular nature' of philosophical questioning, it usually encourages in-depth thinking, and generates more questions specific to the topic in question. According to Smith (1998), it is uncomplicated style and reliable way of questioning and which creates confusion and instability in our assumptions and ideas about the world, that makes the study of philosophy particularly relevant. Easterby-Smith et al. (1997) stated three reasons why research philosophy is vital to research:

- *It helps in refining and specifing the research methods to be employed in research,*
- *It helps the evaluating the different methods by identifying the weaknesses of the approaches at the initial phase of the research.*
- *It helps in original and innovative work by employing methods that were previously outside his or her experience.*

The development of a philosophical view concerning the world requires critical assumptions relating to these two dimensions: the nature of science and the nature of society (Burrell & Morgan, 1979; cited in Holden & Lynch, 2004). These fundamental assumptions relate to ontological, epistemological, methodological, axiological concerns of the world. Vaishnavi and Kuechler (2007) have explained and summarised these assumptions. *Ontology* is the study that relates to the description of the nature of reality. Ontological questions relate to the following: *what reality is, what does entities exist, how do they relate and interact with each other*. In other words, what is real and what is not, and what is fundamental and what is derivative. *Epistemology* is explained as the study that sought to explore the nature of knowledge. It expresses what knowledge is depended and how to be curtained about what is known. *Methodology* expresses the procedures to follow in obtaining the knowledge. *Axiology* is the study of values. In other words, it expresses what values guide the reason for all human actions (Heron, 1996). Every researcher is required to show axiological skill by expressing their values as the grounds for their judgement about the conduct of the research. However, these underlying assumptions about the world are divided over several research perspectives which are discussed in the next section.

3.3.1 Research Paradigm

A research paradigm is understood as a set of beliefs and assumptions that are commonly held within a research community about the concerns of ontology, epistemology and methodology (Johannesson & Perjons, 2014). In other words, it creates a mental model that must influence and organise how the members of a research community perceive their area of study. Vaishnavi and Kuechler (2007) and Johannesson and Perjons (2014) indicated that every research paradigm must address the questions of the following fundamental beliefs of the world: Ontology asks, *What is the world?* Epistemology asks, "*What can be known about the world, and how can knowledge be obtained?"* Methodology asks, "*Which procedures can be employed to obtain knowledge?"* And Axiology asks, "*What is a value?*" There are numerous varieties of research paradigms which are divided across ontological, epistemological, methodological and axiological concerns. It appears positivism and interpretivism are the most common established research paradigms. However, in contrast with existing positivism, interpretivism and other research paradigms that are implicit in the natural sciences and social sciences research, this division did not differentiate another meta-level assumption from the sociotechnical or developmental approach (Vaishnavi & Kuechler, 2007; Hanid, 2014). Gregg et al. (2001) added another meta-level assumption of DSR, which underscores iteration circumspection and how it determines or reveals reality and knowledge that develop from the research effort. Table 3.1 presents these philosophical assumptions of these three research perspectives: positivism, interpretivism and DSR. These research perspectives are well documented in Vaishnavi and Kuechler (2007) and Johannesson and Perjons (2014), which are discussed here.

Table 3. 1 Philosophical assumption of the three research perspectives

Research Philosophy			
Basic Beliefs	***Positivist***	***Interpretive***	***DSR***
Ontology	A single reality Knowable, probabilistic	Multiple realities, Socially constructed	Multiple, contextually situated Alternative world-states Socio-technically enabled
Epistemology	Objective; dispassionate, Detached observer of truth	Subjective (i.e. values And knowledge emerge From the researcher-Participant interaction	Knowing through making: Objectively constrained construction within a context iterative circumscription reveals meaning
Methodology	Observation; quantitative, statistical	Participation; qualitative. Hermeneutical dialectical	Developmental Measure artifactual impacts on the composite system
Axiology: *What is of value*	Truth: universal and Beautiful; prediction	Understanding: situated and description	Control; creation; progress (i.e. improvement); understanding

Source: Vaishnavi and Kuechler (2007)

Positivism was introduced by the sociologist and philosopher, Augustine Comte in 19th century. According to Johannesson and Perjons (2014), Comte attempted to establish sociology as a science by application of natural science perspective on social phenomena. He presented positivism as a reaction to metaphysical and theological world perspective that accepted tradition, divine revelation and authority as legitimate knowledge sources. However, positivism viewed knowledge based on sense, experience and positive verification. On the ontological deposition of the world, positivist researchers view that there is a single reality that exists independently of human actions and experiences. Epistemologically, positivist researchers view objective knowledge about the social world that can only be acquired through observation and experimentation. What it means is that social inquiry must be carried out in an unbiased manner where the researcher completely assumes as a disinterested observer who detaches himself or herself from the subject of being investigated. On methodological deposition, the positivist researchers assert that researchers must engage in an objective and value-free investigation. That is, researchers should be detached from the participation of the research by remaining emotionally neutral to distinguish between feeling and reasoning (Carson et al., 2001). Research evidence is claimed to be obtained from quantitative studies. Experiments constitute the primary research strategies for a subject investigation because they can provide highly objective knowledge. For axiological concern, positivism asserts that the values of the subject investigation reflect the truth and are highly universal and predictive. Although positivism is more appropriate for natural science, it does not capture important aspects of the social world, particularly the subjective construction of social phenomena.

Interpretivism was introduced by a German sociologist, Max Weber in reaction to positivism in the 20th century. Max Weber asserted that the social world, as well as the social actions, are only understood through the grasping of subjective meanings and purposes attached to people's actions. From the ontological view of the world, interpretivism argued that the social world does not exist independent of human interaction or influence. Human actions construct the social world and give meanings to it. Every social phenomenon originates from the interactions and experiences of people. Therefore, there are multiple social realities of the world that are dependent on the subjective interpretations of people based on their actions and experiences. Epistemologically, a social phenomenon is characterised with actions, experiences and subjective meanings of people who participate in it. Knowledge is obtained by viewing people as objects. A social phenomenon can be understood by active participation with the people. In a methodological sense, interpretivism employs qualitative research strategies. In terms of axiological view, knowledge obtained from the social world is situated and descriptive.

Since Gregory Sydney's distinction between scientific method and design method in 1965, researchers like Herbert Simon and Karl Compton advanced this difference. Simon's first publication on "*The Sciences of the Artificial*" stimulated further development of systematic and formalised design methodology relevant to design fields. DSR is research that creates the missing type of knowledge by employing design, analysis, reflection, and abstraction (Kuechler & Vaishnavi, 2004). DSR focuses on the development and performance artefacts to improve the functional performance of the artefact. It employs scientific study and develops artefacts to solve a practical problem which seeks to provide an understanding of the human-machine interface and improving human performance. Ontologically, design science researchers argued that the world exists in multiple realities that are contextually situated and sociotechnically enabled. This means that any of the positivist (e.g. survey, experiments, field studies) and interpretivist (e.g. case studies, action research, ethnographic studies) research strategies can apply to the ontological sense of the world. In an epistemological sense, design science researchers strive for knowing through making. Methodologically, they focus on systematic methods to develop an artefact which can use either of the positivist and interpretivist research strategies or methods. The value of knowledge focuses on understanding and relevance.

With the present study, safety management in the upstream oil and gas industry reflects characteristics of complex sociotechnical systems. It implies that the value of knowledge is to drive the truth and relevance of the knowledge. Therefore, any of the research methods of the positivist and interpretivist will b relevant so far as it can help to achieve the aim of the study.

3.3.2 Philosophical Position of this Study – Pragmatism

Given the fact that the development of DSR emerged primarily from the information systems field, there has been an explicit demand of paradigmatic foundation for DSR. The reason is that the scientific foundation that underlies the application of DSR in the information systems field had not been adequately developed (Purao, 2002). Given the researcher's interest to strengthen bridging the gap between research and relevance, the DSR becomes more useful. Pragmatism is a paradigmatic foundation that places a critical emphasis on the relations between truth and practical utility (Darke et al., 1999; Goldkuhl, 2011). In other words, it underscores both the truth and relevance of knowledge. It considers knowledge as a way to improve action and experience. The aspects of truth and practical utility is essential to improve existing safety in a sociotechnical working environment like the upstream oil and gas industry. This study is positioned within the pragmatist philosophy.

3.4 Research Approach – Design Science Research

The choice of an appropriatapproach for this research is dependent on the pragmatic philosophical stance that will help to achieve the research aim. This study aims at developing a framework for robust safety management in Ghana's upstream oil and gas operations. This study adopts DSR as the research approach. The DSR paradigm of pragmatism has been increasingly discussed in recent years and also gaining more ground for both building knowledge and improving knowledge (Winter et al., 2010). The main goal of the DSR project is to prescribe a practical solution to a real-life problem (Johannesson & Perjons, 2014). Unlike natural and social sciences that describe, explain and predict knowledge, DSR prescribes knowledge by identifying and understanding the real-world problem and propose specific artefact (useful solution) to solve it (Vaishnavi & Kuechler, 2007; Ostrowski et al., 2012; Johannesson & Perjons, 2014). It is shown that DSR involves the study of methods, behaviours and best practices related to the problem analysis and the artefact development process (Winter et al., 2010).

3.4.2 Justification for Adopting Design Science Research

Typical research in safety management in the oil and gas industry has followed mainly descriptive, explanatory and predictive approach. The current safety management perspective is based on engineering risk assessment tradition driven by purely probabilistic-based expression of uncertainty of events and consequences (Aven & Ylönen, 2018). However, this practice is being criticised as lacking the capacity to solve complex systems and inadequate to base safety management on a set of identified scenarios that linked to probability estimates (Flage et al., 2014; Aven & Ylönen, 2018; Jensen & Aven, 2018). In managing safety in a complex system like upstream oil and gas operations, it is impossible to predict the performance of the systems accurately and estimate the risk on the mere ground of knowing the system components performance (Aven & Ylönen, 2018; Jensen & Aven, 2018). There is the complexity of the interaction of the systems which is always susceptible to surprises relative to the application of the knowledge of analysts, experts and models. One approach to deal with the complexity of the systems is to increase the understanding of the system by a robust approach to safety management. The main characteristics of robustness in safety management have examined in chapter two (section 2.4). The main emphasis is the critical recognition of multi-actor and multi-objective governance structure for the conceptualisation of the issues constituting the threats to safety and setting up of institutions and procedures to deal with those threats in upstream oil and gas operations. It must be underscored that the primary significance of the application of DSR approach is the development of an artefact that is driven by the requirement of its *research rigour* and *problem relevance* (Hevner et al., 2004; Ostrowski et al., 2012). In terms of the research rigour, the current study chose several different data collection techniques to establish the awareness of the problem confronted safety management in Ghana's upstream oil and gas industry. For the problem relevance, the current study involved multi-actor participation throughout the entire activities of the DSR process. The multi-actor refers to the several relevant stakeholders in the upstream oil and gas industry that are experiencing the problem. The application of DSR approach will help to prescribe the knowledge that is required to strengthen the robustness in managing safety in the upstream oil and gas industry. DSR prescribes knowledge by identifying and understanding the real-world problem and propose specific artefact to solve it (Vaishnavi & Kuechler, 2007; Ostrowski et al., 2012).

Moreover, the link between DSR projects' essential characteristics and safety management research provides another basis for justifying the adoption of DSR as an approach for the current study. Their relationship explicitly appeared lacking clarity in the research literature. Table 3.2 presents the DSR projects common characteristics identified in the literature that links to safety management research. Those common characteristics found in the DSR projects may include *prescription of knowledge*, *tailored to management research*, *multi-dimensional*, *Continuous improvement*, and *systemic driven*. These characteristics discussed to make the DSR approach more relevant in its application to safety management research.

Table 3. 2 The link between DSR characteristics and safety management research

Author(s)	Description of DSR Characteristics	Classification of Safety Management Characteristics for DSR Projects
Vaishnavi & Kuechler (2007), Johannesson & Perjons (2014)	*Prescription of knowledge*: Prescribing artefacts to solve a real-world problem	Safety management projects produce prescriptive knowledge for both researchers and practitioners. Examples include the domain of government prescriptions, codes of practice and instructional pamphlets such as Australia's AS/NZ 4801; UK's BSI-OHSAS 18001; ISO 9001; API 75.
vom Brocke & Lippe (2010), Van Aken, (2005)	*Tailored to management research:* DSR projects have also been applied in management research to solve managerial and organisational issues	Safety management is an aspect of the overall management functions that determine and implement safety policies. The primary characterisation of safety management lies in its management systems involved in managing the complex

		interaction of people, the technology and organisation.
Shenhar & Dvir (2007), Vom Brocke & Lippe (2010)	*Multi-dimensional framework*: Categorises projects based on novelty, technology, complexity and pace	Safety management research involves different topics being studied which makes the outcome of the study emerged from the contribution of various scientific disciplines. It includes many stakeholders and requires a solution to address the complexity in the performance variability of the socio-technical systems.
Gregor & Hevner (2013)	*Continuous improvement*: Designed to contribute to a new solution for a known problem	In the generic safety management systems (i.e. *Plan–Do-Check-Feedback* system), management takes corrective action and improve on the outcomes from the auditing events. This process takes a cyclical effect at all times for continuous improvement.
Wintter et al. (2010)	*Systemic driven*: Interaction of its parts based on technologic, people and organisational variables.	Safety management systems are systemic - accident is found as an emergent phenomenon in that it emerges from the interactions of many variables within a system. Safety management project identifies sources of injury, near-misses, fatalities, incidents from the whole parts of its constituted components.

3.4.2.1 Prescription of Knowledge

Prescription of knowledge is an essential feature of any DSR project outcome (Vaishnavi & Kuechler, 2007). The prescriptive knowledge contribution of DSR may be in the form of artefacts. These artefacts may include *constructs, models, methods, instantiations, frameworks, architectures* and *design principles* (March & Smith, 1995; Vaishnavi & Kuechler, 2007). Zanko and Dawson (2012) identified several prescriptive knowledges that are related to safety management including: scholars' textbooks (containing concepts, tools, techniques, technologies and insights) and domain of national standard prescription (purview of government prescriptions, codes of practice, advisory pamphlets) directed at students and practitioners in health and safety. Additionally, safety standards also provide prescriptive knowledge such as *Australia's AS/NZ 4801 OHSMS – Specification with Guidance for use*; *UK's BSI-OHSAS 18001 Occupational Health and Safety Management Systems – Specification;* and *DuPont's proprietary OHS programs and systems*. However, these prescriptive knowledge contributions are not either empirically grounded representations of what constitutes safety management, nor their conceptualizations are verified or validated through systematic study (Zanko & Dawson, 2012). DSR offers prescriptive knowledge contributions to the research community and industries which its research rigour and problem relevance are rooted in the traditional research processes, and the industry needs respectively (vom Brocke & Lippe, 2010; Johannesson & Perjons, 2014). The adoption of DSR as the research approach for the present study will contribute to bridging the gap between knowledge and practice through artefact development.

3.4.2.2 Tailored to Management Research

DSR projects have also been applied in management research to solve managerial and organisational issues (Van Aken, 2005). Several studies have used DSR as a research approach in construction management (e.g. Rocha, 2011; Tezel, 2011; Hanid, 2014) and project management (e.g. vom Brocke & Lippe, 2010). It is indicated that the DSR approach can help in developing and implementing innovative managerial tools in construction management (AlSehaimi et al., 2012). It can also be used in the construction of varied sociotechnical artefacts such as decision support systems, modelling tools, governance strategies and many more outcomes (Gregor & Hevner, 2013). These DSR projects link research and practice that further strengthens the relevance of the problem understudied (Kuechler & Vaishnavi, 2004; Johannesson & Perjons, 2014). This makes the DSR approach applicable to management research. From the DSR literature, it is clear that several studies have been carried out within the sphere of management disciplines. However, it appears that the DSR approach has not been considered in the study of safety management. Safety management is an aspect of the overall management functions that determine and implement safety policies (Harms-Ringdahl, 2004; Vinodkumar & Bhasi, 2011). The primary characterisation of safety management lies in its management systems. Management systems are the administrative controls put in place by the organisation to manage the *people*, the *technology* and the *processes* under consideration

(Bridges & Tew, 2010). This is similar to information systems research process, which is shown in Figure 3.1. In this example, the environment defines the problem space, which also contains the phenomena of interest (Hevner, 2004). In the information system research, the environment space is a confluence of *people*, *technology* and *organisation*. The goals, tasks, problems and opportunities are defined by the business needs which are perceived by the people. This perception is shaped by the roles, capabilities and characteristics of the people in the organisation. The needs of the business are appraised in the context of the existing organisational strategies, culture, structure and processes.

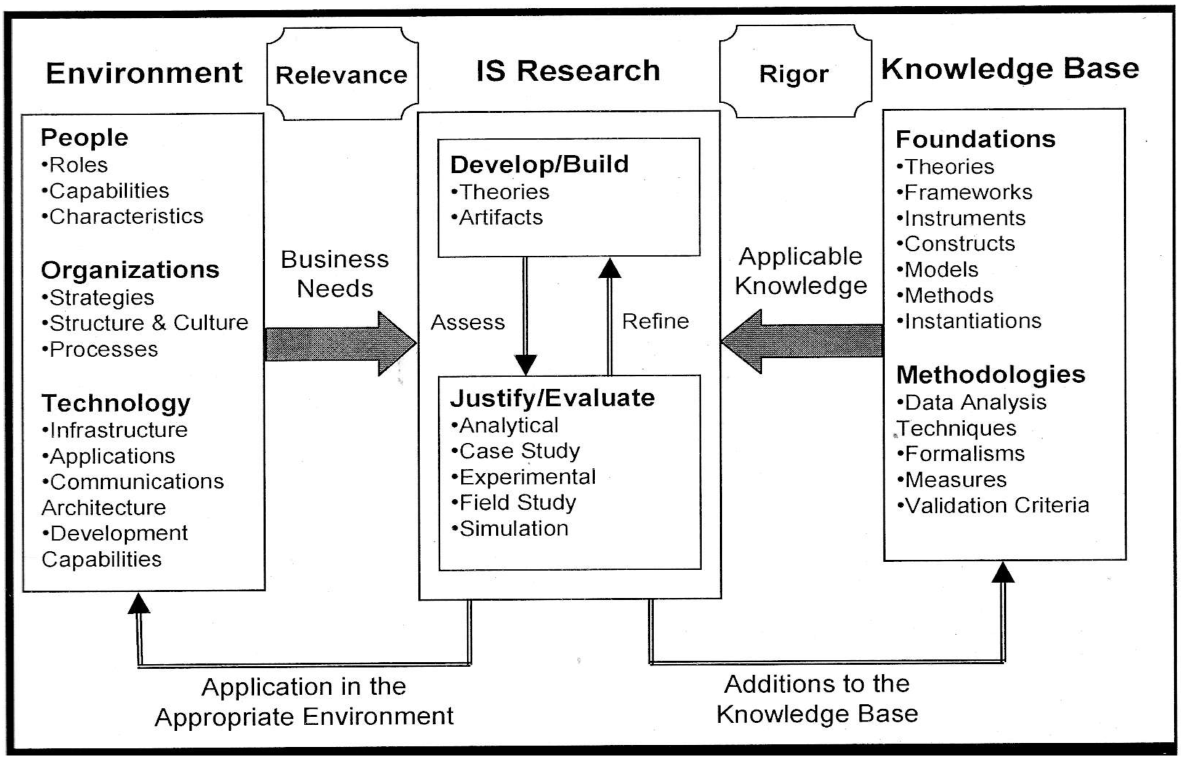


Fig. 3. 1 Information systems research framework

Source: Hevner (2004).

Similarly, the system of safety management in a sociotechnical environment like the oil and gas industry involves the interaction of *technology*, *human* and *organisation* (Jensen & Aven, 2018). The interactions between humans and technology create outcomes that emerge from their collaboration, and such a system consisting technical artefacts and human agents are usually embedded within the complex social structures such as organisational goals, policies and culture, political, environmental, economic and legal elements. This complexity may create performance variability in the systems. According to Holnagel (2005), when variables within the system become too high for the system to absorb them through the interaction of these variables of humans, technology, underlying conditions and barriers (organisation*)* the effect will be undetectable and unwanted outcomes. From the literature, both information systems research and safety management research involve the interaction of these variables such as technology, human and organisation. This, therefore, makes the DSR approach equally relevant to safety management research.

3.4.2.3 Multi-dimensionality

The literature (e.g. Shenhar & Dvir, 2007; vom Brocke & Lippe, 2010) identified DSR projects as multi-dimensional such that it classified projects based on novelty, technology, complexity and pace. These studies indicate that DSR is regularly paced and high-tech technology which deals with different topics to determine the long-term organisational needs of the company. It is suggested that the degree of complexity depends on the individual project scope. Similarly, safety management is a research field that involves a large number of different topics being studied. This makes the outcome of the study emerging from the contribution of various scientific disciplines and therefore making safety management a multi-dimensional field of study (Quinian et al., 2012). There exist several different stakeholders involved in industrial safety management in the oil and gas industry (Baram et al., 2014). For example, the industry may include the following stakeholders: the government, operators, contractors, service firms, the workforce, the community, and the media. The interaction of these stakeholders may contribute to the performance variability of the safety systems. The oil and gas industry is also a complex sociotechnical environment involving a complex interplay of technology, people and organisation. The exploration, development and production aspect of the oil and gas operation is complex that requires the effort of these stakeholders in managing safety in the industry. With these kinds of characteristics, it is necessary to develop a solution to address the complexity in the performance variability of the sociotechnical systems in place. This, therefore, makes the DSR approach equally relevant to safety management research.

3.4.2.4 Continuity of Improvement

According to Gregor and Hevner (2013), DSR is designed to contribute to knowledge in four kinds: *Invention* (inventing new knowledge/solution for new problems), *Adaptation* (known knowledge/solution for new problem), *Routine Design* (known knowledge/solution for known problem), and *Improvement* (new knowledge/solution for known problem). Figure 3.2 shows these knowledge contributions for DSR projects. It must be indicated that the 4th quadrant (i.e. *Improvement*) falls within the aim of the present study. DSR contributes to new knowledge or solution to address a known problem in practice. When people engage in practices, they may experience a practical problem. The practical problem is the gap between *the current state* and a *desirable state*, as perceived by the people involved in the practice (Johannesson and Perjons, 2014). In other words, the gap between the current state and the desired state of the practice is not always explicitly noted in the local (e.g. organisation or industry levels) for a generalisation to be made as a problem exists. According to Gregor and Hevner (2013), such a known problem will require new knowledge or solution to address it.

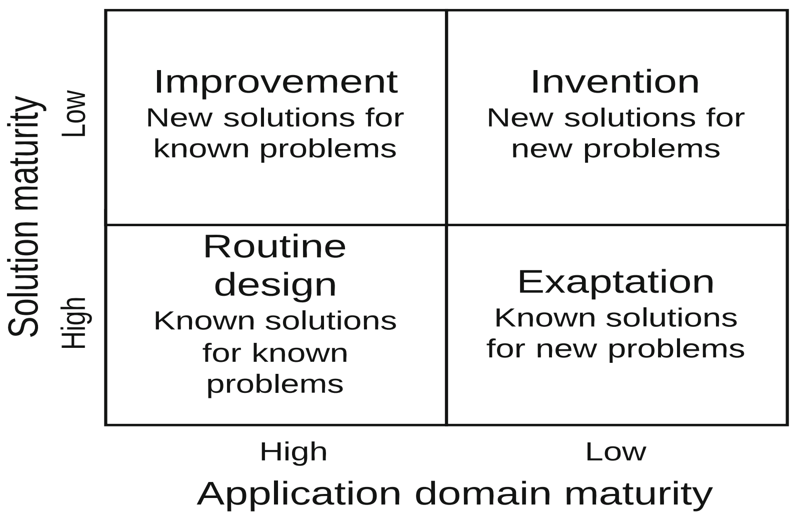


Fig. 3. 2 Design science research knowledge contribution framework

Source: Adapted from Gregor & Hevner (2013)

Safety management is required to be improved in the industry. Given the highly hazardous nature of the oil and gas industry, it is always needed the professional and research communities to provide new knowledge or solution to address existing problems. Continuous improvement of safety performance is a critical emphasis in the oil and gas industry, as reflected in the generic safety management systems model (Hudson, 2001) shown in figure 3.3. In all the activities carried out in each broad element (i.e. *Plan–Do-Check-Feedback* system) of the safety management systems, management takes corrective action and improve on the outcomes from the safety feedbacks. This process takes a cyclical effect at all times for continuous improvement.

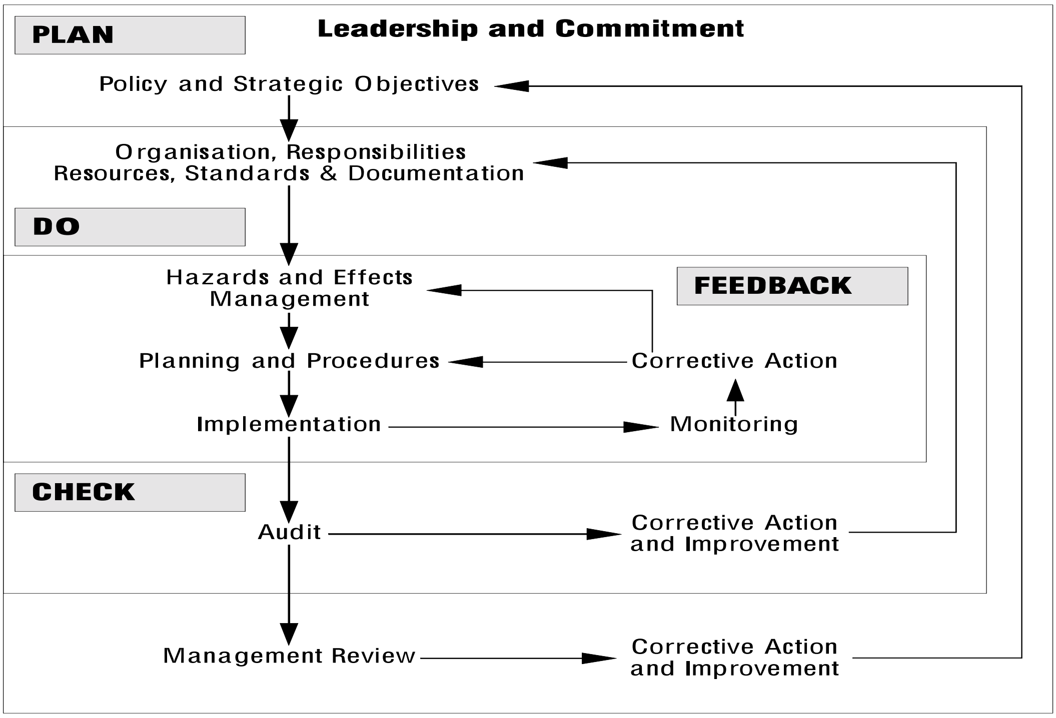


Fig. 3. 3 Generic safety management framework

Source: Hudson (2001)

3.4.2.5 System Driven

System theory is a principle in the sociotechnical system. It is an emergent phenomenon and designed to solve a practical problem for humans. It is a critical feature that drives DSR projects (Winter et al., 2010). It involves the interaction of parts based on technologic, people and organisational variables in sociotechnical systems. This system theory applies to safety management study. Safety management systems are systemic that emerge from the interactions of many variables within their sub-systems (Hollnagel, 2004; Skyttner, 2005). According to Johannesson and Perjons (2014), the design of sociotechnical systems may create a number of challenges because of their distinctive characteristics, in terms of their roles and perspectives of people in such systems, the vagueness of systems boundaries, the need for rules and coordination mechanisms, and the low degree of systems controllability. In Hollnagel (2004) accident causation model, such characteristics may contribute to the performance variabilities of the systems. Given this relationship between system theory and sociotechnical systems, they are relevant in safety management research of a complex sociotechnical environment like the oil and gas industry (Aven & Ylönen, 2018). Thus, the systemic approach is used to find solutions to existing complex sociotechnical systems issues found in both DSR projects in information system and safety management research.

3.4.3 Artefact Type - Conceptual Framework

DSR seeks to provide artefacts to solve a practical problem. These artefacts can be products or processes (Gregor & Jones, 2007). Product artefacts are mostly technical, whiles process artefacts are more of sociotechnical which focuse on the human interactions to produce its intended functions (Venable et al., 2012; cited in Elragal & Haddara, 2019). The literature makes it clear that these artefacts may vary from those formal logics, mathematical equations and models, software applications, to a more straightforward narrative and description of the phenomenon (Elragal & Haddara, 2019). There are several artefacts suggested by the literature that DSR produces. March and Smith (1995) initially categorised the outputs of DSR into four artefacts: constructs, models, methods, and instantiations. However, other researchers have extended the DSR artefacts to cover architecture, frameworks, design principles and theories (Kuechler & Vaishnavi, 2004; Chatterjee, 2015). Such outputs of DSR are produced either in the form of design practice or meta-design (Goldkuhl, 2004; Ostrowski et al., 2012). The *meta-design* provides abstract design knowledge, while *design practice* produces situational design knowledge and other situational results.

The research output that seeks to be achieved at the end of the current study is to produce a framework for robust safety management in the upstream oil and gas industry. It provides a process in the form of an abstract framework that is linked to the sociotechnical environment like the upstream oil and gas industry. There are two types of frameworks: theoretical and conceptual frameworks. These two types of frameworks appear to be used synonymously. However, there are differences between them, and these distinctions are well documented in Imenda (2014). The definitions of these two terms were traced to their original words: theory and concept. Fox and Bayat (2007, p.29) defined theory as "*a set of interrelated propositions, concepts and definitions that present a systematic point of view of specifying relationships between variables with a view to predicting and explaining phenomena*". The theory identifies the relationships between variables to provide explanation and prediction of the phenomenon. Contrarily, Chinn and Kramer (1999, p.252) defined concepts as "*the components of a theory* *which "convey the abstract ideas within a theory"*. Imenda (2014) related framework to a structure that guides researchers to check whether their research objectives and questions are linked to the findings of the data analysis. This forms the context for the Imenda's distinction between theoretical framework and conceptual framework. The theoretical framework relates to the theory that researchers select to guide their research. It relates to the application of one or more theories or a set of concepts drawn to explain the problem. Contrarily; conceptual framework offers an integrative way of bringing together several related concepts from the study. This requires synthesising the existing theoretical and empirical findings of the study. From this background, this study seeks to develop a conceptual framework that could be used to a practical tool to guide the management of safety in Ghana's upstream oil and gas industry.

3.4.4 Challenges Associated with Design Science Research

Although DSR has been more popular in the information systems literature over the last three decades, it is just recently that several researchers have found its relevance in other disciplines. However, researchers have identified some challenges associated with its application. Cloutier and Renard (2018) indicated that DRS engages their readers into complex data governance. The steps in DSR required several data acquisition. The literature pointed out that big data governance has a consequence to individuals, organisations and society. Therefore, this epoch of big data governance had not been adequately understood. This poses challenges to the researcher in terms of collecting different data sets to carry out the various steps in the DSR.

Elragal and Haddara (2019) stated that the evaluation stage of the DSR poses a challenge to researchers as various evaluation mechanisms provide appropriate interpretations of the problem and the feedback to advance the quality of the artefact produced. It is challenging to identify appropriate guidelines in terms of how to choose, design and execute a suitable evaluation strategy. However, given all these challenges, this study adopts a more flexible data collection techniques that would help to fulfil the aim of this study.

3.5 Design Science Research Processes

In this section, the DSR processes established in the literature (e.g. Vaishnavi & Kuechler, 2007; Offermann et al., 2009; Ostrowski et al., 2012; Johannesson & Perjons, 2014) followed to achieve the research aim of the current study are discussed. In the literature, there are different names used for the various activities of the DSR projects. However, the DSR processes adapted by Vaishnavi and Kuechler (2007) appeared to be the general DSR processes model adopted in the literature (figure 3.4).

In these studies, most of the DSR activities are renamed but seek to achieve the same DSR goal. It must be indicated that what matters most in any DSR project is the critical requirement for *research rigour* and *problem relevance* (Hevner et al., 2004; Ostrowski et al., 2012). The current study adopts the following activities of the DSR process as established in the DSR literature: establishing awareness of the problem, *defining requirements of the artefact, Developing the artefact* and *evaluating the artefact*. As shown in figure 3.5, in an effort to fulfil the research rigour and the problem relevance of this DSR project, each activity of the DSR adopted for this study has its own data collection and data analysis techniques that help to achieve the research objectives of the current study.

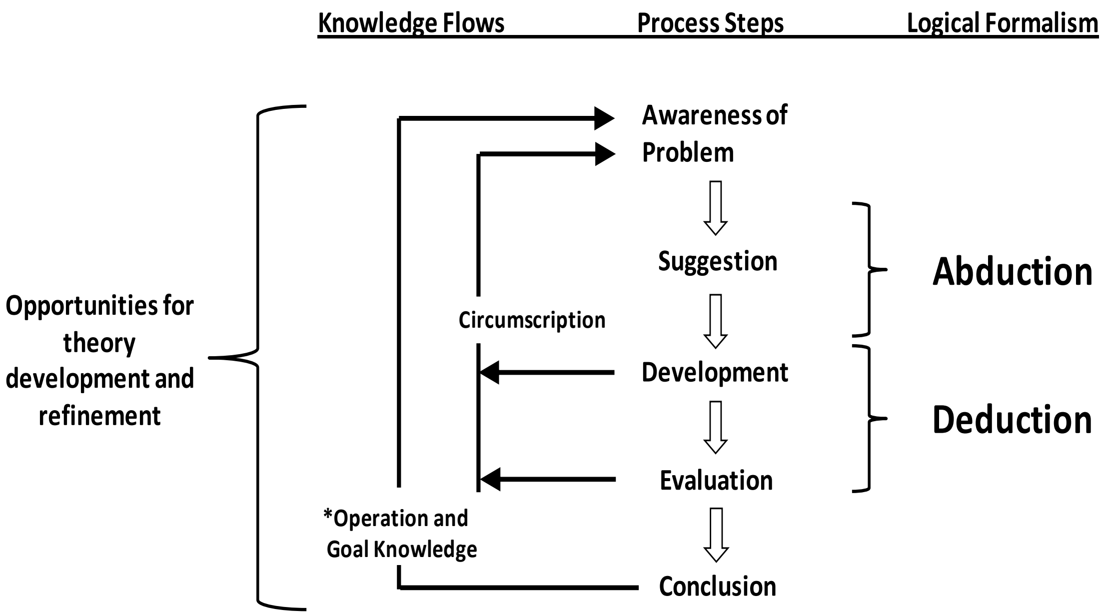


Fig. 3. 4 General design science research methodology model

Source: Vaishnavi and Kuechler (2007)

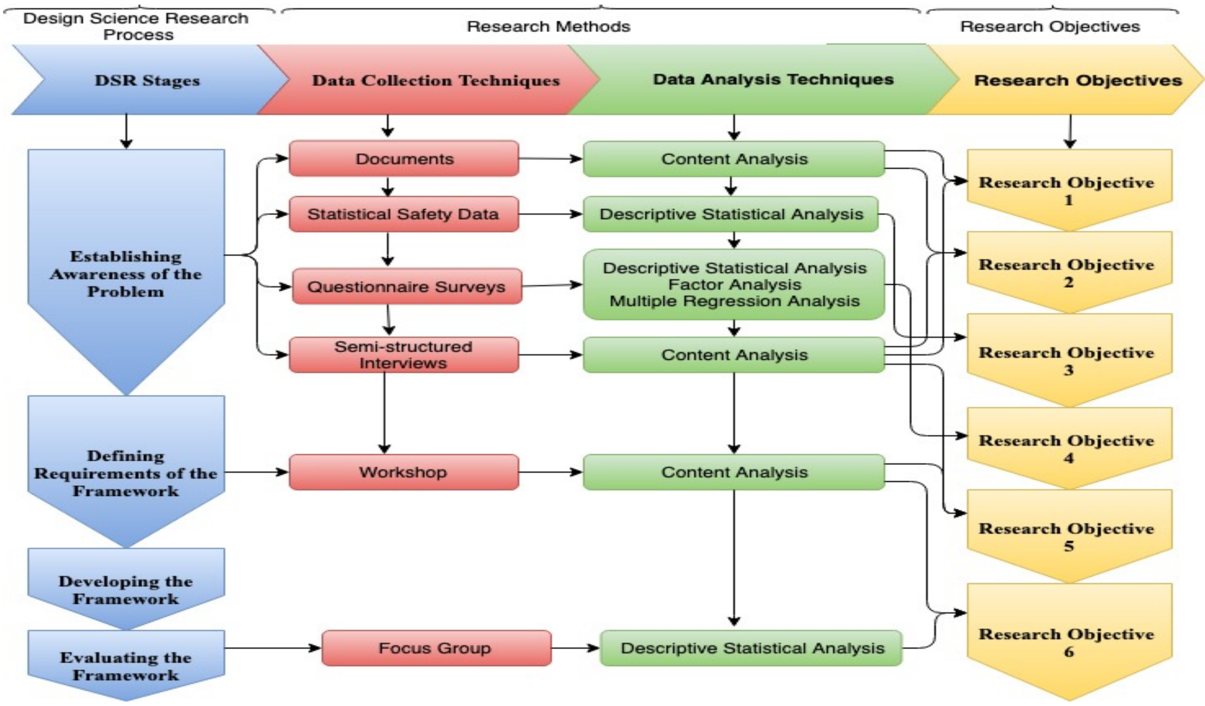


Fig. 3. 5 Adopted DSR process, research methods and research objectives

3.5.1 Establishing Awareness of the Problem

The explication of the problem is the first activity of the DSR research process which seeks to investigate and analyse a practical problem. As indicated by Johannesson and Perjons (2014), this activity aims at formulating the initial problem precisely, justify its importance and investigate its underlying causes. When the initial problem is obscurely expressed or incompletely understood, it requires an investigation into it so that a suitable solution can be found. DSR is sometimes called *Improvement Research* because it emphasises the problem-solving or performance-improving nature of the practice (Vaishnavi and Kuechler, 2007). In its application to this study, the following techniques are used to collect data to establish awareness of the issues confronting safety management in Ghana's upstream oil and gas industry:

- Documents
- Statistical safety data
- Questionnaire surveys
- Semi-structured interviews

In this activity, oil and gas professionals from operating and contracting organisation as well as professionals from the government (Ministry of Energy) and the regulatory agencies are recruited to elicit information on issues confronting safety management in Ghana upstream oil and gas industry. The results of this activity will be based on and compared with existing related work to ensure well-founded and original results.

3.5.2 Defining Requirements of the Framework

Defining requirements of the artefact is the second activity of the DSR process that suggests the ways to address the problem defined by the first activity of the DSR processes. In other words, it identifies and outlines the requirements that can solve the practical problem in practice. This stage aims at identifying and outlining an artefact that can address the problem and to gather requirement on the solution (Johannesson & Perjons, 2014). The suggestions for a problem solution are abductively drawn from existing knowledge or theory base for the problem area (Peirce, 1931; cited in Vaishnavi & Kuechler, 2007). The requirements are properties of an artefact that are considered as desirable by the stakeholders in a practice, and that are to be used for guiding the development of the artefact (Johannesson & Perjons, 2014). The tentative design (solution) is used to implement an artefact in the next activity of the DSR processes.

In this study, the application of this activity is carried out through a workshop where the same participants recruited for the establishment of the awareness of the problem confronting safety management in Ghana's upstream oil and gas industry are used to define the requirements of the artefact to address the problem. The results of this activity are based on and related to existing safety management practices in the oil and gas industry. The requirements are formulated in a precise, concise, and easily understandable way. Justification is made to each requirement as well as specifying the sources of the requirements and describe how the requirements have been defined.

3.5.3 Developing the Artefact

Development of an artefact constitutes the third activity of DSR processes. This artefact development is based on the activity of the earlier activities (i.e. *the establishment of awareness of the problem* and *definition of the requirements*) of the DSR processes. In this activity of the DSR processes, no research method is needed to develop the artefact. Not to rule out the relevance of research methods in the development of an artefact in the DSR process, the purpose of this activity is to produce prescriptive knowledge by creating an artefact. Because of this, research methods are less influential in this activity of DSR processes (Johannesson &

Perjons, 2014). This activity is applied by developing a framework that addresses the established safety management issues and fulfils the requirements of those issues that were defined by the stakeholders in the previous activity. In this case, it will include both the functionality and structure of the framework for robust safety management. This activity involved the utilisation of the following resources:

- Knowledge from the research literature.
- Views from relevant stakeholders.

3.5.4 Evaluating the Artefact

The evaluation of the artefact represents the fourth activity of the DSR processes. This activity seeks to determine how well the developed artefact can solve the established safety management problem and the extent it fulfils the requirements defined by the stakeholders. Because of the practical difficulty in getting most of the relevant stakeholders together for another workshop to evaluate the model, focus group as a research method will be selected to evaluate the relevance of the artefact to the upstream oil and gas industry. In the DSR literature, there is no consensus regarding criteria to evaluate an artefact. Prat et al. (2014) developed evaluation criteria from their review of several dimensions of the artefact. This study adopts the following criteria to evaluate the artefact: goal generality, understandability to people, applicability to an organisation, harnessability of technology, comprehensiveness in structure, clarity in structure, consistency with activity, and Robustness and learning capability. In terms of the type of evaluation strategy, this study adopts *Ex ante evaluation*. The ex-ante evaluation requires the artefact to be evaluated without being utilised or even being fully developed (Johannesson & Perjons, 2014). This study will choose a naturalistic evaluation to validate the produced artefact. In other words, because the artefact will be the process type, it will not require an artificial setting to evaluate it. The researcher will evaluate the proposed artefact in a real-world setting where the industry participants will assess the relevance of the artefact in the process of addressing the complexity, uncertainty and ambiguity of risk-related issues that are associated with safety management in the upstream oil and gas industry.

3.6 Research Methods

Although research methods have been used in many different studies, a review study by Chu and Ke (2017) has revealed that no consensus exists among researchers what constitute research methods and how it is categorised. Many different researchers have different understanding and interpretation of what constitute research methods. Research methods are defined as methods for collecting and analysing data (Johannesson & Perjons, 2014; Chu & Ke, 2017). Thus, it strictly includes two things: *data collection techniques* and *data analysis techniques*.

In considering what Wallace (1971) referred to as the instrumentation in social research, Baker (1999, p. 203) recapped the two defined types of instrumentation that are important for scientific investigation: those that are exclusively based on "*human sensory organs"* (i.e. "seeing" things); and those that are based on "*technological augmented sensory organs*. The former instrumentation is the type that requires scientific investigation to be made based on participant observation, whereby the researcher's basic instruments are confined to his or her eyes and ears. The latter instrumentation is the type that requires surveys whereby the researcher employs a questionnaire or an interview technique to support the primary sensory data collectors. In terms of the difference between the two defined types of instrumentation, Riley (1963) and Baker (1999) have clarified that data emanating from observation reflect an objective perspective of the system. Thus, the data represent the network of actions and reactions among the constituents of the group. Data from surveys (e.g. questionnaire, interview) represent the subjective network of orientation and interpersonal relationships among the members of the group. In other words, the data collected reflect the underlying ideas, feelings, and depositions of the members in acting to others as well as to define and assess these others in varied ways. In the current study, the latter instrumentation forms the primary method for data collection, which incorporates quantitative and qualitative methods of collecting data.

Amaratunga et al. (2002) discussed these methods as the research traditions have received controversies regarding their relative virtues in a methodological application. Quantitative methods emerged from the perspective that places more considerable trust in making numbers represent concepts or opinions. In contrast, qualitative methods emerged from the perspective that focused on words and observations to express reality because of describing people in natural situations. As shown in Table 3.3, each method has its advantages and disadvantages.

In the current study, mixed methods of data collection are adopted since different data collection techniques are required to define the problem confronting safety management in Ghana's upstream oil and gas industry. This will help to strengthen the research rigour of the current study.

Table 3. 3 Research method types and their strengths and weaknesses

Methods	Strengths	Weaknesses
Quantitative	Ability to collect a large sample. Ability to test the hypothesis. Ability to generalise findings	Inflexible and artificial in nature. Inability to capture the human phenomenon.
Qualitative	Ability to understand people's meaning. Data is collected openly. Ability to develop theory. Ability to generate data in natural setting	Time coming. Interpretation of data becomes cumbersome. Associated with limited sample
Mixed	Strengthens research rigour. Offers a complete knowledge relevant to inform theory and practice. Offers deeper insights and understanding of the findings.	More expensive to conduct. Difficult to analyse and provide inferences to interpret findings. Generate a large volume of information/data. Time-consuming

Source: Adapted from Amaratunga et al. (2002) and Akotia (2014)

3.6.1 Data Collection Methods

To achieve the aim of this study, there are five different data collection methods adopted. They include the following methods: documents, questionnaires, semi-structured interviews, workshop and focus groups. Table 3.4 presents the objective for adopting these methods, the sample frame, sampling procedures and sampling criteria.

Table 3. 4 Summary of types of data collection method adopted for this study

Methods	***Reasons for Adoption***	***Sample Frame***	***Sampling Procedures***
Documents	Contains existing safety statutes and regulations as well as official safety statistics which will help to achieve research objective 1 & 3.	Existing safety statutes and regulations as well as official safety statistics Relevant to the upstream oil and gas industry	-
Questionnaires Survey	Elicit views from a larger group of workers from various organisations in Ghana'supstream oil and gas industry.	Employees working in Ghana's upstream oil and gas industry	Random sampling
Semi-structured Interviews	Obtain in-depth information on the issues confronting safety management in the industry	Organisations' top/line managers, HSE managers/supervisors, supervisors, regulators in the upstream oil and gas industry.	Purposive sampling
Workshop		Organisations' top/line managers, HSE managers/supervisors, supervisors, regulators in the upstream oil and gas industry.	Purposive sampling
Focus Groups		Organisations' top/line managers, HSE managers/supervisors, supervisors, regulators in the upstream oil and gas industry.	Purposive sampling

3.6.1.1 Documents

Documents form an essential source of data in research. It usually contains textual data but may also encompass some information such as audio or video files, images, or photographs.

Johannesson and Perjons (2014) identified several types of documents used for scientific research that include: government publications (e.g. official statistics, laws, regulations, etc), organisational records (e.g. annual reports, sales figures, personnel records, etc), academic publication (e.g. journals, conferences, workshops, doctoral thesis, etc), newspapers and magazines, personal communication and social media streams. Documents as sources of data can help to obtain a great deal of information within a short period and cheaper in terms of cost implications. However, one key issue relating to the use of documents for scientific research is the judgement of its credibility and biases factors. It is well acknowledged that documents such as academic publications and government publications are more credible mainly because they are produced by the state that usually uses experts for scientific investigation (Johannesson & Perjons, 2014). In this study, safety statutory and regulatory documents relevant to Ghana's upstream oil and gas industry are collected. This will help the researcher to assess the robustness of existing safety regulatory regime for Ghana's upstream oil and gas industry.

3.6.1.2 Safety Statistical Data

Safety statistical data represent the quantitative safety data that were reported to the regulator. The collection of these data will be based on the IOGP reporting classification, as examined in chapter two (section 2.5.1.1). Data collections on these classifications will help to determine the safety performance indicators for Ghana's upstream oil and gas industry (table 3.5). All operating organisations, contracting organisations, and any other organisations with the license to undertake upstream oil and gas activities are required by the regulations to report all their safety performance indicators to the regulatory agency. These documents will help the researcher to examine the safety performance indicators for the upstream oil and gas industry in Ghana.

Table 3. 5 IOGP safety reporting classification

Quantitative Data	Classifications
Safety statistical Data	• Fatalities: • Injuries: • Incidents • Near-misses • Medical treatment cases • Reported diseases

	• Restricted work cases • First aid cases

3.6.1.3 Questionnaire Surveys

Questionnaires are written documents that contain several questions to be distributed to a defined number of respondents for responses (Johannesson & Perjons, 2014). They are generally considered to be one of the most used data collection techniques in social science research. It is seen as a type of survey usually used to collect data that requires each person to respond to the same set of questions in a predetermined manner (De Vaus, 2014; cited in Saunders et al., 2016). There are two different types of questionnaires exist for researchers to consider: *Self-completed* and *Interviewer completed questionnaires.* The differences occur due to how they are delivered, returned or collected and the number of contacts you have with respondents (i.e. the accessibility to respondents). These two types of questionnaires are described as follows:

- **Self-completed questionnaire:** This type of questionnaires requires respondents to complete a set of questions, and the distribution of the questionnaires could be done through the internet, postal or mail, and delivery and collection. The postal or mail questionnaires require the researcher to post the questionnaires to each respondent who is also required to return the completed questionnaires. The delivery & collection questionnaires require the researcher to deliver the questionnaires by hand to each respondent and collect them later.
- **Interviewer-completed questionnaire:** This particular type of questionnaire requires the interviewer to record the answers from each respondent. These questionnaires can be undertaken through either telephone or face to face where the interviewer physically meets the respondent and asks the questions face-to-face. This interview is different from the usual semi-structured and unstructured interviews as there exists a defined set of questions that the interviewer must not deviate at all.

In this study, a self-completed questionnaire type was used through delivery and collection means to assess workers' perceptions of the predictive influence of safety climate factors on hazard risks in Ghana's upstream oil and gas industry. Questionnaires can help to elicit views from a larger group of workers on the current safety climate in Ghana's upstream oil and gas industry. There are different stakeholders in the oil and gas industry, which in many cases contribute to varying views of the problem at hand and thereby making these differences explicit. The basis for using the questionnaires was to provide an overview of workers' perceptions of human and organisational factors influencing safety management in Ghana's upstream oil and gas industry. Questionnaires are more appropriately used for descriptive and explanatory research (Saunders et al., 2016). In terms of its appropriateness in descriptive research, it is usually used to obtain information on attitude and opinion, and organisational practices. The descriptive study is more helpful in identifying and describing the variability in a different phenomenon. It is also appropriate in explanatory research that helps to examine and explain the cause-effect relationship of the variables. The weaknesses of using questionnaires may include difficulty to design, time-consuming and do not provide in-depth information about the phenomenon understudied (Johannesson & Perjons, 2014). However, a closed questionnaire kind is adopted to offer more elaborative and creative responses. Because of its lack of in-depth investigation of the phenomenon, there are other different data collection techniques (i.e. semi-structured interviews) that have been adopted by the current study to provide an in-depth investigation of the phenomenon understudied.

3.6.1.3.1 Questionnaire Survey Design and Measures

After a decision was made to conduct questionnaire surveys, the researcher designed the questions into three sections: demographic information, workers'safety climate perceptions and workers' hazard risks perceptions. The demographic information section sought to elicit general information about the background of the respondents which covered gender, age, nationality, education qualification, organization classification, location of activities, job categories, relevant job experience before the current job and current job experience. The workers'safety climate perceptions section sought to collect information about the safety climate of Ghana's upstream oil and gas industry. The workers' hazard risk perception sought to elicit information on hazard risk in the industry. The invitation letter to these surveys are attached in appendix B1.

The questionnaire surveys were measured by a 5-point Likert scale as captured in the instrument (see appendix C). Likert scale instrument is used to measure the attitudes of people in certain conditions (Joshil, 2015). It is more useful in understanding opinions or perceptions related to the single phenomenon of interest. The strengths of these instruments included that they are suitable for a larger sample size, based on empirical data pertaining to subjects' responses as against judges' subjective opinions and also produces a high reliability and validity due to its ability to create homogeneous scales and increases the probability of a uni-dimensionality of measures (Burns, 2000). However, their weaknesses lie in the fact that the total score of the individual construct may have little meanings because there are several patterns of items that measure the same score. Additionally, such an instrument may produce a 'fake score'. This is because such measures are always associated with acquiescence and social desirability. The acquiescence emerges when respondents are inclined to agree to statements irrespective of their content. The social desirability arises when respondents agree or disagree to statements which the social consensus would direct. Burns (2000) suggested that acquiescence can be avoided by performing an order of positive and negative items randomly.

Table 3.6 presents the the 5-point Likert items scales for the safety climate and hazard risk measures. Respondents are asked to indicate their agreement scores of a 5-point Likert items scale from *strongly disagree* to *strongly agree* with 67 items that covered the following constructs; safety policies safety priority, safety training, safety rules and procedures, management commitment, equipment maintenance, safety communication, supportive environment, safety involvement safety empowerment, management of change, safety supervision, safety motivation and safety behaviour. These constructs were identified as latent variables from the literature review (section 2.6.3.2). It requires respondents to indicate their agreement scores of a 5-point Likert items scale from *Very unsafe to Very safe* with 22 items that covered the following hazards: slips or trips, falls from height or dropped object, cut or puncture or scrape, medical malaria or gastric or food poisoning, overexertion or strains, struck by or impact, confined space, asset damage, caught in or under or between, exposure noise or chemical or biological or vibrations, electrical exposure, diving accident, fire or explosion or burn, equipment failure, hydrocarbon releases, spills, weather and wind conditions, transport accidents (e.g. car, helicopter crashing), vessel interruptions, sabotage act and other hazards. These hazards were identified from the literature review (section 2.6.4.2).

Table 3. 6 A 5-point Likert items scales

Safety Climate Scale	*Strongly disagree*	*Disagree*	*Undecided*	*Agree*	*Strongly agree*
Hazard Risk Scale	*Very unsafe*	*Unsafe*	*Undecided*	*Safe*	*Very safe*

Score	1	2	3	4	5

However, a random sampling technique was used to collect the questionnaires data. It must be indicated that the questionnaires were distributed to 300 respondents from six organisations in the oil and gas industry which received 70.7% (N = 212) response rate. These respondents were workers with their backgrounds in the following job categories: engineering professionals, operation management, contractors, maintenance/craft technicians, maintenance management and other related job categories in the upstream oil and gas industry. The respondents were recruited from six companies in Ghana's upstream oil and gas industry which included operating and contracting organisations. Copies of the questionnaires (including the consent forms, information sheets) were made available to the workers at the reception desk of each organisation. Both the completed and non-completed self-completed questionnaires were returned to the various reception desks and the researcher went to collect them.

3.6.1.4 Interviews

The literature (Hamid, 2014; Saunders et al. 2016) identifies two main types of interviews:

1. **Standardised Interviews:** it involves a researcher developing an interview schedule in questionnaire form which lists the wording and sequencing of the question sets.
2. **Non-standardised Interviews:** This type of interviews involves two different forms that include one-to-one and one-to-many.
   - *One-to-one* – It may include *face to face interviews*, *telephone interviews* and *electronic interviews*.
   - *One-to-many* – It may include *group interviews*, *workshop*, *focus groups* and *electronic group interviews*.

In this study, non-standardised interview type is used for the qualitative research which adopts both forms: face-to-face interviews (i.e. semi-structured interviews) and workshop and focus groups.

3.6.1.4.1 Semi-structured Interviews

Generally, qualitative research that involves interviews is categorised into three main parts that include the following:

- *Structured Interviews*
- *Semi-structured Interviews*
- *In-depth Interviews*

- **Structured Interviews:** This category of interview employs questionnaire base that involves a pre-determination and standardisation of questions (Saunders et al., 2016). This is referred to as interviewer-administered questionnaires, where the interviewer reads the questions to the interviewee and then records the answers in a standardised schedule (Hamid, 2014). This category of the interview is less time consuming and more applicable to 'quantitative research interviews'. It is quantitative research interviews because they are usually used to elicit data to collect quantifiable data for analysis. However, its application does not provide in-depth information about the top.

- **Semi-structured Interviews:** This category of interview requires a list of themes and questions prepared by the researcher before the interview. The order of questions may vary depending on how the conversation flows. The conversations are recorded either by video-recording, audio-recording or note-taking. The literature refers to this category of an interview as a participant interview because the conservation is such that the interviewer directs the interviewee to respond to the questions. It provides some degree of in-depth information on the top and easy for the researcher to identify the answers to the themes. However, it is time-consuming, and sometimes the materials used for the recording may breakdown thereby obstructing the recording of the conversations.

- **In-depth Interviews:** This category of the interview is employed to explore for in-depth information of a general area of interest (Hamid, 2014). In this interview, there is no pre-determination of a list of questions to make interviewee respond to them. The literature refers to this category of the interview as the informal process and is 'non-directive' as the interviewer allows the interviewee to respond generally to the questions. It provides highly in-depth information on the top. However, it is time-consuming concerning the conversations and the transcription of the interviews.

In this study, semi-structured interviews are adopted to help establish the awareness of the problem confronting safety management in Ghana's upstream oil and gas industry. Appendix H provides key informant guide to these semi-structured interviews. The list of questions used to design the semi-structured interviews are derived based on the findings of the literature review chapter. The semi-structured interview is designed from the main themes that emerged from literature review findings. The themes were derived from the main elements characterizing robustness regulation and barriers to the implementation of safety management systems.

Purposive sampling technique was employed for the semi-structured interview data, which helped to recruit 14 professionals working in the industry in different managerial and supervisory roles. The participants worked in different organisation types that include regulatory institutions, government agencies, operating companies, contracting companies and the Labour union. After this process, the participants contacts details were taken and were informed of the subsequent study.

2.6.1.5 Workshop

Workshop is defined as an arrangement whereby a group of people learn, acquire new knowledge, perform creative problem-solving, or innovate concerning a domain-specific issue (Ørngreen & Levinsen, 2017). The literature found the design of workshop to fulfil to three main perspectives: as a means, as practice and a research methodology. Workshop as a means aims at domain-specific issues and characterize a large body of literature in which the workshop is understood as a means to achieve a goal. Workshop as a practice focuses on investigating the link between the workshop and its form and outcomes. Workshops as research methodology emphases on the studying of domain-related cases employing the workshop format as a research methodology. Workshop produces an avenue for engagement and collaboration and sharing experience in the subject area (Ørngreen & Levinsen, 2017; Ahmed & Asraf (2018). However, there are some challenges with organizing workshops such as cost, time-consuming, and the difficulty of getting the participants to confirm their availability to a pre-date.

In this study, a workshop is used to fulfil participants' expectations on the outcomes that sought to improve safety management in Ghana's upstream oil and gas industry that linked to their interests. While at the same time, use as a promising tool for collecting data that produce reliable and valid data for the study. The appendix I provided the workshop guide. The workshop was conducted under the theme: "*Robustness thinking in safety management: How do we improve the issues in Ghana's upstream oil and gas industry*". This theme was necessitated by the findings of the literature review and the earlier empirical results of the documents, safety statistical data and the semi-structured interviews. The essence of the workshop was to elicit suggestions from the participants on how to address the issues found in the first stage of the DSR. Purposive sampling technique was used for the recruitment of the participants for this study. The participants used for the semi-structured interviews are also used for the workshop. However, 12 participants took part of the workshop.

2.6.1.6 Focus Group

A Focus group is a form of an interview in which a group of participants participate and discuss a specific topic of interest (Johannesson & Perjons, 2014). It involves a small group of people from similar backgrounds or experience that have volunteered to discuss a specific of interest. There are several advantages of conducting a focus group including the ability to offer a large amount of data, provides access to information that might be otherwise unobservable and offer an opportunity to make comparisons that participants make between their experiences. However, it is costly to conduct and time-consuming to conduct it. In this study, a focus group is conducted to validate the framework produced by the research findings. Purposive sampling technique was used for the recruitment of the participants. Participants used for the elicitation of the requirements of the framework in the second stage of the DSR are recruited for this process. It must be indicated that 9 participants were involved in the focus group validation.

3.6.2 Data Analysis Techniques

Data analysis provides derivation of valuable information from data for scientific investigation (Johannesson & Perjons, 2014). Because data do not speak for themselves, these large volumes of data are required to be transformed (i.e. prepared, interpreted, analyse and presented) into manageable and meaningful information for description, explanation, prediction and prescription of phenomena under investigation. There are two main types of data analysis: *quantitative* and *qualitative analysis*. In this study, data collected are analysed in both quantitative and qualitative ways.

3.6.2.1 Quantitative Data Analysis

This section describes the quantitative analysis adopted for this study. In this study, quantitative data obtained from upstream safety outcomes and questionnaires will be subjected to descriptive statistical analysis, factor analysis and multiple regression analysis.

3.6.2.1.1 Descriptive Statistical Analysis

Descriptive statistics are numbers used to summarise a sample of data to describe what entails in the sample (Bagley, 2009). It involves summarising and organising a sample data quantitatively that can be easily be understood. It works perfectly in describing a sample data but not to make inferences from a sample to the entire population. It helps the researcher to compare one sample from one study to another and also identify sample characteristics that have the possibility of influencing the conclusion. Descriptive statistics are basically presented in several forms such as *tables* for displaying detailed data, *charts* for viewing data visually (e.g. *bar chart* for showing frequencies; and *pie chart* for showing proportions), *line graphs* for showing trends in data, and *aggregate measures* such as mean, median, mode, range, and standard deviation (Johannesson & Perjons, 2014). In the current study, quantitative safety data obtained from the regulatory agency will be analysed in a combination of tables, bar charts and pie charts. This would help to describe and provide a quick understanding of the data on the safety performance indicators for Ghana's upstream oil and gas industry. Descriptive statistics were performed on the demographic background of the safety climate data. The focus group data were analysed in descriptive statistics where pie charts were used to indicate the percentages of feedback on criteria defined for the evaluation of the framework.

3.6.2.1.2 Exploratory Factor Analysis

Factor analysis is an old structural model developed by Spearman in 1904. It explains the correlations among several different variables to indicate the latent sources of variance that explain for the relationships among several variables. Factor analysis works under the idea observable variables can be reduced to fewer latent variables that share a common variance and are unobservable. It is useful when large datasets made up of several variables can be reduced by observing groups of factors (Yong & Pearce, 2013). It is suitable for research that involves several variables, items from questionnaires that can be reduced to a smaller set. Factor analysis can be employed in two ways: confirmatory factor analysis (confirming or negating the hypothesized structure) and exploratory factor analysis (discovering a latent structure). In this study, given a large number of variables understudied, factor analysis is performed to explore the latent constructs. There were 14 potential factors identified in the literature review (section 2.6.3.2). Therefore, these factors are reduced to identify the latent variables.

3.6.2.1.3 Multiple Regression Analysis

Regression is a statistical method used to determine the linear relationship between two or more variables. It is basically used for prediction and causal inference. Multiple regression analysis was chosen as an appropriate data analysis technique to assess the predictive influence of the safety climate factors on the perception of hazard risks. Regression analysis helps to examine the relationship between two or more variables of interest and infer the causal link between the independent variables and dependent variables (Hinton et al. 2014). This technique would help to achieve the research objective 4.

3.6.2.2 Qualitative Data Analysis

Qualitative data analysis is more applicable to qualitative data that may include text, photo, videos, images, and sounds. There are three different ways to analyse qualitative analysis that include: content analysis, discourse analysis and grounded theory (Johannesson & Perjons, 2014). Content analysis works by classifying themes from the texts into categories where the frequencies are calculated. Discourse analysis focuses on the implicit and concealed meanings of the texts, which consider a broader context covering the interviewee's or the writer's intentions, and primary assumptions. In this case, the writer has to make use of concepts and theories to make meanings of the texts. Apart from being used as a research strategy, grounded theory can be employed in analysing qualitative data. The coding emerges from the researcher's text and not pre-existing theory. In this study, the semi-structured interview data are analysed in the content analysis approach.

3.6.2.2.1 Content Analysis

The content analysis approach is applied in the quantification of words, themes and categories within texts (Kulatunga, 2008). The essence of content analysis is to organise the themes of the texts into categories where the frequencies are calculated in each category. With the application of content analysis, inferences, objectivity and systematic are key features that make up the analysis. The literature identified the ways to carry out the content analysis, which include the following:

- choosing a sample of a text
- breaking down the texts into units
- developing categories for analysis
- coding the units in line with the categories
- calculating the frequency of the units for the individual category
- analysing the texts about the frequencies

Some strengths are associated with the application of content analysis. Its use is simple and clear, which contributes to high reliability where research will arrive at the same results. It is more suitable for studying non-complex texts. The underlying assumption underpinning the counting of the words indicates that the most mentioned words usually expresses the essential concerns of the interviewees. However, there are some weaknesses with the application of the content analysis as it is oblivious to context because mainly the individual units form the analysis (Johannesson & Perjons, 2014). This means that the link between the units and the intentions of the interviewees are not explicitly considered. This study, there two coding types that were applied to analyse the semi-structured interviews: deductive and inductive coding. Inductive coding is more suitable for exploratory research stage that makes it possible for categories and codes to originate from the texts (Kulatunga, 2008). There is some coding that falls in between the induction and deduction approach in coding. As some categories can be earlier organised from the literature review, which increases it by adding more as one goes along with the text. This approach was also applied in this study. According to Kulatunga (2008), deductive coding starts with the prior organisation of the categories with the coding reflecting the theory and linking them to the texts. It must be indicated that it is more appropriate for confirming the stage of the study. However, it is noted that such an approach has the propensity to abandon the concepts and categories that could not emerge from the prior-organised categories.

3.6.3 Softwares for the Data Analysis

There are several available software packages for data analysis that may include the following: NVivo, MATLAB, SAS, IBM SPSS, QSR N6, Decision explorer, and host of others. However, researchers (e.g. Lewins & Silver, 2006; Saunders et al, 2007) have indicated that the choice of appropriate softwares will depend on several factors including the amount of data available for analysis, the research methodology used, the amount of time available for the study; the kind of the computer's operating systems and memory, and the availability of support required to learn the softwares. In this study, the researcher seeks to use SPSS, and Nvivo to help in handling the data process. The SPSS software provides an easy way of analysing quantitative data and reduces errors. The Nvivo software helps to organise extensive qualitative data into themes, retrieve data quicker and most efficient as well as identifying themes across the data set.

3.6.4 Sampling Approach

Sampling is the process of choosing a representative group from the population, which is understudied. This is a vital part of the research process because it helps in determining the accuracy of the distribution of the data. There two different main approaches to sampling: probability and non-probability. Probability sampling gives every member of the population an equal chance to be selected for the study. As indicated in section 3.6.1, random probability sampling and purposive sampling are applied to this study. A random sampling technique was used for the questionnaire survey because it gives an equal chance to each element of the population (Alvi, 2016). Purpose sampling technique was adopted for the sem-structured interviews because it allows the researcher to identify and select participants of information risk cases that linked to the study (Palinkas et al., 2015).

3.8 Pilot Study

A pilot study refers to a small study to test research protocols, data collection instruments, sample recruitment strategies, and other research techniques in preparation for a larger study (Hassan et al., 2006). It is determining if the questionnaire survey instrument, the key informant interview guide or the observation form is understood well on a few samples. In this case, the problem areas and deficiencies associated with the survey instrument, interview guide or the observation form are identified before the main study. It helps to reveal the confusion and other problematic questions before the main research commences. In the context of this study, pilot studies were conducted on the questionnaire survey instrument and the semi-structured interview guide. It helps to become familiar with the procedures in the protocol. In this process, invitation letters and informed consent forms were made available to the respondents and the interviewees.

- **Questionnaire Survey Instrument:** A pilot study was conducted with 50 sample size which yielded the following 11 items deleted from the instrument: “name of installations” (demographic information); “I am not even aware if there is existence of safety policies at this organisation”, “I ignore safety regulations to get the job was”, “I don’t adhere to code of practice when under pressure”, “my line manager/ supervisor does not always inform me of current concerns and issues of safety”, “operational pressures don’t lead to cutting corners where process safety is raised”, “I am not adequately trained to respond to emergency situations in my work environment”, “experiences with near-missess”, experience of workplace injuries (safety climate); and “violent acts”, “oil spills”, “crashes” (hazard risks).

  The main reason for deletion of these items was due to the negative wording and repetition of meanings of the items which could seriously affect the factorial construction and criterion validity (McLarnon et al. 2016) and the reliability of the scales (Salazar 2015). In short, the main instrument for the study was made up of 99 items containing the following: demographics information (10 items), safety climate measure (67 items) and hazard risks (22).

- **Semi-structured Interviews Guide:** It is cumbersome to predict how the participants will interpret the questions. A pilot study was conducted for two interviewees in Ghana’s upstream oil and gas industry. The main objectives for this pre-test were to assess the quickness of responses to the questions, assess how the concepts and words were adapted to the context of the interviewees, determine the understanding of the questions and finally determine how long or short the interview guide lasted? The researcher found that many of the questions received quick responses, some concepts were not understood within the context of the study, and the interview guide lasted for more than 60 to 90 to minutes because the researcher lost control of the interview along the way. These issues were considered, and the interview guide was revised (see appendix H).

3.9 Reliability and Validity of Data

Noble and Smith (2015) defined reliability as the consistency of the analytical procedures that include controlling the research method and personal biases which may have influenced the research findings. The authors defined validity to mean the precision in which the research findings accurately reflect the data. Both quantitative and qualitative research must reflect reliability and validity of findings.

- **Quantitative Research**: Reliability of a scale of the questionnaire can be determined in two different ways: Temporal stability and Internal consistency (Pallant, 2016). The former is tested by administering the questionnaires to the same people on two distinct periods, and the computation of the correlation between the two scores are obtained. The latter is the Cronbach's Alpha test developed by Lee Cronbach in 1951 that measures the extent to which the items constituting the scale all measure the same underlying attribute or construct (Tavakol et al., 2011; Ursachi et al., 2015). Thus, it describes the degree to which all the items measure the same construct which must be determined before any test can be performed. It expresses as a number between 0 and 1. A general rule governing the internal consistency determines that Cronbach's alpha coefficient of 0.6 – 0.7 indicates an acceptable level of reliability, and 0.8 and above implies a very good level (Ursachi et al., 2015). In this study, the internal consistency test is adopted to determine the reliability of the scale of the questionnaire. This is because it can easily be computed by using IBM SPSS, which economises time.

- **Qualitative Research:** There is no accepted consensus on the standard for judgement of qualitative research. Researchers have been criticised qualitative research because it lacks transparency in terms of analytical procedures, lacks scientific rigour with an inadequate justification of the methods adopted, and the findings being merely a collection of personal opinions subject to researcher bias (Sandelowski, 1993; Rolfe, 2006, Noble & Smith, 2015). However, Noble and Smith (2015) have suggested that researchers need to incorporate strategies to enhance the credibility of a study during research design and implementation. It must be indicated that credibility of this study has been enhenced through piloting of the interview guide, purposive sampling employed, the use of Nvivo software for organising the data, the use of direct quotations to develop to develop argument and the description of the research process (Kulatunga, 2008).

3.10 Research Ethics

The researcher has obtained ethical approval from the University of Salford after satisfying all of the ethical requirements in order to proceed with empirical data collection and recruit participants for survey and interviews (see appendix B1).

3.11 Summury

This chapter presented the research methodological framework for the study. It defined pragmatism as the philosophical position of the study. It adopted DSR as an approach for the study. A conceptual framework is chosen as the main DSR artefact to be produced. The DSR process selected for the study included establishing awareness of the problem, defining requirements of the framework, developing the framework and evaluating the framework. These processes employed research methods covered both quantitative and qualitative research. Random sampling and purposive sampling are used at the main sampling approaches for the study. Both the questionnaire surveys and semi-structured interviews were piloted. The reliability and validity of both quantitative and qualitative research are indicated. It indicated the ethical consideration of the study.

CHAPTER 4: DATA ANALYSIS AND RESEARCH FINDINGS

4.1 Introduction

The preceding chapter presented the research methodology of the study that adopted design science research as the approach for the current study. The current chapter presents the data analysis and the research findings for the four stages of the DSR process adopted for the study. These stages of the DSR activity include the following:

- Stage 1: Establishment of awareness of the problem of the current study. Data analysis from documents, safety statistical data, questionnaire surveys and semi-structured interviews are provided to present the key research findings for the succeeding stage of the DSR process.

- Stage 2: Define the requirements of the framework for robust safety management in Ghana's upstream oil and gas industry. Data analysis from a workshop will be made to present the key research findings for the next stage of the DSR process.

- Stage 3: Develop a framework for robust safety management in Ghana's upstream oil and gas industry. The research findings of stages one and two of the DSR activity as well as the literature, are synthesised to develop a conceptual framework.

- Stage 4: Evaluate the framework for robust safety management. Data analysis from the validation focus groups will be analysed to refine the framework.

The research findings of these stages are summarised for discussion in the next chapter.

4.2 Stage 1: Establishing Awareness of the Problem

This section presents the first activity of the DSR. The first activity is to establish the awareness of the problem of this study. Thus, it defines the problem facing safety management in Ghana's upstream oil and gas industry. The goal of stage 1 is to formulate precisely the initial problem facing safety management in Ghana's upstream oil and gas industry, justify its relevance and investigate its underlying causes. It establishes the problem experienced by the relevant stakeholders involved in Ghana's upstream oil and gas industry and its importance. The study reviews documents on existing safety statutes and regulations; examines the safety statistics on safety performance indicators, analyse the data from the questionnaire surveys to identify the safety climate factors that have a predictive influence on hazard incidents risks, and analyse the semi-structured interview data to provides an in-depth understanding on issues affecting robust safety management. The key issues from the empirical findings are defined as the problem confronting safety management in Ghana's upstream oil and gas industry.

4.2.1 Data Presentation and Analysis for Stage One

In stage 1 of this chapter, several different sources of data were used to establish the awareness of the problem confronting safety management in Ghana's upstream oil and gas industry. These data are presented and analysed to establish the awareness of the problem confronting the safety management in Ghana's upstream oil and gas industry.

4.2.1.1 Documents – Safety Statutes and Regulations

From the literature review chapter (section 2.3.2.2.1), Table 4.1 presents the documents constituted Ghana's safety statutes and regulations that are relevant to the upstream oil and gas operations:

Table 4. 1 Safety statutory and regulatory documents

- The Factories, Offices, and Shops Act (Act 328), 1970.
- The Labour Act (Act 651) 2003.
- Environmental Protection Act (Act 490), 1994.
- Ghana Shipping (Protection of Offshore Operations and Assets) Regulations
- Petroleum (Exploration and Production) Act (Act 919), 2016.
- The Petroleum Commission Act (Act 821), 2011.
- Petroleum (Exploration and Production) HSE Regulations (L.I 2257), 2017

These statutes and regulations are reviewed in assessing the robustness of existing safety regulatory regime for Ghana's upstream oil and gas industry. The assessment is conducted based on the following criteria derived from the literature review in section 2.4.2.3:

I. *Scope of regulatory properties governing upstream oil and gas operations*
II. *Features of the integrative risk governance*
III. *Sustainability of system functionality*
IV. *Adaptability to changed situations.*

4.2.1.1.1 Assessment of Robustness of Ghana's Safety Regulatory Regime

The study carried out document review on the existing safety statutes and regulations relevant to Ghana's upstream oil and gas industry (see appendix D). Table 4.2 summarises the results. *Criterion* 1 examined the extent to which the following safety topics were covered: *the safety and health protection of personnel and facilities*, *environmental protection*, *employment standards and work environment*, *emergency planning*, *management systems with clear responsibilities, division of authority* and the *regulatory approach*. However, oil spill preparedness requirements and liability for the accident were not adequately covered in existing safety statutes and regulations. In *criterion II*, the link between the features of Ghana's safety regulatory regime and the critical requirements of Renn's model was reviewed. The assessment revealed that Ghana's safety regulatory regime for its upstream oil and gas industry appeared limited in several ways in addressing the essential elements constituting an integrative risk governance.

With *criterion III*, the assessment indicated no established procedures in existing safety statutes and regulations that addressed the issues of *sustainability of the functionality of the system*. In *criterion IV*, the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations* reflected some provision for *adaptability to changed situations* as it requires standards for blowout preventers. The need for the regulatory regime to reflect the requirement for standards for blowout preventers became a lesson learnt from the *Deep Horizon Disaster* in 2010. Ghana adjusted this lesson to its current safety regulations. Presently, there is a requirement for operators, contractors, and any entity conducting upstream oil and gas activities to ensure that there is a well control equipment designed to have the capacity to ensure barrier integrity and well control. However, there are no existing safety guidelines that have reflected the detailed adjustment of the prevailing safety advances in the upstream oil and gas industry. The key findings of this assessment are presented in the next section.

Table 4. 2 Summary of results of the review of the existing safety regulatory regime

Criteria	Key Elements Assessed	Main Findings
		Present
I. *Scope of regulatory properties governing upstream oil and gas operations*	Safety and health protection of personnel and facilities.	Yes
	Environmental protection.	Yes
	Employment standards and work environment.	Yes
	Emergency planning.	Yes
	Oil spill preparedness requirements	Limited
	Liability for accident.	Limited
	Management system requirements with clear responsibilities.	Yes
	Division of authority.	No
	Regulatory approach.	Yes
II. *Features of integrative risk governance*	A requirement for multiple actor-network involvements of risk framing	No
	Incorporation of human and organizational factors into risk assessment.	No
	The requirement for the legitimisation of the judgement of risk.	No
	The requirement for safety culture and inclusive	No
	The need for inclusion of multiple actors in the deliberation of risk issues.	No
III. *Sustainability of system functionality*	Sustainability of the principal features of the Safety Case regime.	No
IV. *Learning Capability*	Adaptability to changed situations.	Limited

4.2.1.1.1.1 Key Findings of the Documents Survey

Table 4.3 presents the key findings of the review of the existing safety regulatory regime for Ghana's upstream oil and gas industry. The analysis points to several gaps in the current safety regulatory regime governing Ghana's upstream oil and gas industry. In terms of the existing scope of regulatory properties, there appeared to be incoherence and limitation. Features of integrative risk governance which are critical requirements for handling complexity, uncertainty and ambiguity were not addressed in the existing safety case regime. The study found that the current safety regulatory regime has not had an adequate experience of the establishment of procedures for the development of an open and transparent dialogue on risk. The study found no safety guidelines required to implement the change management regime. These regulatory issues are discussed in the next sections.

Table 4. 3 Key findings of the assessment of the safety regulatory regime

Criteria	Main Issues Identified
I	Incoherent and limited scope of the existing regulatory properties
II	Lack of requirement for multiple actor-network involvements in risk framing. The limited requirement for human and organizational issues. Lack of legitimization of the methods and processes for judgement of risk. The use of traditional compliance monitoring strategies Lack of requirement for inclusion and discourses among stakeholders.
III	Inexperience in sustainability of the functionality of the Regime.
IV	Limited level of adaptability to changed situations.

4.2.1.1.1.1.1 Incoherent and Limited Scope of the Existing Regulatory Properties

The findings on the scope of regulatory properties governing Ghana's upstream oil and gas operations indicate that the existing safety regulatory regime appeared incoherent and limited in scope. There are only two safety laws that are directly relevant to Ghana's upstream oil and gas industry. They include *Petroleum (Exploration & Production) Act* and the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations*. The *Petroleum (Exploration & Production) Act* provided general statutory requirements for both the safety and efficiency exploitation of the oil and gas resources for the full benefit and welfare of the citizens of Ghana. This *Act* appeared in the form of a separate statute that further mandated the minister to make regulations and guidelines towards its effectiveness. The *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations* were established in 2017 that specifically provided for the health and safety of personnel and facilities, environmental protection, work environment, emergency planning and management system in the upstream oil and gas operations. Existing regulations were not adequately developed to deal with oil spill preparedness requirements particularly on spill preparedness, roles and responsibilities in spill response, and capacity for response. Existing legal provisions on the handling and managing oil spill response were limited to deal with major oil spill response. Liability for an accident was not adequately provided in the existing statutes and regulations.

4.2.1.1.1.1.2 Lack of Requirement for Multiple Actor-Network Involvements

The review found that there were no institutionalised procedures for operators, contractors or state entities to set up a framing structure that characterised multiple actor-network involvements in screening the risk issues. Both the *Petroleum (Exploration & Production) Act* and the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations* required organisations to submit a risk assessment to the regulator for approval to undertake upstream oil and gas activities. Existing safety laws emphasised the *Safety Case* concept that required the operators, contractors or the state entity to demonstrate that the system and process that had been adopted was safe in terms of ensuring the health and safety of the personnel, facilities and the environment. No explicit requirement emphasised multiple actor-network involvements in framing the risk issues.

4.2.1.1.1.1.3 Limited Requirement for Human and Organizational Issues

Existing safety regulation required the operators, contractors or any entity undertaking upstream oil and gas activities to perform a risk analysis following best industry practice. It involved the establishment of their criteria for risk estimates. Given the high technical competence requirements in the performance of such engineering frame by operating companies, there was some level of room in the existing safety statutes and regulation for the outsourcing of this QRA to include the involvement of specialist consultants. In the review, it was found that the current *Safety Case* regime was mainly characterised with engineering frame that had limitation in emphasising on the requirement for incorporation of human and organizational factors into the risk estimates.

4.2.1.1.1.1.4 Lack of Legitimization of the Processes for Judgement of Risk

The analysis indicated that existing safety statutes and regulations provided for '*Risk Acceptability Criteria*' as the method to evaluate risk. They required the operators, contractors or any entity undertaking upstream oil and gas activities to identify and minimize risk to a level as "*low as possible*". These methods have their challenge as their outcomes are derived from probability-based estimates. Probability-based evaluation for decision making about risk appeared to provide no or limited room for the legitimisation of the practices and processes on the judgement of risk. Involvement of the stakeholders in the judgement of risk is one of the critical ways of addressing the uncertainties of knowledge and potential surprises associated with existing upstream oil and gas operations. It requires legitimization to provide transparent and democratic processes on the judgement of risk evaluation. Ghana's safety statutes and regulations governing the *Safety Case* approach does not explicitly require the legitimization of the methods and procedures for the judgement of risk evaluation in the upstream oil and gas operations.

4.2.1.1.1.1.5 The Use of Traditional Compliance Monitoring Strategies

The analysis established that existing safety statutes and regulations applicable to the upstream oil and gas industry required the regulator to use traditional compliance monitoring strategies such as the auditing and checklists tools to enforce compliance. It must be indicated that fulfilling the compliance requirements cannot adequately guarantee a sustainable safety performance. Given the challenges in terms of deficit in technical competence and availability of resources that are usually associated with public agencies may affect the effectiveness of monitoring and controlling of safety standards in the industry. The current safety statutes and regulations do not emphasise the requirement for these elements of cooperation and dialogues with several actors involved in the upstream oil and gas operations in working to improve safety performance in the industry.

4.2.1.1.1.1.6 Lack of Requirement for Inclusion and Discourses among Stakeholders

In risk governance, the key features of communication strategies may require *the inclusion* of all relevant actors in the deliberation of risk issues and institutionalisation of the fora for *discourses* on risk issues. The analysis indicated that existing safety statutory and regulatory requirements for strategies regarding risk information sharing lacked the emphasis on inclusion of all relevant actors in the deliberation of risk issues and requirement for the incorporation of procedures to facilitate discourse*s* among the various stakeholders that emanated from different background in view of promoting meaningful interactions towards confrontation of uncertainties.

4.2.1.1.1.1.7 Inexperience Towards Sustainability of the functionality of the Regime

One of the essential indicators for robust safety regime is to survive for a longer period with no detailed modifications to preserve its principal functional characteristics in confrontation to both internal and external disturbances. The review indicated that the current principal functional features of Ghana's safety *Safety Case* regime for its upstream oil and gas industry had lasted for less than ten years. The balance of interests of different stakeholders appeared less effective as there had been no statutory and regulatory requirement of the establishment of procedures for the development of open and transparent dialogue in addressing the complexity uncertainties and ambiguity issues associated with the upstream oil and gas operations.

4.2.1.1.1.1.8 Limited Emphasis on Learning Capability

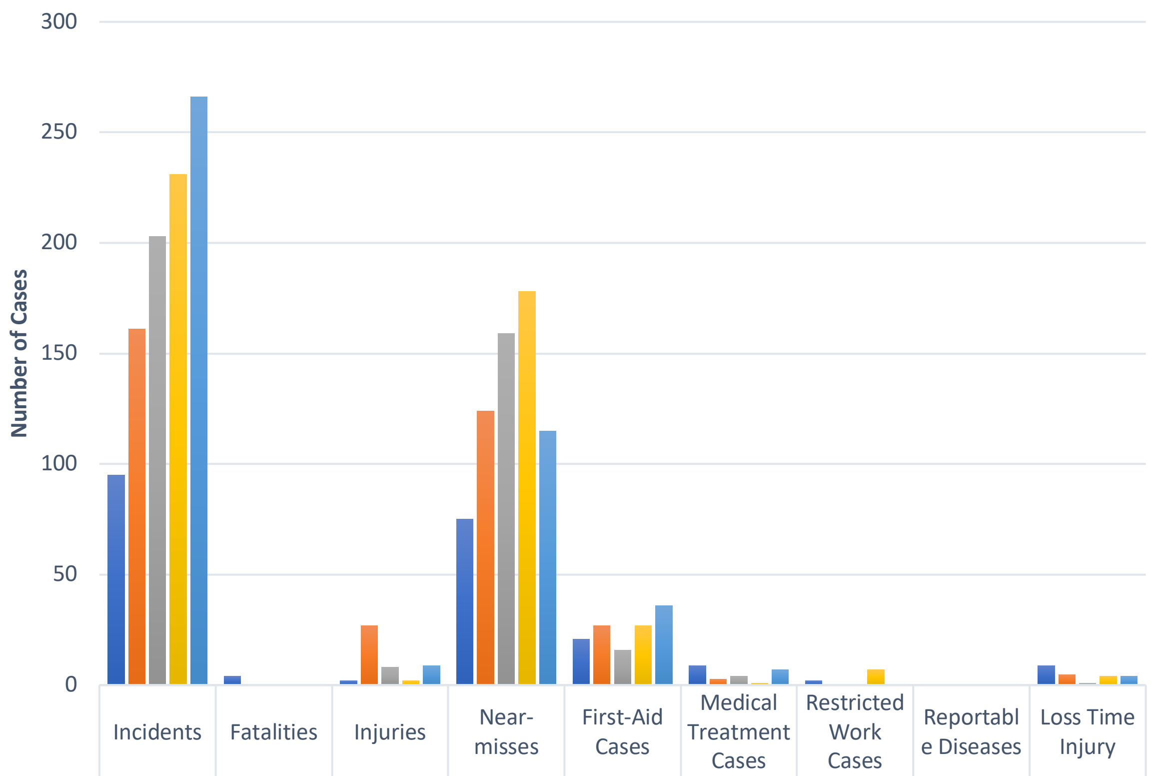
The analysis indicated a limited level of adaptability to changed situations. It was found from the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations* that there was an incorporation of the requirements for blowout preventers in the areas of drilling and well systems. The requirement for standards for blowout preventers in the areas of drilling and well systems emerged from the lessons that were learnt from the *Deep Horizon Disaster* in 2010. The true reflection of adaptability to changed situations in existing safety regime can be found in existing safety guidelines designed by the regulator. However, there are currently no safety guidelines developed for Ghana's upstream oil and gas industry to govern the change management regime.

4.2.1.2 Safety Statistical Data

This section presents the descriptive statistical analysis of quantitative safety data that covered Ghana's upstream oil and gas operations from 2014 to 2018. The purpose of this section is to analyse the safety performance indicators. The data were analysed to cover the IOGP standard classification that include the following indicators: *Fatalities*, *Injuries*, *Incidents*, *Near-misses*, *First Aid Cases* (FAC), *Medical Treatment Cases* (MTC*), Restricted Work Cases* (RWC), *Reported diseases* and *Loss Time Injuries* (LTI). The data were reported to the regulatory agency by the various operating companies, contracting companies and other organisations that had the mandate to undertake upstream oil and gas related activities in Ghana. It must be indicated that these unpublished data covered the period from 2014 to 2018. In this analysis, these data were subjected to descriptive statistical analysis to determine the safety performance indicators for Ghana's upstream oil and gas industry for the same period. This analysis addresses the research objective 3 of the current study.

4.2.1.2.1 Safety Performance Indicators for Ghana's Upstream Oil and Gas Industry

Figure 4.1 presents the safety performance indicators for Ghana's upstream oil and gas industry from 2014 to 2018. The analysis has shown that *incident cases* continued to indicate an increasing trend from 2014 to 2018 (i.e. 95 to 266 cases). *Injury cases* were relatively low within only two years (2016-2017) and increased in 2018. *Near-miss cases* relatively risen from 2014 to 2017 and shown a decrease in 2018. The *FAC* continues to increase from 2016 to 2018. The MTC, *RWC*, and *LTI* are relatively low from 2015 to 2018. Apart from the 4 fatalities cases in 2014 which were due to a helicopter crash in transporting workers for offshore operations, there have not been fatality case up to 2018. There have not also been *Reportable diseases* from 2014 to 2018. However, from the analysis. It is indicative to note that *incidents* occurrence appeared to be the critical issue regarding the safety performance of Ghana's upstream oil and gas industry. It is essential to ascertain the kinds of the incident category that are composing this increase in incident cases.



	Incidents	Fatalities	Injuries	Near-misses	First-Aid Cases	Medical Treatment Cases	Restricted Work Cases	Reportable Diseases	Loss Time Injury
2014	95	4	2	75	21	9	2	0	9
2015	161	0	27	124	27	3	0	0	5
2016	203	0	8	159	16	4	0	0	1
2017	231	0	2	178	27	1	7	0	4
2018	266	0	9	115	36	7	0	0	4

Fig. 4. 1 Safety performance indicators for Ghana's upstream oil and gas industry

4.2.1.2.1.1 Incident Categories

It must be indicated that the data set for incident category cases that covered the period from 2014 to 2016 were not made available for this study. Therefore, this analysis is limited to the last two years of data for incident category cases. Figure 4.2 presents the analysis of incident category cases that were recorded between 2017 and 2018. It indicated that *Struck by/Impact* recorded the highest contribution to the rising trend of incidents in upstream oil and gas activities from 34 cases in 2017 to 68 cases in 2018. The *Releases* (*oil, gas & chemicals*) is the next incident category that contributed to the rising trend of incidents occurrence from 43 cases in 2017 to 57 cases in 2018. *Falls from height/Dropped objects* also provided to the occurrence of the increasing incident recorded 32 cases in 2017 and decreased to 28 cases in 2018. The *Cut/puncture/scrape*, *Equipment failure* and *Electrical exposure* appeared to have relatively contributed to the rising trend of incidents occurrence in Ghana's upstream oil and gas activities. It must be indicated that incident categories such as the struck by/Impact, hydrocarbon releases, and falls from height/dropped objects are the main contributors to the occurrence of the rising incident in Ghana's upstream oil and gas industry.

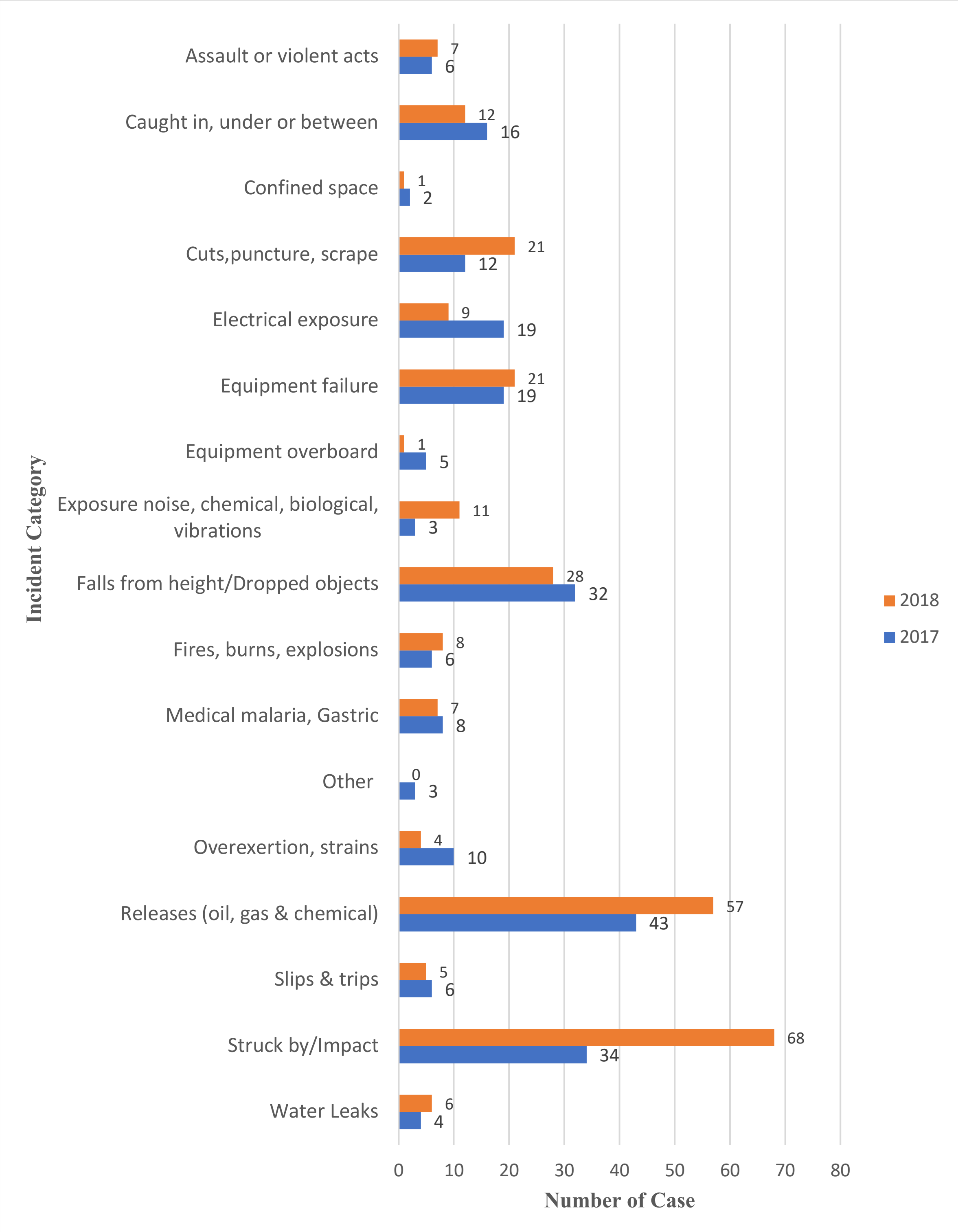


Fig. 4. 2 Incident Categories for Ghana's Upstream Oil and Gas Operations

4.2.1.2.1.1.1 Upstream Oil and Gas Activities and their Incidents Contributions

To ascertain the interface between these incidents and activities involved, an analysis of the various upstream oil and gas activities carried out relative to their incident categories' contributions. In Figure 4.3, it is clearly indicated that *production operations* related activities produced 101 cases to incidents in which hydrocarbon releases and equipment failure represented its main contribution. The *office/warehouse* related activities contributed 94 cases of the incident of which struck by/impact and falls from height/dropped objects mainly represented its main contribution. The *lifting/crane/rigging/deck operations* related activities contributed 73 cases to the incidents with falls from height/dropped objects and struck by/impact represented its main contribution. The *construction/installation/subsea* related activities produced 52 cases of the incidents in which hydrocarbon releases and struck by/impact made its main contribution. The *transport*-related activities contributed 50 cases to these incidents occurrent. Moreover, upstream activities (*accommodation/catering/services*, *maintenance/inspection/testing*, *drilling/workover/well* services) produced several incident categories that contributed to this rising trend of the incidents. However, upstream activities such as *seismic/survey* and *commissioning* made a little contribution to incident in the industry.

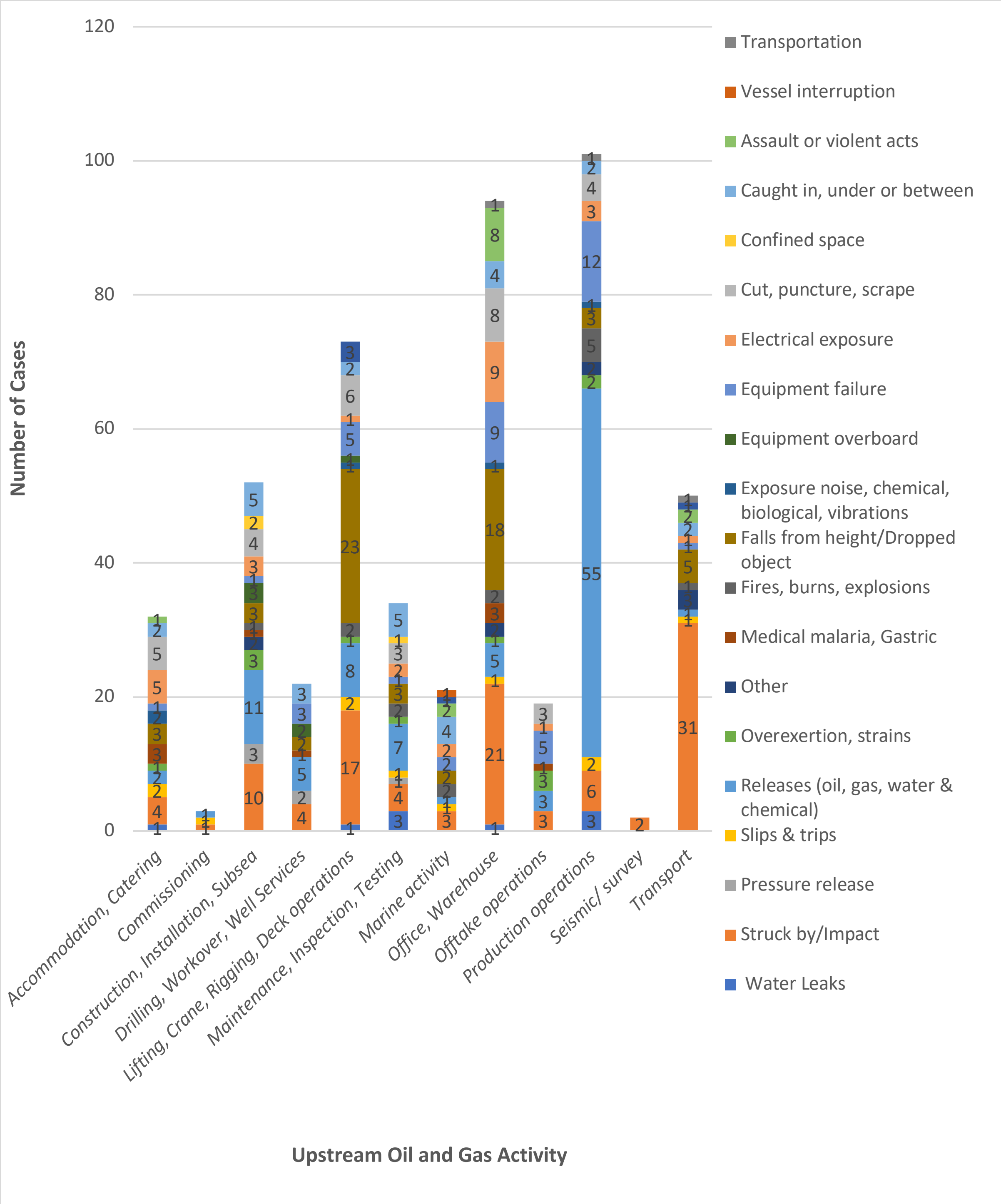


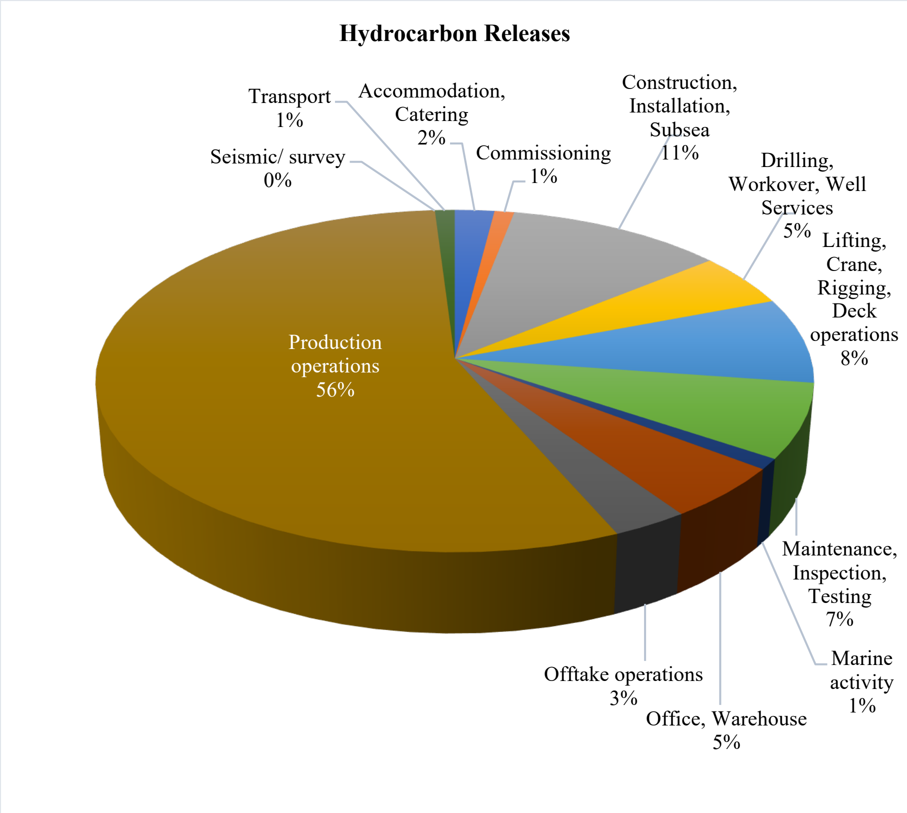
Fig. 4. 3 The interface between activities and incident categories

From the analysis, among other upstream oil and gas activities, the following played key roles in incidents occurrence:

- *Production operations*
- *Office/warehouse*

- *Lifting/crane/rigging/deck operations*
- *Construction/installation/subsea*
- *Transport*

The main incident categories produced by these upstream oil and gas activities have indicated several contributions. It must be indicated that 56% and 30% of production operation related activities contributed to the occurrence of hydrocarbon releases and equipment failure incidents respectively (see figure 4.4). 37% and 25% of lifting/crane/rigging/deck operation related activities contributed to falls from height/dropped objects incidents and to cut/puncture/scrape incidents respectively (see figure 4.5). It is shown that 29% of transport-related activities contributed to struck by/impact incidents.



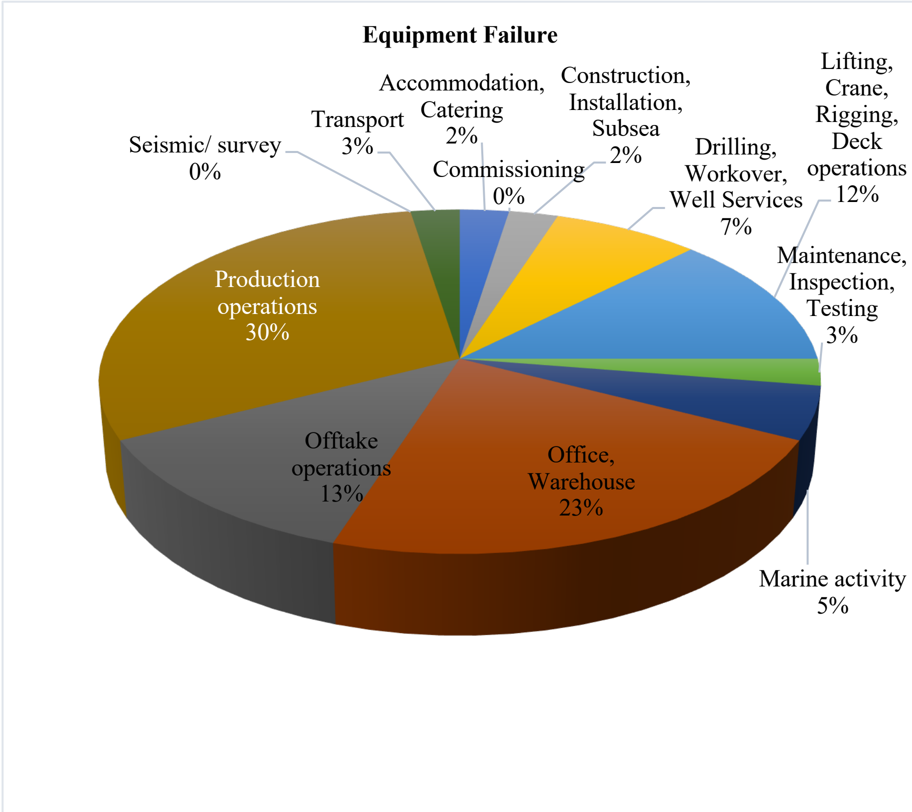
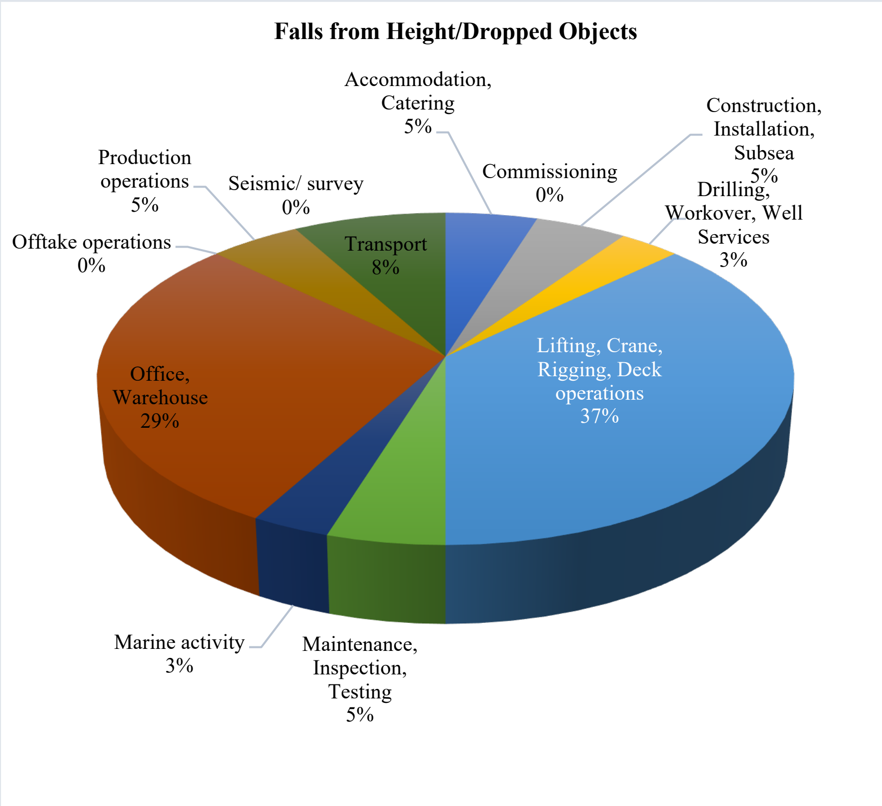


Fig. 4. 4 Contribution of incident categories by production operation activities



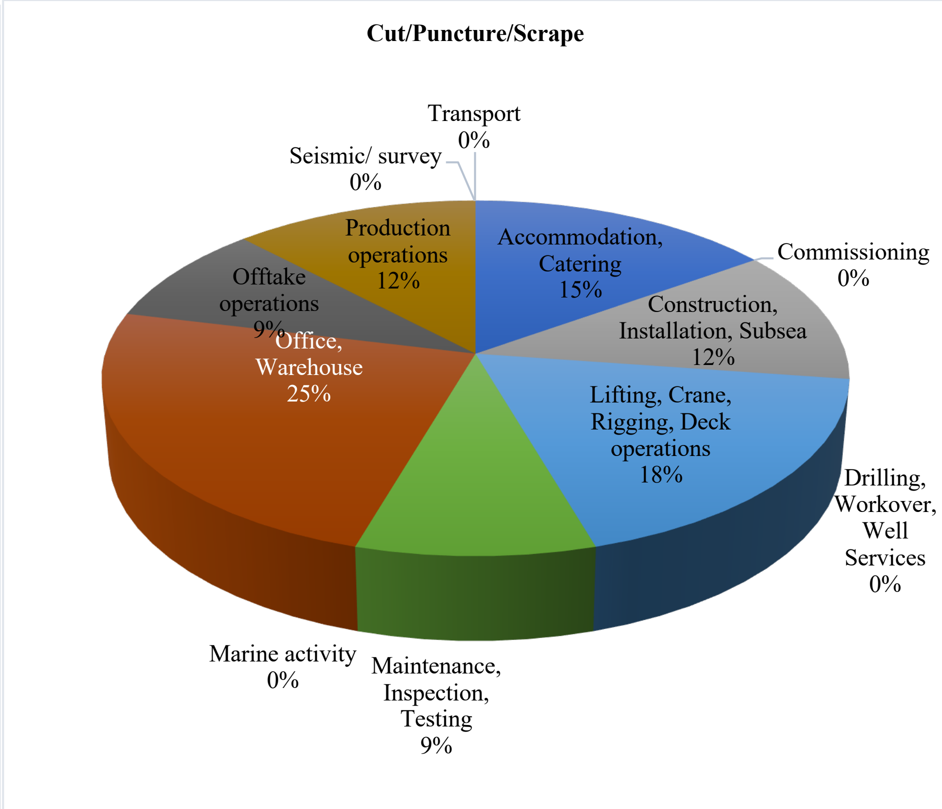


Fig. 4. 5 Contribution of incident categories by upstream oil and gas activities

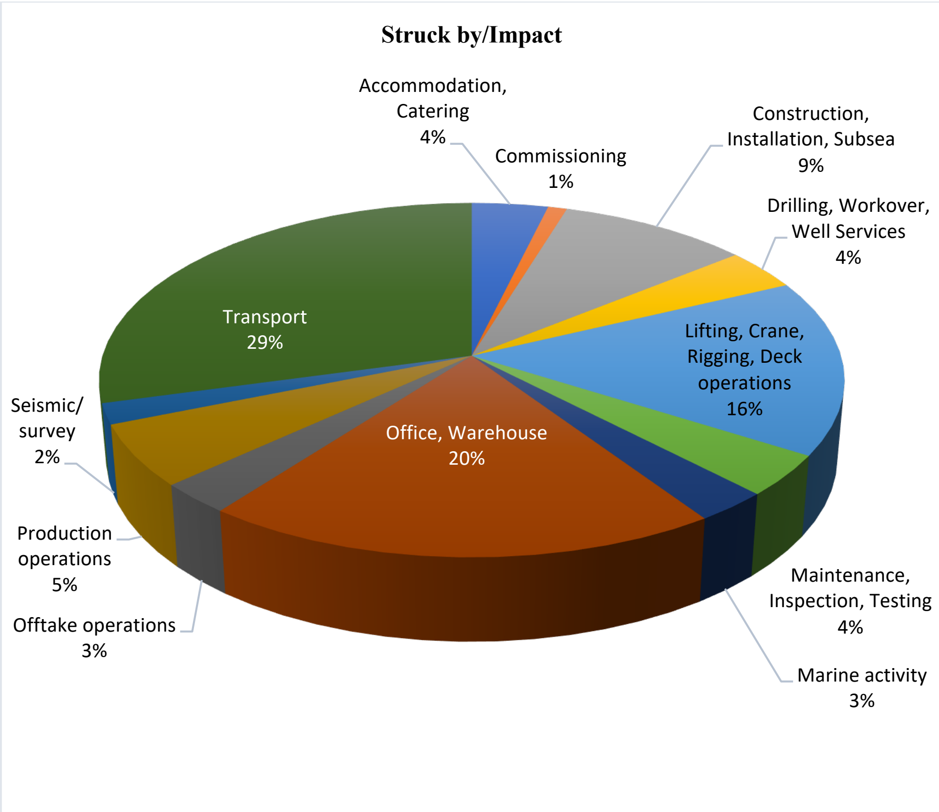
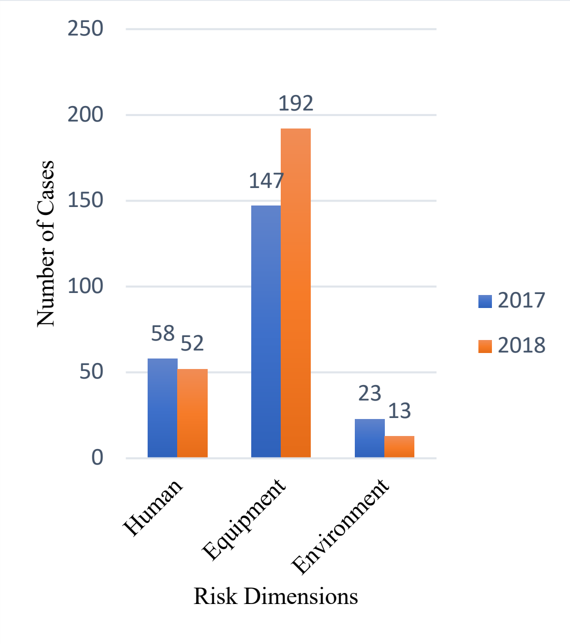


Fig. 4. 6 Contribution of incident categories by transport related activities

4.2.1.2.1.1.2 Incidents Contribution to the Risk Dimensions

As indicated in the literature review chapter (see section 2.3.2.2.), the upstream oil and gas activities are inherently hazardous that may result to incidents occurrence with its potential consequences to human, equipment and the environmental risks. Figure 4.5 shows the contribution of incidents to the risk dimensions in Ghana's upstream oil and gas industry. In the last two years, the interface between incidents and personnel, including environmental risks, has declined. Whereas, the interface between incidents and equipment risk continues to rise. In terms of the contribution of these incidents to the risk dimensions, the equipment risks represented the highest (70%) followed by human (23%) and the environment (7%). The incidents contribution to human risk is mainly related to impairment as occupational accidents continue to reduce despite there was a higher recorded case in the occurrence of struck by/impacts incidents. The incidents contribution to environmental risk appeared relatively low as cases in water leaks and spills related cases were barely low. However, the main challenge is the continuous increase in incidents that imply the risk of equipment. The occurrence of hydrocarbon releases is a challenge as it affects equipment risks.



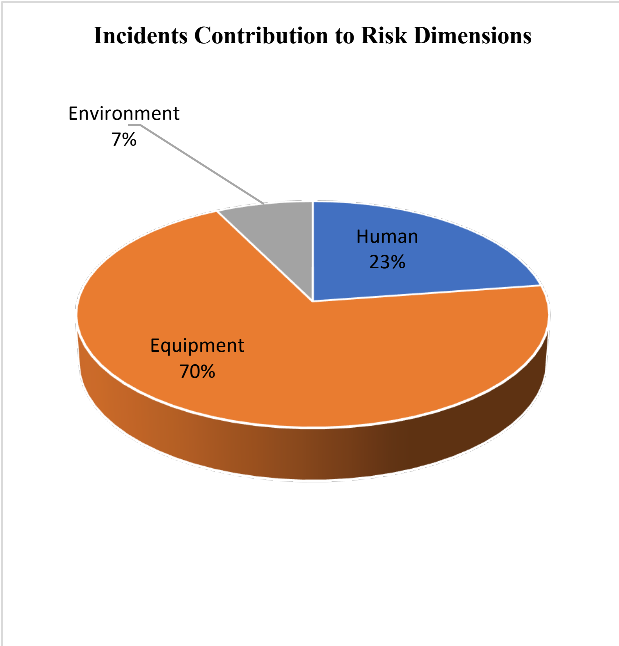


Fig. 4. 7 Trend and contribution of incidents to the risk dimensions

4.2.1.2.2 Key Findings of the Safety Performance Indicators

The analysis of the safety performance indicators shows a rising trend of the incident from the past five years in Ghana's upstream oil and gas industry. The main incident categories driving this increment include the following:

- *Struck by/impact*
- *Hydrocarbon releases*
- *Falls from height/dropped objects*
- *Cut/puncture/scrape*
- *Equipment failure*
- *Electrical exposure*

These incidents were primarily contributed by the following upstream oil and gas related activities: production operations, office, warehouse, lifting, crane, rigging, deck operations, constructions, installation, subsea and transport. It must be pointed out that the main task ahead from these analyses is to identify the main factors that drove the increasing trend of incidents occurrence in Ghana's upstream oil and gas industry. This becomes the main task for consideration in the next sections.

4.2.1.3 Questionnaire Surveys

This section presents the empirical analysis and findings of the assessment of workers' perceptions of the predictive effect of safety climate factors on hazard incident risks in Ghana's upstream oil and gas industry. The questionnaires were distributed to full-time workers from eight organisations in Ghana's upstream oil and gas industry. The data obtained from the questionnaire surveys were analyzed concerning achieving the research objective 4 of this study. This section covers the demographic information of the respondents, data analysis and the key findings of the questionnaire surveys.

4.2.1.3.1 Demographic Information of the Respondents

Self-completed questionnaires were distributed to 300 workers which recorded a response rate of 70.7%. Table 4.4 presents the demographic information of the respondents. It indicates that 78.8% of the respondents were male. Majority of the respondents (44.3%) had their ages within the range of 30 to 39 years. About 89.6% of the respondents were Ghanaians, and the majority of them (50.5%) had a bachelor's degree qualification. In terms of organisational classification, 57.1% of the respondents worked in operating companies. Concerning their areas of operation, 69.9% of the respondents worked in the offshore environment. The respondents worked in many different job categories that included: engineering professionals (42.5%), maintenance/craft technicians (20.3%), operation management (20.3%), contractors (7.5%), maintenance management (17%) and other jobs (8%). It was found that most of the respondents (51.9%) had no related work experience before their current position. It must be indicated that the majority (45.8%) of the respondents had their current job work experience ranging between 7 and 10 years. What it means is that most of the respondents were employed from the beginning of the upstream oil and gas production in Ghana.

Table 4. 4 Demographic information of the respondents

Variable	**Frequency (*N=212)***	**Percent** (*%*)
Gender		
Male	167	78.8
Female	44	20.8
Age		
Under 25	5	2.4
25 - 29	53	25
30 – 39	94	44.3
40 – 49	56	26.4
50 or above	4	1.9
Nationality		
Ghanaian	190	89.6
Other	22	10.4
Education qualification		
SSCE	5	2.5
Diploma	24	11.3
Bachelor Degree	107	50.5
Master Degree	70	33
Doctoral Degree	6	2.8
Organisation Classification		
Operating Company	121	57.1
Contracting Company	91	42.9
Area of operation		
Offshore	146	69.9
Onshore	65	30.7
Job functioning Category		
Engineering professionals	90	42.5
Maintenance/craft technicians	43	20.3
Operation management	10	12.3
Contractors	7	3.3
Maintenance Management	22	10.4
Other		

Work Experience before Current Job		
None	110	51.9
1-3 years	33	15.6
4-6 years	32	15.1
7-10 years	*28*	13.2
Above 10 years	9	4.2
Current Job Work Experience		
Less than I year	10	4.7
1-3 years	48	22.6
4-6 years	*53*	25.0
7-10 years	97	45.8
Above 10 years	4	1.9

4.2.1.3.2 Cronbach's Alpha Coefficients of the Constructs

To test the reliability of the items, Cronbach's Alpha was used as the most appropriate approach since it measures the internal consistency of the scale. It expresses as a number between 0 and 1. A general rule indicates that Cronbach's alpha coefficient (α) of 0.6 – 0.7 implies an acceptable level of reliability, and 0.8 and above implies a very good level (Ursachi, et al., 2015). However, it indicated that values greater than 0.95 suggested not necessarily useful because of its possibility of showing redundancy of the scale (Hulin et al., 2001). In this study, the Cronbach's alpha was computed for all the factors that included: safety climate factors (14 elements) and the hazard risks. As shown in table 4.5, the results of the internal consistency of all the items indicate an acceptable level of reliability (α = .619).

Table 4. 5 Constructs internal reliability

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.619	.467	15

4.2.1.3.3 Descriptive Statistics and Pearson Correlations of the Variables

Table 4.6 presents the means, standard deviations, and Pearson correlation coefficients of all the measured variables. Supportive environment (*M* = 4.32; *S.D.* = .432), safety priority (*M* = 4.19; *S.D.* = .44), safety policies (*M* = 4.09; *S.D.* = .37), equipment maintenance (*M* = 4.09; *S.D.* = .34), and safety behaviour (*M* = 4.04; *S.D.* = 1.21) indicated the higher scores of the mean. In terms of the correlations among the constructs, the Pearson correlation was performed because the data distribution was normal. This parametric analysis relies on these assumptions: that the relationship between the variable is linear, the existence of normality of the data distribution to the population and evenly distributed points on the straight line. It must be indicated that these assumptions were not violated before the analysis was carried out. The Pearson correlation test indicates a pattern of relationship among all the variables studied. In terms of the direction of the relationship, there exists a positive relationship among the safety climate variables in general. Importantly, the Pearson correlation indicates a statistically significant negative relationship between many of the safety climate variables and the hazard incident risks. Workers' perceptions of feeling "unsafe" for hazard incident risks were found negatively correlated with these safety climate variables: safety policies ($r = -.18$, $p < 0.5$), safety training ($r = -.04$, $p < 0.5$), management commitment ($r = -.09$, $p < .05$), equipment maintenance ($r = -.15$, $p < .05$), safety communication ($r = -.07$, $p < 0.5$), safety motivation ($r = -.01$, $p < .01$), and safety behaviour ($r = -.03$, $p < 0.1$).

Table 4.6 Descriptive statistics and correlations of the variables

	M	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. **SP**	4.09	.37															
2. **PR**	4.19	.44	-.19**														
3. **TR**	1.95	.60	-.17*	.15*													
4. **RP**	1.88	.32	-.59**	-.04	-.04												
5. **MC**	2.64	1.00	-.27**	.04	.10	-.25**											
6. **EM**	4.06	.34	.07	-.18**	.12	-.14*	.28**										
7. **CM**	3.16	1.29	.04	-.05	-.01	-.16*	.19**	.20									
8. **SE**	4.32	.42	-.34**	.18**	-.11	.06	-.20	-.13	-.07								
9. **IN**	2.47	.96	.11	.01	-.03	-.11	.31**	.22**	.16*	-.09							
10. **EP**	2.64	1.00	.30**	.27**	.00	-.28**	.54**	.10	.21**	-.15*	.45**						
11. **MG**	2.75	1.15	.23**	-.02	.06	-.24**	.51**	.08	.21**	-.20**	.42**	78**					
12. **SV**	2.87	1.10	.24**	-.03	-.00	-.25**	.39**	.09	.24**	-.13	.41**	.72**	.82**				
13. **MO**	3.62	1.06	.26**	-.01	-.08	-.20**	.22**	.04	.10	.01	.25**	.32**	.31**	.53**			
14. **BE**	4.04	1.21	.04	.04	-.06	-22**	-.31**	.01	.05	.10	-.20**	-.31**	-.31**	-.28**	-.10		
15. HZ	1.6	.48	-.18*	.07	-.04	.17*	-.09	-.15*	-.07	.14*	.12	.13	.17*	.10	-.01	-.03	

N = 212, *. *p*< 0.05. ****.** *p*< 0.01.

Abbreviated factors: 1=Safety Policies (***SP***); 2=Safety Priority (***PR***); 3=Safety Training (***TR***); 4=Safety Rules & Procedures (***RP***); 5=Management Commitment (***MC***); 6=Equipment Maintenance (***EM***); 7=Safety Communication (***CM***); 8=Supportive Environment (***SE***); 9=Safety Involvement (***IN***); 10=Safety Empowerment (***EP***);11 =Management of Change (***MG***); 12=Safety Supervision (***SV***); 13=Safety Motivation (***MO***); 14=Safety Behaviour (***BE***); and 15= Hazard Incident Risks (***HZ***).

4.2.1.3.4 Results of the Exploratory Factor Analysis

The study identified many factors from the literature review that measured safety climate perceptions (see section 2.3.4.2.4) in Ghana's upstream oil and gas industry. Given this, Exploratory Factor Analysis (EFA) was performed to identify the latent variables for safety climate perceptions. Before the computation of the EFA, four essential requirements must be met on the suitability of the data set that includes: *sample size must be higher than 150*, *the strength of the relationship among the factors*, *linearity* and *outliers among cases* (Pallant, 2016). The sample size used for the current study is higher than 150. Table 4.7 presents the results of the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity. The general rule of thumb indicates that for satisfactory factor analysis to be computed, KMO measure of sampling adequacy should be higher than .5 (Hinton et al., 2014). The data set was appropriate for the principal component analysis as KMO indicated .709 and Bartlett's Test of Sphericity of the relationship between the factors was significant (x^2 = 1005.969, $p < .05$). Based on these results, the EFA was computed.

Table 4. 7 Results of the KMO and Bartlett's test for the variables

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.709
Bartlett's Test of Sphericity	Approx. Chi-Square	1005.969
	Df	91
	Sig.	.000

The 14 safety climate factors derived from the literature were subjected to principal components analysis with orthogonal varimax rotation using IBM SPSS (version 25). Figure 4.6 and table 4.8 show the *scree plot* and the *Total Variance Explained* about how many components to extract respectively. Using Kaiser's criterion (Kaiser, 1974), components with eigenvalues greater than one were extracted. The *scree plot* shows that five components had eigenvalues greater than 1. The *Total Variance Explained* also revealed the presence of five components with eigenvalues greater than 1, explaining 28.6%, 11.8%, 9.7%, 8.8% and 8%
Of the variance, respectively. This is further supported by the *Monte Carlo PCA for Parallel Analysis* (see appendix F) which indicated only five components with eigenvalues higher than

the corresponding criterion values for the randomly produced data matrix of the same size (14 variables x 212 respondents).

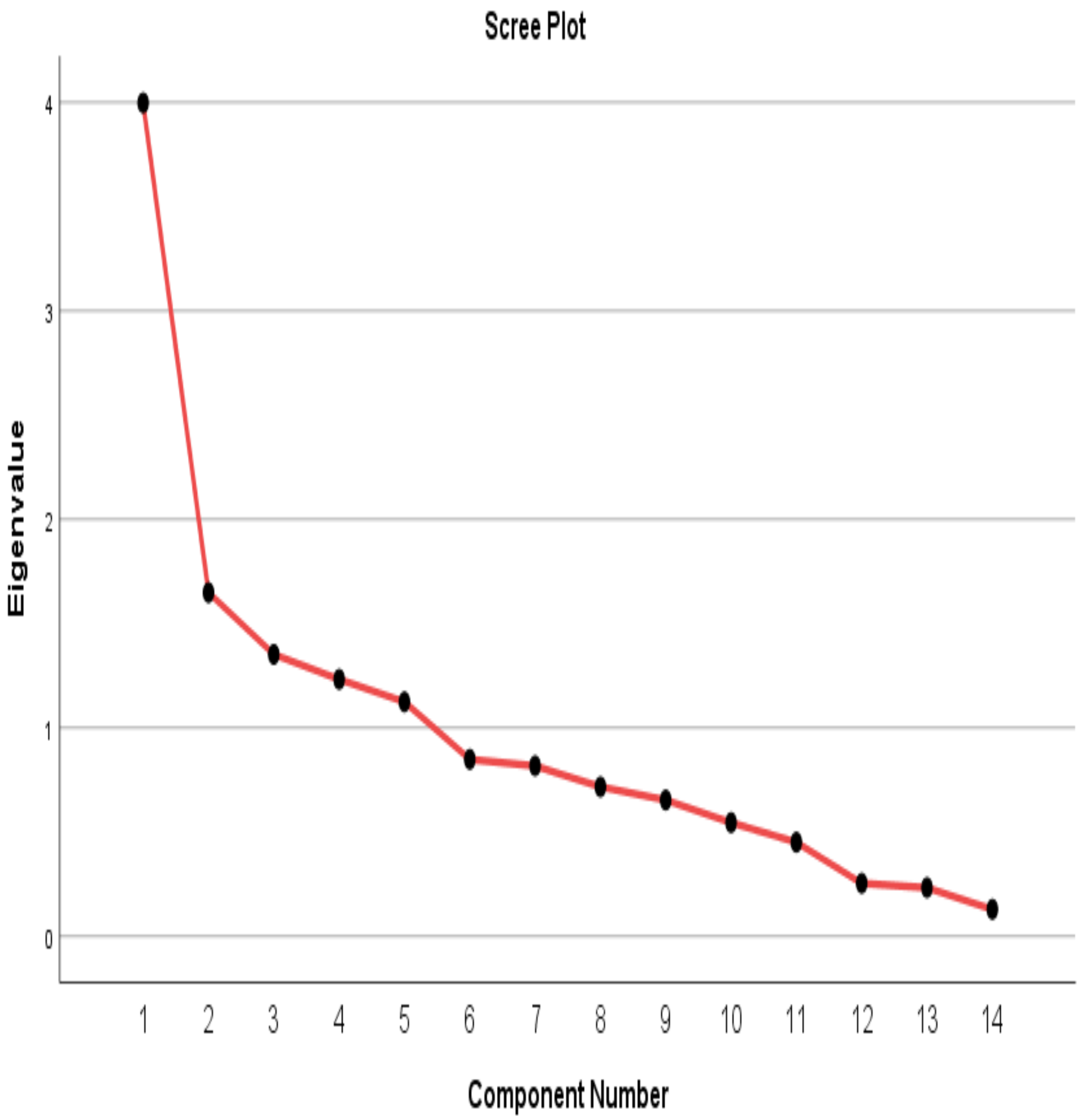


Fig. 4. 8 Scree plot of the exploratory factor analysis for safety climate factors

Table 4. 8 Total variance explained for the safety climate variables

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.998	28.557	28.557	3.998	28.557	28.557
2	1.649	11.776	40.333	1.649	11.776	40.333
3	1.352	9.658	49.991	1.352	9.658	49.991
4	1.232	8.801	58.792	1.232	8.801	58.792
5	1.124	8.032	66.824	1.124	8.032	66.824
6	.848	6.057	72.881			
7	.817	5.835	78.716			
8	.716	5.116	83.832			
9	.653	4.663	88.495			
10	.545	3.891	92.387			
11	.450	3.217	95.604			
12	.254	1.811	97.415			
13	.233	1.663	99.077			
14	.129	.923	100.000			

Extraction Method: Principal Component Analysis.

Table 4.9 presents the combined outputs of the *Rotated Component Matrix* and the *Communality* coefficients of the components. The results indicated that four components were extracted with eigenvalues greater than 1, which had communality coefficient scores above 50%. Table 4.10 presents a summary of the main factors that were retained in the EFA. The first component (1) retained four factors that included: *Safety supervision*, *Management of change*, *Safety empowerment*, and *Management commitment*. The second component (2) retained three factors, such as *Safety policies*, *Safety rules and procedures,* and *Safety behaviour*. The third component (3) retained two factors that included: *Safety priority* and *Supportive Environment*. The fourth component (4) retained two factors that included: *Equipment maintenance* and *Safety communication*. Finally, the fifth component (5) kept two factors, such as *Safety Training* and *Safety priority.* These five components (i.e. F_1, F_2, F_3, F_4, & F_5) retained in the EFA constituted the underlying latent variables for the safety climate measure which are used as independent variables for the multiple regression analysis to determine which factors have more predictive influence on the hazard risks in Ghana's upstream oil and gas industry.

Table 4. 9 Results of the exploratory factor analysis for the variables

Factors	Rotated Component Matrix[a]					Communality
	F_1	F_2	F_3	F_4	F_5	(h^2 =100%)
Safety Policies		.730				.829
Safety Priority			.531		.584	.706
Safety Training					.812	.687
Safety Rules and Procedures		-.849				.788
Management Commitment						.561
Equipment Maintenance				.780		.679
Safety Communication	.601			.667		.520
Supporting Environment			.773			.633
Safety Involvement						.441
Safety Empowerment	.862					.767
Management of Change	.876					.790
Safety Supervision	.876					.793
Safety Motivation						.488
Safety Behaviour		.536				.672

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
[a]. Rotation converged in 5 iterations.

Table 4. 10 Summary of the latent factors retained in the EFA

Components Extracted	Main Factors Retained
1	• Safety supervision • Management of change • Safety empowerment
2	• Safety policies • Safety rules and procedures • Safety behaviour
3	• Safety priority • Supportive Environment

4	• Equipment maintenance • Safety communication
5	• Safety training • Safety priority

4.2.1.3.5 Multiple Regression Analysis

Multiple regression analysis was used to test which factors have a more predictive influence on hazard incident risks. The results presented in table 4.11 indicate that the model is statistically significant, explaining 14.4% of the variance in influencing the hazard incident risks. The Analysis of Variance (ANOVA) tested the statistical significance of the multiple regression analysis (see appendix G). Table 4.12 presents the results of multiple regression. The results indicate $F(5, 206) = 6.937$, $p < .0005$, which confirms its statistical significance. Factor 1 (F_1) indicates a more predictive influence on incident incident risks ($\beta = .210$, $p < .05$). Factor 2 ($\beta = -.194$, $p < .05$), factor 3 ($\beta = .163$, $p < .05$) and factor 4 ($\beta = -.163$, $p < .05$) indicate predictive influence on hazard incident risks accordingly.

Table 4. 11 Model summary of the multiple regression analysis

Model	R	R^2	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.380[a]	.144	.123	.44864	.144	6.937	5	206	.000

a. Predictors: (Constant), REGR factor score 5 for analysis 1, REGR factor score 4 for analysis 1, REGR factor score 3 for analysis 1, REGR factor score 2 for analysis 1, REGR factor score 1 for analysis 1
b. Dependent Variable: Hazard incident Risks

Table 4. 12 Results of multiple regression

Predictor	Unstandardized Coefficients B	Standardized Coefficients *β*	t	*p*
F1	.101	.210	3.266	.001
F2	-.093	-.194	-3.011	.003
F3	.078	.163	2.527	.012
F4	-.078	-.163	-2.522	.012
F5	-.046	-.096	-1.487	.139

$F(5,206) = 6.937, p < .05$

4.2.1.3.6 Key Findings of the Questionnaire Surveys

Safety climate perceptions have a predictive influence on hazard incident risks in Ghana's upstream oil and gas operations. From the workers' perspective, the following organisational safety climate factors have a relatively higher predictive effect on hazard incident risks in the upstream oil and gas operations: safety supervision, management of change and safety empowerment. It was indicated that safety policies, safety rules and procedures and safety behaviour have a relatively high predictive effect on hazard incident risk. Factors such as safety priority, supportive environment, equipment maintenance and safety communication have a relative effect on hazard incident risks in the upstream oil and gas operations.

4.2.1.4 Semi-structured Interviews

This section presents the analysis of the empirical investigation of the semi-structured interviews conducted for this study. This section seeks to identify the issues confronting safety management in the upstream oil and gas industry. Safety management involves two key aspects: the prescription of safety norms and ways to ensure that these norms are complied. Focusing on issues relating to safety regulations and implementation. The analysis was carried out to grasp the real problems that are influencing robust safety management in the industry currently. This section covers the background of the interviewees (referred to in this study as participants), the themes for ascertaining the issues affecting safety management, the analysis of the issues and the key findings from the semi-structured interviews. The details regarding the participant information sheet, semi-structured interview protocol, semi-structured interview questions and semi-structured interview transcript are attached in appendices H1, H2, H3 and H4 respectively.

4.2.1.4.1 Background of the Participants

The research commenced the semi-structured interview with questions seeking to capture the background information of the participants. Background information elicited from the participants covered these areas: central position or role in the organisation, core functions or operations of your organisation, the location of the company's activities and years of current job experience. Table 4.13 presents background information of the participants. The data were obtained from 14 professionals working in Ghana's upstream oil and gas industry in different managerial and supervisory roles. The participants worked in different organisation types that covered regulatory institutions, government agencies, operating companies, contracting companies and the labour union. Most of these organisations engaged in both offshore and onshore related oil and gas activities. The average years of participants current job experience is eight years.

Table 4. 13 Background information of the Interview participants

Participant Code	Main Position	Organisation Type	Job Location	Years of Current Job Experience
PO1	HSE compliance Monitoring officer	Regulatory Institution	Offshore & Onshore	6
PO2	HSE manager	Operating Company	Offshore	4
PO3	HSE Supervisor	Contracting Company	Offshore & Onshore	12
PO4	HSE manager	Contracting Company	Onshore	7
PO5	HSE manager	Operating Company	Offshore & Onshore	6
PO6	Line manager	Operating company	Offshore & Onshore	8
PO7	HSE Supervisor	Contracting Company	Onshore	12

PO8	Contractor	Contracting company	Onshore	7
PO9	HSE supervisor	Contracting company	Offshore & Onshore	9
PO10	HSE Compliance Monitoring officer	Regulatory Institution	Offshore & Onshore	10
PO11	Monitoring officer	Government agency	offshore	9
PO12	Maintainance manager	Government agency	Onshore	9
PO13	Labour officer	Labour Union	Offshore & Onshore	10
PO14	Maintainance manager	Operating company	Offshore & Onshore	6

4.2.1.4.2 Main Themes Investigated in the Semi-structured Interviews

The argument for this study is the need to adopt an integrated risk governance approach for safety management in Ghana's upstream oil and gas industry. This requires a multi-stakeholder involvement in all the processes of remaining proactive in handling risks associated with the upstream oil and gas operations. Given this, the semi-structured interviews were designed to focus on five main themes identified in the literature:

- *integrative risk governance framework*
- *sustainability of the functional characteristic of the safety case regime*
- *adaptability to changed situations*
- *issues influencing safety regulations*
- *barriers to the implementation of safety management systems.*

These themes were investigated to identify the issues affecting safety management in Ghana's upstream oil and gas industry. Table 4.14 provided the number of responses for the the various themes investigated. These responses were derived from the nvivo software analysis.

Table 4. 14 Key themes and their number of responses

Themes	No. of Responses	No. of References
Multiple stakeholders' involvement in framing risks	13	14
Interdisciplinary estimation of risk	13	14
Legitimization of the risk appraisal	12	14
Management of risk issues	12	13
Risk information sharing	11	12
Sustainability of the functionality of the Safety Case	12	13
Adaptability to changed situations	9	11
Issues influencing safety regulations	12	17
Barriers to the robust implementation of SMS	13	17

4.2.1.4.2.1 Integrative Risk Governance Framework

Under the integrative risk governance framework, the study identified five key elements which include the following: multiple stakeholders' involvement in framing risks, interdisciplinary estimation of risk, the legitimisation of the risk appraisal, management of risk issues and risk information sharing.

4.2.1.4.2.1.1 Multiple stakeholders' Involvement in Framing Risks

The study investigated the multiple actor-network involvement in the framing of the risks in the upstream oil and gas industry. The participants were asked to indicate their views on which stakeholders were involved in the framing of the risk issues. There were four responses (i.e. PO2, PO5, PO6, PO14) that indicated broader stakeholders' involvement were made to their organisations' risk framing. These participants stated that there were representatives from the following institutions and organisations involved in the risk framing: Ministry of Energy, Petroleum Commission, Environmental Protection Agency, GNPC, Ghana Maritime Authority, Fisheries Commission, contractors, suppliers and community authorities. These stakeholders are involved in the initial stage of the facility, and this was indicated in one of the responses of the participants:

> "*In our recent contract, and you know our company is a multinational with most of our operations offshore, we had to perform a risk assessment of the contract area and the facility which started by identifying the various potential impacts and risks that our activities will pose to the environment and the people. So, we conducted several meetings that we engaged several representatives from various institutions such as the energy ministry, GNPC, PC, EPA, GMA, fishing communities, our contractors and suppliers to work together. We have traditional authorities from those communities that will be affected by our activities. So, we have a broader net to screen and identified the issues…"* [PO2].

However, the study found that these multiple stakeholders' involvement as indicated by these participants were mainly limited to the framing of social and environmental risks and responses of the participants show this as evident in PO3 response:

> "*The Environmental and Social Impact Assessment (EIA) regulations require us to identify the potential impacts and risks of our operations that will have consequences to human lives and the environment. This makes us to follow the process stipulated in the regulations*."

The participants indicated that the process in multiple actor-network involvements is complicated in framing the risk issues as most of their contracts have limited schedule which will not make it possible to involve all the stakeholders required in screening for the problems. They pointed out that there was a delay in responding and honouring of the invitation of stakeholders to frame as pointed out below:

> *"I must say it is very cumbersome and challenging to have our invitation letters acknowledged and honoured by several of the stakeholders. Because of such challenges, we hardly go to that extent of involving several stakeholders to such exercise. We do our best! We only look at the most relevant ones. Don't forget, we have a time limit to get our contract executed, and we are very conscious of that…" [PO3].*

Moreover, some of the participants indicated that because the industry is operating a safety case regime, which is a self-regulation regime. Therefore, the essence of multiple stakeholders' involvement in the safety case is less significant. This impression was pointed as follows:

> "*With the safety case regime, it is a self-assessment thing. So, it is you assess the risk associated with your facility, and you are telling us that you have put in place adequate measures to reduce the risk as low as possible. You do it out of the state engagement. However, before the starting of the facilities, we have what we called the Endurance Test Operation, where your safety case is tested at its full working operations. There is no need to have stakeholders' engagement on safety case document when it is pre-produced. However, since there are local risks, like the fishing activities, malaria, weather, you have to submit this to the commission*" *[PO1].*

These comments give the impression that there were limited stakeholders involved in the framing of risk issues in Ghana's upstream oil and gas industry. Existing risk framing was more skewed to eliciting knowledge of environmental and related social problems. Workers involved in the framing of risk issues under the safety case regime was essential in prioritisation of the understanding of risk. Labour union involvement appeared missing from the risk framing.

4.2.1.4.2.1.2 Interdisciplinary Estimation of Risk

This study investigated the interdisciplinary nature of existing risk estimation in Ghana's upstream oil and gas industry. Participants were asked to indicate the extent of their interdisciplinary approach in estimation risk in their respective organisations. As pointed in the literature, risk estimation must cover both assessments of the physical harm in which a risk source produces and the investigation of the state and quality of knowledge that are linked to the hazards risk. In other words, how human and organisational influences are linked to the hazard, risks or vulnerabilities. The existing risk estimation reflected more on the aspects of the risk assessment. Most of the participants indicated that the current risk assessment is extensive, which covers health, safety, environment and economics risk as pointed out in the response of *PO11*:

> "*Our risk assessment is based on a cost-benefit approach where we assess the risk broadly covering the economic risk, the fatalities and injuries risks of our personnel, the facilities risk and the environmental risk*"

Several of the participants indicated that existing risk assessment on the facilities was comprehensive and experienced risk assessment groups always conducted this. This was evident in one of the participants by *PO1*:

There is quite extensive work they do that mostly covers health, safety, environmental, economic risks. Most often they meet the requirements. With the risk assessment, the IOCs are quite well vested in that given their vast experience of that. They do internal risk engagement for hazard identification which is a significant engagement activates where they engage the large crowd to perform the risk assessment for various risks they could have encountered with the project. So, for that sense, the likelihood that they would miss risks in their operations for risk assessment they had done for over 15 years is very low. So, for risk assessment, I will say they are well vested.

However, there were areas in the risk assessment that required more attention such as the weather conditions, corrosions and fishing activities. It was found that these areas have critical risk implications for offshore facilities. Again, in terms of the assessment methods, QRA was mostly applied in the industry. *PO1* further elucidated these issues:

"... there is always the need to incorporate the local risks I mentioned earlier. Beyond the weather and the fishing activities that had been a problem in the offshore environment, salinity in salt, which is causing most of the facilities, causing rust. Some of these risks are to be identified in Ghana. Most of our risk analyses are a quantitative risk assessment. For qualitative risk, I say big no, hardly! We don't do most of these qualitative risk assessments. We have a lot of drilling analysis. We rely on an assessment that you can measure immediately. So, it is a quantitative way".

The study found that risk assessment had been the main focus on risk estimation in the upstream activities. Existing risk assessment needs to adequately capture the weather conditions, corrosions and fishing activities risks. However, the gap in existing risk estimation relates to the limitation in the application of qualitative risk assessment methods to identify the issues that are linked to the risks.

4.2.1.4.2.1.3 Legitimization of the Risk Appraisal

Stakeholders involvement in the judgement of risk is critical in addressing uncertainty, and this requires legitimization to provide transparent and democratic processes on the judgement of risk evaluation. The study investigated existing approaches to evaluating risk issues in Ghana's upstream oil and gas industry. Most of the participants indicated ‘mechanistic approach' where companies were only interested in satisfying the risk acceptance criteria, which in context reducing risk as "low as possible". The participants indicated the application of the ALARP principle driven by several tools for evaluation of their risks. Examples of such tools are presented as follows:

> *PO7* response: *"The risk matrix method, the cost-benefit criteria are key for our decision making here. Various standards are consulted in line with each facilities risk limit."*
>
> *PO11* response: *"Our operations are governed by various international safety standards and national safety regulations. Although no risk limit is prescribed to us, we are required to reduce risk to a low level.*
>
> *PO11* response: *"We have various methods to make the decision on the risk that includes risk matrix criteria, cost-benefits, individual risk criteria, societal risk criteria and qualitative risk criteria".*
>
> *PO1 response: "We have the filling modes, HAZID, HAZOP, Bow-tie. These are some of the tools they use in the risk evaluation process because we are dealing with the process and not occupational nature. It is more process-oriented. So the FMEA and others are the most preferred tools being used in the risk evaluation so far".*

However, in terms of legitimisation of the appraisal process where relevant stakeholders are involved in the decision making, the study found limited involvement of the stakeholders as evident in participant response:

> "*The HSE regulations require us to reduce risk as low as possible. There is some little level of consultation in terms of getting the government agencies to be part of our decision making. You know we cannot ignore the regulator. Sometimes we engage them in our decision making on risks*" *(PO7).*

It was found out that the main feature on risk appraisal present in Ghana's safety case regime was the relatively mechanic approach which was more rooted in satisfying the regulatory requirement of reducing risk as low as possible. There was a limited involvement of the regulator as the underlying model of risk regulation was self-regulation. The government agencies appeared not adequately involved in the decision making on risks.

4.2.1.4.2.1.4 Management of Risk Issues

Managing risk issues is related to the safety culture and monitoring and controlling risk. The study investigated the issues influencing the safety culture and the monitoring and controlling of risk. The participants indicated safety culture practices as a gap for both the local workforce and contractors in the upstream oil and gas operations, as shown as follows:

> *PO1*: "*The culture here is the seriousness of the management. With the IOCs in terms of their financial loan regimes from the IFCs, there are high expectations of environmental and safety sensitivity. So culturally, their sides continue to improve. The challenge has always been the local environment where Ghanaian safety performance is quite low. The average Ghanaian does not consider safety as a major threat to our existence. The challenge has always been to transfer the corporate perception to the local contractors. The difficulty has been to get them to a level where they need to accept to operate in a safe manner. This has always been a challenge for the industry. The local workforce does in the Ghanaian way where they don't understand they are always required to work in a safe way. They don't accept to work in a safe manner*".
>
> PO3: *"There is a lot to be done in that regard, bringing up the local contractors and service providers and other relevant stakeholders to that level to appreciate the safety and the role of safety in the operations, there is a gap there, so we must work to bridge that gap"*.

In relation to the monitoring and controlling of risk, the study found compliance monitoring as the primary mechanism employed in the oil and gas industry. It was found that both operating and contracting organisations are required to comply with existing safety regulations. Some of the operating companies have multi-stakeholder auditing activities that were carried out as indicated:

> *PO5*: "*We have various institutions and bodies that conduct their independent audit, so the regulatory agency audit forms part of the many other audits and monitoring works. The banks are doing that the funding agencies are doing that, the insurance companies are doing that, i.e. carrying out their independent audit*".
>
> *PO1*: "*For monitoring, the expectation is that the IOCs who are contracting has to have assurance from their contractors, but they themselves have a periodic audit of the contracting activities and engage the regulator on the course of the year*".

However, some of the participants indicated the inadequacy of the existing compliance monitoring mechanism used by the regulatory authorities.

4.2.1.4.2.1.5 Risk Information Sharing

As ascertained in the literature, communication of risk featured establishment of procedures to facilitate discourses on uncertainties, supporting the development and sustainability of trust among several stakeholders, and inclusion of multiple stakeholders. The study investigated how communication of risk was handled in Ghana's upstream oil and gas industry. Several participants indicated the inadequacy of existing strategies for risk information sharing as highlighted here:

> *PO6*: "*We do share information on the outcomes of our risk assessment, incident investigations to our personnel, management and the commission*".
>
> *PO7*: "*If you share information on letters, emails, and during meetings, how effective will you advance an effective risk information sharing? It is certainly not the way forward. We need to have discourse on risks. I think we must look beyond these*".
>
> *PO1*: "*The IOCs use the bulletin system where they share information about incidents across the operations. They submit a report to us, and we also share with the other actors within the petroleum space. The internal communication has always been the bulletin system. Where I sit, it is down! Communication is down*".

Several of the participants indicated these techniques for sharing information on risks: letters, emails, morning meetings and permit meetings as revealed:

> *PO1: "They use emails, letters, morning meetings, permit meetings. So, incidents report go through these techniques. These techniques have been used by the IOCs to the contractors too.*

The study found that existing strategies for sharing information on risk were not adequate as the industry lacks institutionalisation of discourses for risk information sharing among all the stakeholders.

4.2.1.4.2.2 Sustainability of the Principal Functionalities of the Safety Case

The study investigated the issue on the sustainability of the principal functionalities of Ghana's safety case regime. It was indicated that the safety case approach was not a new concept in the global oil and gas industry. Its fundamental functionalities have been implemented under the self-regulatory styles, and that have been successful as pointed out as follows:

PO1: "*With the functional features of the safety case, it is accepted generally, and I don't think the Ghanaian risks are higher than the southern American risk or the North Sea risks. It is the same risk we all use the same safety case. It is appropriate and exhaustive. So, it is appropriate*".

Some of the participants indicated that it was too early to judge its sustainability in Ghana fully. They noted that practising safety case regime under self-regulation does not guarantee zero risks but depends on the joint partnership of the stakeholders. This was highlighted here:

PO12: "*Our industry is young, so we have not had enough time to realise the full benefits of this safety case implementation in terms of accidents. I know and I am sure you have read much about that, this safety case thing originated from the UK and other countries have also adopted it. Can we say that since its implementation, the UK had not experienced several incidents in their upstream activities? Definitely no! For me, the sustainability of it has to be looked at from the working partnership between the industry and the regulatory agencies*".

However, several participants disclosed a gap regarding the working partnership among the stakeholders in the industry, as indicated below:

PO1: " *It requires a lot more engagement from the stakeholders. This is where there is a challenge, particularly engagement of the regulator, contracting parties, state agencies and the implementation of all these requirements in the safety case. This comes to periodic audits, and unfortunately, there is a gap in our national agenda as it is not a high priority. We need the support of the leadership for the HSE department to ensure that operating companies put their things to ensure safe operations in our industry*".

The study found that existing safety case governing the self-regulatory regime of Ghana has not been sustained for a longer period. There appeared to be a limited engagement of stakeholders in implementing the safety case approach in the industry.

4.2.1.4.2.3 Learning Capability

As indicated in the literature, because of the market competition in the upstream oil and gas industry, several activities undergo rapid changes in technology and organisational management. Given this, there were alterations in technology, chemical processes, equipment, procedures and changes to facilities which required the engagement of stakeholders. This study investigated the issues associated with adaptability to changed situations. The study found that there were few instances where the regulatory authorities were engaged in the process for major changes to facilities as indicated below:

> *PO10*: "There *have been some few cases where those earlier operating companies had changes in their facilities, and they had to engage us on how to implement that on their management systems, and we went through, and it was accepted by the commission [Regulator]. In these days of our operations, we have not had such engagement for this management of change situations*'.

> *PO1*: "*Management of change regime exists in the HSE regulations that should work in case there is a major change in the facilities, they should be brought to the attention and engagement of the regulator. It is reactive in the sense that in case of any major change in the facility, you have to react to the regulator for engagement where you are required to submit a risk assessment on that change for approval by the regulator'.*

The participants acknowledged the existence of management of change requirements in the upstream oil and gas operations. The reactive nature of the existing change management regime gave the impression that companies responded to changes when incidents had happened. This was an apparent deficit of the requirement for proactive management of safety in the industry. It was found that operators only engaged the regulatory authorities on major changes to the facilities. The definition of major change to facilities was not clearly stated. There were some changes to facilities that were not brought to the attention of the regulatory authorities. These issues might account for an inadequacy in adaptation to changed situations which was a critical requirement in robust safety management.

4.2.1.4.2.4 Issues Influencing Safety Regulatory regime

The study investigated the issues influencing safety regulations in Ghana's upstream oil and gas industry. Table 4.15 presents the issues identified by the participants as those that influenced safety regulatory regime in Ghana's upstream oil and gas industry. From the analysis, the 14 (100%) participants indicated that lack of national safety policies, lack of safety guidelines and lack of independence of the regulatory body affect existing regulatory regime. Here is the presentation of some examples of the responses of the participants:

> PO8: *"As a country, safety is not a top priority to our leaders, and that is why up to now, there are no existing national safety policies".*

PO12: *"Ever since we started the oil and gas industry, there have not been single HSE guidelines developed by the state. We rely on those international standards…".*

P011: "*There have been conflicting views on the independence of the PC (regulator). We have many people that are saying we should separate the HSE functions of the PC from its core mandate of licensing. I share this view because a single body responsible will fill its gap of independence*".

13 (92.9%) of the participants disclosed that there is no regulatory policy on safety research and development in the current state of the upstream oil and gas industry. For example, PO10 response revealed the following:

PO10: "*As we speak now, there is no regulatory policy on safety research and development for the country to develop adequate capacity in addressing safety risks in the industry".*

12 (85.7%) participants pointed out existing safety laws are scattered, which affect the coherence of safety regulations in Ghana's upstream oil and gas industry. For example, PO3 shared this:

"like I said we have laws scattered; we have the factory inspectorate, we have the environmental protection regulations, health and safety regulations for the upstream sector, so these pieces of regulations are those that governing the sector as of today and it affects the coherence of how effective we must regulate the upstream activities".

10 (85.7%) and 9 (64.3%) of the participants revealed that insufficient resource and inadequate safety requirements in procurement for local contractors affect the efficacy of the safety regulation in upstream oil and gas industry. 6 (42.9%) of the participants shared the view that corruption emanating from officials in regulatory institutions affect the effectiveness of enforcement of the safety regulations. For example, PO10 revealed his experience:

"*When fishermen are picked up by the Navy, and when they come to shore, they make some few calls, you must relinquish and give them back their motor. And this is a very simple issue that can be dealt with, but if you look at the intricacies of the thing, nobody wants to take a gaze. And this is straightforward enforcement that we ought to have done, but we can't do at this state because fishermen are crying, they know politicians, they will call their MP, they will come, and you don't have a case with them. So, it's a major problem because of 'whom you know' and stuffs like that; you are unable to complete the enforcement fully we must have done*".

In short, the study found the following issues to have influenced safety regulations in Ghana's upstream oil and gas industry: lack of national safety policies, lack of safety guidelines and lack of independence of the regulatory body, lack of policies for investment in safety training and development, scattered safety laws, insufficient resources, inadequate safety requirements in procurement for local contractors and corruption.

Table 4. 15 Regulatory Issues identified by interview participants

Issues Identified	**Participants (*N* = 14)**	
	Number of Responses	**Percent (%)**
Lack of national safety policies	14	100
Lack of safety guidelines	14	100
Lack of independence of the regulatory body	14	100
Lack of policies for investment in safety training and development	13	92.9
Scattered safety laws	12	85.7
Insufficient Resources	10	71.4
Inadequate safety requirements in procurement for local contractors	9	64.3
Corruption	6	42.9

4.2.1.4.2.5 Barriers to Robust Implementation of Safety Management Systems

The study explored the barriers to robust implementation of safety management systems in the upstream oil and gas operations (table 4.16). 18 (100%) responses of the participants indicated poor safety culture practice among the workforce and the local contracting companies affect the implementation of the companies' safety management systems. 14 (100%) of the participants indicated a knowledge gap and 12 (85.7%) pointed out inadequate safety involvement as barriers to the implementation of safety management systems. 11 (78.6%) of the participants revealed the following barriers to implementation of safety management systems in their respective organisations: lack of supporting environment, inadequate communication and lack of awareness creation. 10 (71.4%), 9 (63.3%), and 8 (57.1%) of the participants indicated lack of motivation, poor contractor safety management and limited resources as the barriers to the robust implementation of safety management systems in the upstream oil and gas operations. However, from the analysis, the main barrier was the safety culture practice among the workforce and the local companies. Several of the barriers can be linked to the safety climate constructs.

Table 4. 16 Identified barriers by interview participants

Barriers	Participants (*N* = *14*)	
	Number of References	**Percent (%)**
Poor safety culture	14	100
Knowledge gap	14	100
Inadequate safety involvement	12	85.7
Lack of supporting environment	11	78.6
Inadequate communication	11	78.6
Insufficient monitoring	11	78.6
Lack of awareness creation	11	78.6
Lack of motivation	10	71.4
Poor contractor safety management	9	63.3
Limited resources	8	57.1

4.2.1.4.3 Key Findings of the Semi-structured Interviews

The analysis of the semi-structured interview pointed to several weaknesses associated with existing safety management in Ghana's upstream oil and gas industry. The key findings are summarised as follows:

- *Inadequate integrative risk governance framework:* The issues identified here included: insufficient multiple stakeholders' involvement in the risk frames; limitation in application of qualitative risk assessment methods to identify the problems that were linked to the risks; the weather conditions, corrosions and offshore fishing activities were critical to the risk of offshore oil and gas operations; existing risk acceptance criteria was relatively mechanical as it aimed at satisfying the regulatory requirement; poor safety culture practice by contracting organisations; lack of independence of the supervisory authority and lack of institutionalization of discourses for risk information sharing among all the stakeholders.

- *Existing safety case regime lacks robustness***:** The safety case regime has not been sustained for a more extended period under the self-regulations.
- *Inadequate change management regime*: Existing change management regime is reactive to incidents and lacks adequate engagement of stakeholders in implementation.
- *Limited support for safety regulation*. Existing safety regulations are challenged with several issues such as lack of national safety policies, lack of safety guidelines and lack of independence of the regulatory body, lack of policies for investment in safety training and development, scattered safety laws, insufficient resources, inadequate safety requirements in procurement for local contractors and corruption.
- *Poor safety culture affects the robust implementation of safety management systems.*

4.2.2 Defining the Problem of the study

Since the commencement of commercial oil and gas production in Ghana in 2010, safety is now beginning to receive attention in both the industry and the research community. A review of the current safety regulatory regime points to several gaps which include incoherence and limitation of the scope of the regulatory properties, features of integrative risk governance as critical requirements for handling complexity, uncertainty and ambiguity were not reflective in the existing safety case regime and no safety guidelines. An earlier analysis of the unpublished data indicated a rising trend of hazard incidents in Ghana's upstream oil and gas industry. These hazard incidents were mainly occurred during production operations, office, warehouse, lifting, crane, rigging, deck operations, constructions, installation, subsea and transport-related activities and have most interfaces with existing facilities. However, to identify the issues influencing these hazard incidents, questionnaire surveys were conducted, which indicated that poor safety culture practices determined by safet climate measures, have a predictive influence on hazard incident risks. The semi-structured interviews conducted among the professionals in safety managerial or supervisory and compliance monitoring related positions revealed several key issues such as existing safety case regime lacks robustness, inadequate integrative risk governance framework, insufficient change management regime, limited support for safety regulation and poor safety culture poses difficulties to the robust implementation of safety management systems. Therefore, the current safety management regime is inadequate to address the complexity, uncertainty and the ambiguity associated with Ghana's upstream oil and gas operations.

4.3 Stage 2: Defining Requirements of the Framework

This section presents the second activity of the DSR process. The purpose of this activity is to define requirements and outline a solution to address the explicated probem established in section 4.2.2. In this context, a requirement is defined as a property of the framework that is considered desirable by the stakeholders in the industry and that is to be utilised for guiding the development of the framework (Johannesson & Perjons, 2014). The study organised workshop and elicited views on ways to address the issues defined. These views were outlined for consideration for the development of a framework for robust safety management in Ghana's upstream oil and gas industry.

4.3.1 The Workshop

The workshop was organised under the theme: "*Robustness thinking in safety management: how do we improve the issues in Ghana's upstream oil and gas industry*". In this workshop, the same participants recruited for the semi-structured interviews in the first DSR activity were the only target population considered for this activity. Because these participants are the main beneficiaries of the DSR outcome, they must be used throughout the rest of the DSR activities. However, it must be indicated that only 85.7% of the participants attended the workshop. The organisation of this workshop confronted several challenges including several postponements of the workshop due to unavailability of the participants and insufficient resources.

4.3.1.1 Key Areas to Elicit Solutions

This section presents the results of the participants suggestions regarding ways to improve safety management in Ghana's upstream oil and gas industry. There were three main categorised issues that were presented to the participants for elicitation of solutions:

- *Regulatory influences*
- *Integrative risk governance*

- *Improving existing safety culture*

4.3.1.1.1 Regulatory Influences

There were nine mechnisms suggested by the participants to improve the regulatory issues identified in phase activity (see section 4.2.). Table 4.16 presents the mechanisms suggested by the participants to address the regulatory issues. 11 (91.7%) participants suggested that the country's upstream oil and gas industry must have a separate independent HSE regulatory agency. This suggestion represented the first solution to fill or address the existing regulatory issues in the industry. The current arrangement in terms of the main role of the PC covers both the granting of licenses and safety compliance monitoring of companies' upstream oil and gas activities. The second suggestions made by 10 (83.3%) participants covered both government formulation of national HSE policies and the development of national regulatory framework to capture relevant safety statutes, regulations and guidelines. It was suggested that government formulates national HSE policiesthat incorporates the upstream oil and gas industry. Presently, there is no developed HSE policies at the level of the ministry of energy (Petroleum) and there are existing pieces of safety laws. These safety laws relevant to the upstream oil and gas are required to be brought under one regulatory framework. 9 (75%) participants representing the third suggestions indicated that government should set up a fund that would be utilised specifically for investment in safety training and development of the technical competence of the HSE department and the local contractors. This could help to improve the knowledge gap in the industry. 8 (66.7%) participants which represented the fourth suggestions indicated an establishment of adequate contractors' safety development and reward schemes and regulatory agencies must provide adequate resources for addressing HSE issues in the industry. 7(58.3%) participants reprenting the fifth suggestions pointed out that contractors must be made to demonstrate enough HSE content during tender process. 6 (50%) participants representing the sixth suggestion pointed out a pre-assessment of contractors' safety skills, capacity and equipment on sites, and the requirement for an effective co-ordination, supervision, communication and co-operation as on site.

Table 4. 17 Mechanisms to address the regulatory issues in the workshop

Mechanisms for Regulatory Improvement	Participants (*N* = 12)		
	Ranking of Suggestions	**Number of Suggestions**	**Percent (%)**
Establishment of a separate HSE regulator	1st	11	91.7
Government formulates national HSE policies	2nd	10	83.3
Development of an integrated regulatory framework to capture relevant safety statutes, regulations and guidelines	2nd	10	83.3
Establishment of fund for investment in technical safety training and research	3rd	9	75
Establishment of adequate contractors' safety development and reward schemes	4th	8	66.7
Provision of adequate resources for safety	4th	8	66.7
Contractors must be made to demonstrate sufficient HSE content during tender process	5th	7	58.3
There must be requirement for pre-assessing contractors' safety skills, capacity and equipment on sites before allowed to start work	6th	6	50
Operating companies must provide effective co-ordination, supervision, communication and co-operation on sites	6th	6	50

4.3.1.1.2 Adequate Integrative Risk Governance

The study elicited suggestions from the particpants on how to improve the current risk governace in Ghana's upstream oil and gas industry. There were five main areas that characterised the elements of integrative risk governance which had issues in the upstream oil and gas operations. They include inadequate stakeholders' involvement in the risk frames, limited application of qualitative risk assessment methods to identify the human and organisational issues that were linked to the risks; mechanistic nature of risk appraisal as it mainly satisfied regulatory requirements; poor safety culture practice particularly by contracting organisations, and inadequate risk information sharing. This section presents the mechanisms suggested by the participants to improve the governance of risk in the industry.

4.3.1.1.2.1 Multiple Stakeholders' Involvement in Risk Framing

The study identified several local actors that were required to be involved in the risk framing. Table 4.17 presents the relevant stakeholders that must be considered in the framing of the risk issues. It must be indicated that 12 (100%) participants suggested that the following stakeholders as important for the risk framing: PC, EPA, operators, shareholders, management (staff), workers, contractors, GFC, GAF, NADMO, and GFS. 11 (91.7%) participants suggested GFS, GCAA, and GMET as relevant stakeholders. 10 (83.3%) participants suggested the labour union as an important stakeholder to the risk framing. 9 (75%) and 8 (66.7%) participants indicated GMA, GPHA and the local authorities as relevant stakeholders for the risk framing respectively.

Table 4. 18 Multiple stakeholders' involvement in risk framing

Stakeholders relevant in risk framing	**Role of Stakeholders in risk framing**	**Participants (*N* = 12)**	
		Number of suggestions	**Percent (%)**
PC	Health and safety protection	12	100
EPA	Environmental protection	12	100
Operators	Oil and gas operating activities	12	100
Shareholders	Funding the operating activities	12	100
Management (staff)	Managing day-to-day operations	12	100
Workers	Undertaking operational activities	12	100
Contractors	Oil and gas contracting activities	12	100
GFC	Regulation of offshore fishing activities.	12	100
GAF	Marine security	12	100
NADMO	Disaster management	12	100
GFS	Fire prevention	11	91.7
GCAA	Regulation of air transport	11	91.7
GMET	Provision of meteorological information	11	91.7
Labour union	Protection of workers' condition of employment	10	83.3

GMA	Protection of marine environment	9	75
GPHA	Port regulations (FPSOs)	9	75
Local authorities	Protection of local economic livelihood	8	66.7

4.3.1.1.2.2 Risk Estimation

The study elicited suggestions on the best methods to ensure that human and organisational issues were incorporated into the risk estimations. As shown in table table 4.18, 7 (58.3%) participants stongly agreed that objective risk assessment rooted in engineering probabilitics modelling of scenarios and events should continually be employed. 5 (41.7%) participants stongly agreed with the suggestion of qualitative risk assessment of the background knowledge of the risks. In terms of these two types of risk assessment, the majority of the participants favoured the engineering probabilistic modelling of the scenarios and events. However, the 12 (100%) participants strongly agreed to the need to utilise both the engineering probabilistic modelling of the scenarios and events, and the concern assessment of the issues linked to these scenarios and events.

Table 4. 19 Views on interdisciplinary risk estimation

Emphasis on methods of risk etimations	*N*	*Strongly agree*	*Agree*	*Undecided*	*Disagree*	*Strongly disagree*
Objective risk assessment (Probabilistic modelling of scenarios and events)	12	7 (58.3%)	4 (33.3%)	0 (00%)	1 (8.3%)	0 (00%)
Qualitative risk assessment of background knowledge linked to risks (Concern assessment)	12	5 (41.7)	4 (33.3%)	0 (00%)	3 (25%)	0 (00%)
Both	12	12 (100%)	0 (00%)	0 (00%)	0 (00%)	0 (00%)

4.3.1.1.2.3 Ligitimization of Risk Acceptance Criteria (RAC)

Table 4.19 presents participants suggestions on ways to improve RAC in the risk evaluation. Existing practice mandated the industry to reduce risk as low as possible. However, 11 (91.7) participants suggested that government (i.e. the regulator) must set the RAC and not the industry. In addressing the legitimacy issues in the industry, majority of the participants 10 (83.3%) suggested the presence of transparency to avoid the propensity of the company or the industry to obscure the real risk. 9 (75%) participants indicated accountability and trust between the regulator and the companies as mechanisms to address the legitimacy issues in the risk evaluation. 8 (66.7%) and 7 (58.3%) participannts suggested the involvement of experts in the risk appraisal and workshop involving the relevant stakeholders to deliberate on the risk respectively.

Table 4. 20 Participants suggestions on improving risk appraisal

Mechanisms for Ligitimising RAC	**Participants (*N* = 12)**		
	Ranking of suggestions	**Number of suggestions**	**Percent (%)**
Government must set the RAC	1st	11	91.7
Transparency	2nd	10	83.3
Accountability	3rd	9	75
Trust between companies and PC	3rd	9	75
Involvement of experts	4th	8	66.7
Workshop involving key stakeholders on risk deliberations	5th	7	58.3

4.3.1.1.2.4 Monitoring and Controlling of Risk Isuess

The particpants suggested some ways to improve risk management in the upstream oil and gas industry. Table 4.21 presents the participants' suggestions to improve risk governance. 11 (91.7%) suggested dialogue and the strengthening of safety culture in the industry as important ways to address the risk management issues in the industry. 10 (83.3%) were of the view that collaboration between the companies or the industry the government (regulator) should exist to improve safety performance in the industry. In addition to this, 7 (58.3%) particpants suggested that the need to ensure enough competence in the auditing activities by the regulator.

Table 4. 21 Participants suggestions to improve risk management

Mechanisms	Participants (N = 12)		
	Ranking of suggestions	Number of suggestions	Percent (%)
Development of dialogue between companies and PC	1st	11	91.7
Strengthening of safety culture	1st	11	91.7
Collaboration between companies and PC	2nd	10	83.3
Frequent and surprise visits to companies' sites	3rd	9	75
Sufficient technical competence in auditing	4th	7	58.3

4.3.1.1.2.5 Risk Information Sharing

Several means to share information about risk have been suggested. Table 4.21 presents the participants' suggestion of mechanisms to improve risk information sharing. The first mechanism is the email messages as 12 (100%) participants acknowledged that it was fast to share information to stakeholders. 11 (92.7%) suggested permit meetings and companies' morning meetings as another way information about risk could be shared. 9 (75%) and 8 (66.7%) participants suggested the need to have quarterly roundtable discussions with the players of the industry and the regulatory agencies respectively.

Table 4. 22 Participants' suggestions of mechanisms improve risk information sharing

Mechanisms	Participants (N = 12)		
	Ranking of suggestions	Number of suggestions	Percent (%)
Email messages	1st	12	100
Permit meetings	2nd	11	91.7
Companies morning meetings	2nd	11	91.7

Quarterly round table discussions with players and the regulatory agencies	3rd	9	75
Annual safety forum/conference	4th	8	66.7

4.3.1.1.3 Safety Culture Drivers

It must be indicated that all the participants acknowledged that improving safety culture was a complex issue. This means that it requires a collective effort from all the stakeholders involved in the upstream oil and gas industry. Table 4.22 shows several suggestions that can drive safety culture improvement in the industry. 12 (100%) participants suggested the need for investment in safety training and development and behavioural change of workers. 11 (91.7%) indicated that leadership commitment must reflect on both safety values and actions. 10 (83.3%) suggested effective change management, active participation and involvement in safety and effective communication channels, both 'top-down' and 'bottom-up' approaches. 9 (75%) participants submitted that a positive supporting and guiding working environment must be created at the sites. 8 (66.7%) indicated the need for reward packages to stimulate safety behaviour at the workplace. It must be stated that 7(58.3%) suggested the need for learning from incidents and accidents and continuous improvement of safety in the industry.

Table 4. 23 Suggested drivers of safety culture improvement in the workshop

Drivers	**Participants (*N* = 12)**		
	Ranking of Suggestions	**Number of Suggestions**	**Percent (%)**
Investment safety training and development	1st	12	100
Behavoural change	1st	12	100
Leadership commitment to both safety values and actions	2nd	11	91.7
Effective change management	3rd	10	83.3
Active participation and involvement in safety	3rd	10	83.3
Effective communication channels both 'top-down' and 'bottom-up' approaches	3rd	10	83.3
Positive supporting and guiding working environment	4th	9	75
Reward packages	5th	8	66.7

Learning from incidents and accidents	6th	7	58.3
Continuous improvement	7th	7	58.3

4.3.1.2 Outline of the Solution

There were three main themes that the participants suggested mechanisms to improve in the industry: regulatory influences, integrative risk governance and culture influences. These themes have influences on incidents and accident risks in the industry.

Regulatory influences have been identified in the literature as critical contributors to numerous incidents and accident in the oil and gas industry (Carden et al, 2017; Theophilus et al., 2017). These contributory influences relate to deficiencies in the governance of national statutes, regulations and international standards. The participants suggested seven ways to improve existing regulatory issues in Ghana's upstream oil and gas industry:

- There must be a separate independent HSE regulatory.
- Government must establish national HSE policies.
- There must be a unified safety regulatory framework to cover statutes, regulations and guidelines.
- Government must set up fund for investment in safety capacity training and research.
- There must be establishement of adequate contractors' safety delopment and reward schemes.
- Provision of adequate resources.

Integrative risk governance has become a critical approach to address the complexity, uncertainty and ambiguity issues associated with risk in the oil and gas industry (Marjolein et al., 2011; Renn, 2014). The basic aim of the integrative risk governace is to involve the relevant stakeholders in the gathering, assessing, evaluating, managing and communicating the risks knowledge. The participants suggested the following mechanisms to address the the risk governance deficiencies in Ghana's upstream oil and gas industry:

- *Multi-stakeholder involvement approach in risk frames*: It must cover the various government agencies, the industry actors (shareholders, operating organisations, contracting organisations, staff and workers), labour union and the local authorities.

- *Interdisciplinary risk assessment*: Existing engineering probabilistic risk assessment must incorporate the backgound knowledge of human and organisational issue that link to the risk.
- *Legitimisation of the risk evaluation*: This requires the government setting the RAC, tranparency between the company or the industry and the regulator, accountability to stakeholders and the government, involvement of experts in the risk appraisal and the deliberation of the risk isues among the relevant stakeholders.
- *Controlling and monitoring of risk*: It involves dialogue between the companies or the industry and the government regulatory agencies, strengthening of safety culture, collaboration between the companies or the industry and the government regulatory agencies, regular visitation to companies' sites and the sufficient technical capacity in auditing.
- *Risk information sharing*: Various mechanisms have been suggested to improve risk information sharing which include the following: emails messages, permit meetings, organisations' morning meetings, qaurterly roundtable discussion with the companies or the industry players and the government regulatory agencies, and the establishent of annual safety forums or conferences.

Safety culture has been established to improve safety performance in the industry. It drives regulatory performance (Yang, 2019), organisation's implementation of safety management systems (NEB, 2014), and workers safety behaviour at the workplace (Álvarez-Santos et al., 2018). The study suggested several drivers that would improve existing poor safety culture in the regulatory agencies, companies and the workers. The following drivers are required to improve safety culture in the upstream oil and gas industry: investment safety training and development, behavoural change, leadership commitment to both safety values and actions, effective change management, active participation and involvement in safety, effective communication, positive supporting and guiding working environment, safety motivation, learning from incidents and accidents and continuous improvement of safety.

4.4 Stage 3: Developing the Framework

This section presents the third activity of the DSR process. It seeks to develop a framework that fulfills the defined problem and requirements in stage 1 and 2 of the DSR process respectively. The main resources for this activity were drawn from the literature and the empirical findings of this study. The main concepts that formed the structure of the proposed conceptual framework were outlined and linked to the empirical findings of stage 1 and 2 of the DSR process. The conceptual framework was developed and described.

4.4.1 Proposed Conceptual Framework

As indicated in chapter 1 (see section 1.4), the final research objective of this study is to develop and refine a framework for robust safety management in Ghana's upstream oil and gas industry. According to Imenda (2014), a framework provides a structure that are based on data collected from various sources.

In this section, a proposed conceptual framework was developed which focused on the key concepts from the literature and the main information through the documents review, questionnaire surveys, semi-structured interviews and the workshop (figure 4.7.). Given this context, the key components forming the structure of the framework was defined for the proposed conceptual framework. This proposed conceptual framework could be used as a practical tool to guide robust safety management in Ghana's upstream oil and gas industry.

4.4.1.1 The Core Components Defining the Proposed Conceptual Framework

Based on the literature and the empirical findings of this study, four components were derived to constitute the structure of the proposed conceptual framework. They include the following:

- Level 0: *Sociotechnical structure*
- Level 1: *Integrative risk governance*
- Level 2: *Safety climate drivers*
- Level 3: *Feedback*

These components were linked to the literature and the empirical findings of the study.

4.4.1.1.1 Level 0: Sociotechnical Structure

As indicated in the literature review chapter (section 2.2), safety management is a control problem (Rasmussen, 1997; Björn & Rollenhagen, 2014; Li & Guldenmund, 2018). In a high-risk environment like the oil and gas industry, there is a complexity associated with the upstream oil and gas operations that involves the interactions of the government, regulatory agency, industry (drilling-rig owners, operating organisations and various different contracting organisations) and the workers. Such complexity of the systems has interations of the technology, humans and the organisation which features interwoven domains of knowledge. This complexity may create performance variability in the systems. Therefore, safety becomes a dynamic property of the systems. Given this, all these stakeholders are required to be co-ordinated systematically in a manner that will control the performance of the manchine (technology), workforce (humans) and the physical environment (organisation). In this context, the first start of the conceptual framework is to recognise the critical importance of sociotechnical system theory in safety control. It addresses the complexity issues in the systems. The sociotechnical systems feature captures the hierarchical safety control structure in the upstream oil and gas operations. It identifies the roles of the government, regulatory agency, industry and the workforce towards fulfilling the primary aim of the safety function. As pointed out in the literature review chapter (section 2.2), the basic functions of safety management include the protection of human beings, property and the environment from unacceptable risks.However, from the data analysis (see section 4.3.1.1.1), the participants indicated the need for national HSE policies for the industry. They also pointed out the need for an integrated HSE regulatory framework for the industry that captures the relevant national safety statutes, regulations, guidelines as well as the international standards and industry best practices.

As indicated in the document review (see section 4.2.1.1.1.1)**,** the current regulatory framework for Ghana's upstream oil and gas industry lacks coherence and adequacy relative to the scope of the regulatory properties. From the literature review chapter (see section 2.7), the industry is required to robustly implement its safety management systems. Within the context of this study, the industry broadly covers both the operating and contracting organisations. In the industry, in some cases, the operating organisations may lack the technical expertise to execute the tasks and therefore require outsourcing. Therefore, contracting activities are critical for the industry. Ghana's local content regulations for the upstream oil and gas industry puts a mandatory requirement of the operating companies to recuit both th local workforce and the local contracting organisations. However, the data analysis (see section 4.2.1.4.2.5) indicated existence of knowledge gap in HSE requirements among local contractors. From the data analysis (see section 4.3.1.1.1), it is important that operating organisations when outsourcing, must emphases the requirement for an adequate HSE scope in contractors' qualification process, pre-assessment of contractors' safety skills, capacity and equipment used for their work. These requirements would help to improve the contractors'safety management systems implementation. The findings of the questionnaire surveys also indicated workers' unsafe acts in Ghana's upstream oil and gas industry (see section 4.2.1.3.6). Such unsafe acts have an effect on the implementations of the safety management systems in the industry.

To address the complexity of the risk related issues that are imbedded in the hierarchincal level of the upstream oil and gas operations, safety must be conceived as an emergent property of a sysatem. This requires that the interwoven domain of knowledge relating to risk in all the hierarchical levels that are linked to the upstream oil and gas operations must be considered. Government is to develop policies towards the fulfilment of the safety functions (i.e. HSE policies). The regulatory agency is required to make safety rules and enforce them. In other words, it must develop a regulatory framework that must reflect both national and international contexts. This is because the upstream oil and gas industry reflects globalisation characters (Mearns & Yule, 2009; Blakstad, 2014). The regulatory agency must provide for national safety statutes, regulations and guidelines. It must also provide for international best industry practice to reflect those international characters. This regulatory framework must be enforced to ensure that the industry comply with to achieve the safety goal. The industry is required by regulation to implement a safety management system. It must develop HSE competence assessments for their outsourcing activities. This must involve the interation between operating and contracting companies in terms of HSE competence. Contractors must demonstrate an adequate HSE scope in the qualification process, pre-assessment of contractors' safety skills, capacity and equipment must be conducted. There must be collaboration, supervisions and effective communication between them. Workers' unsafe acts are key barriers to implementation of organisational safety management systems. This is because a high-quality human performance in terms of its interaction with with technology and organisational processes is critical to improve safety performance. However, after identification of the various safety control issues emerging from the hierarchical sociotechnical systems, an effort must be made to integrate the institutional structure, policy process guiding and confining the collective operaions of the various stakeholders. This requires an integrative risk governance.

4.4.1.1.2 Level 1: Integrative Risk governance

Given the complexity, uncertainty and ambiguity risk-related issues associated with upstream oil and gas operations, the literature review chapter (section 2.4.2.1) indicated an integrative risk governance approach is critical to handle such issues. It must cover the requirement of multiple actor-network in framing the risks, interdisciplinary risk assessment, legitimisation of the method and process in evaluating the risk, management of the risk which requires monitoring and controlling of the risk, and risk information sharing which emphasises inclusion of stakeholders (Renn, 2014; Hale, 2014; Linkov et al., 2018). The main research findings from the documents review (section 4.3.1.1.2.1) suggested the need to have a multi-stakeholder involvement in the framing of the risk issues that must cover the various government agencies, industrial actors, labour union and the local authorities. The activities of these stakeholders influence the risk of the upstream oil and gas industry. For instance, from the semi-structured interview (section 4.2.1.4.3), it was indicated that the weather conditions, corrosions and offshore fishing activities pose a risk to the offshore oil and gas operations. Regulatory agencies such as the GMET and GFC must be involved in the framing to help in profiling the localised knowledge of risk. The findings of the workshop suggested the need to have interdisciplinary risk assessment which must incorporate human and organisational factors to the QRA. The legitimisation of the RAC has become a vital issue in the literature. The authority to control the risk of upstream oil and gas activities is inherent in the sovereignty of the state, which is exercised through the regulatory agencies. The current safety regulatory regime reflects government-enforced self-regulation. The participants (see 4.3.1.1.2.3) indicated that the government should set the RAC as well as providing procedures that defined transparency, accountability, trust, investment of experts and stakeholders' deliberation of the risk. The workshop (see section 4.3.1.1.2.4) suggested the need for dialogue, strengthening of safety culture, collaboration and regular surprise visitation and to sites and adequate competence in auditing as essential ingredients to have an effective monitoring and controlling of risk in the industry. The study indicated the need to have an improved strategy to communicate risk information to the stakeholders. The study (see section 4.3.1.1.2.4) suggested these strategies such as emails, permit meetings, morning meetings, monthly roundtable discussion and annual safety forum as essential ways to improve existing risk information-sharing approach.

4.4.1.1.3 Level 2: Safety Climate Drivers

Safety culture influences safety performance. The literature (section. 2.6) indicated that safety culture drives policies and procedures, implementation of an organisational safety management systems and the behaviours of the individual workers. In other words, it drives the regulatory, organisational and workers' influences. One primary assumption in the safety literature is that workers' safety or unsafe behaviours are a function of the prevailing safety culture of the organisation. Because of the conceptual challenges in measuring organisational safety culture, safety climate is mostly applied to measure the tangible outputs or indicators of an organisation's safety culture (Guldenmund, 2010). Safety climate has been established as a robust indicator that drives the implementation of safety management systems (Kim et al., 2019).

However, from the data analysis, both the documents review (see section 4.2.1.1) and the semi-structured interviews (section 4.2.1.42.4), participants identified several regulatory issues in Ghana's upstream oil and gas industry. The participants (section 4.3.1.1.1) suggested fundamental mechanisms to improve the current regulatory issues in the industry. These mechanisms are summarised to include the following: establishment of a separate independent HSE regulator, development and review of HSE policies to improve safety performance, provision of adequate safety statutes, regulations and guidelines, establishment of fund for investment in capacity building and research, provision of sufficient contractors' safety development and reward schemes, and provision of adequate resources for safety.

Moreover, from the data analysis of the semi-structured interviews (section 4.2.1.4.2.5), the main barrier to robust implementation of organisational safety management systems in Ghana's upstream oil and gas industry was the poor safety culture practice among the local workforce and the local companies. The data analysis of the questionnaire surveys (section 4.2.1.4) indicated the following as key essential factors of safety climate that influence organisational safety performance: safety supervision, management of change, safety empowerment, management commitment, safety policies, safety rules and procedures, safety prioritisation, supportive environment, safety communication and safety behaviour. To improve safety supervision in the organisations, active participation of line managers, supervisors and the workforce, swift response to safety-related issues and provision of sufficient safety technical knowledge. Improvement in management of change issues requires adequate specification of roles and responsibilities of line managers, supervisors and management, regular update of information on the change procedures and the facilities, and effective controlling of the process continuity, resources and the outsourcing. Safety empowerment can be improved when there is a creation of a free working environment where workers are encouraged to influence safety decisions and permitted to correct safety-related issues. The main important ways to improve management commitment is where leaders are committed in their values and actions towards driving safety performance. Safety policies are required to be well understood and implemented in the activities of the managers and workers. Safety rules and procedures must be adequately written to reflect the working safety requirements of the facilities. The best way to improve safety prioritisation is where safety-related issues are prioritised in decision making as against production. There must be a supporting and guiding working environment of the activities of the individual workers.

4.4.1.1.4 Level 3: Feedback Mechanisms

The emphasis of safety key performance indicators is to monitor the system performance. Monitoring system performance requires both reactive and proactive indicators. Feedback mechanism offers an important avenue for the industry to learn from its failures. It must address both the reactive and active indicators. The former are the safety outcomes relating to incidents, accidents, injuries and fatalities. The latter reflects on the active monitoring of risk control systems to provide feedback on performance. Feedback on the safety outcomes and the safety climate will help to improve safety in the Ghana's upstream oil and gas industry. In this study, these two indicators will help to improve on the learning capability of the existing safety regime.

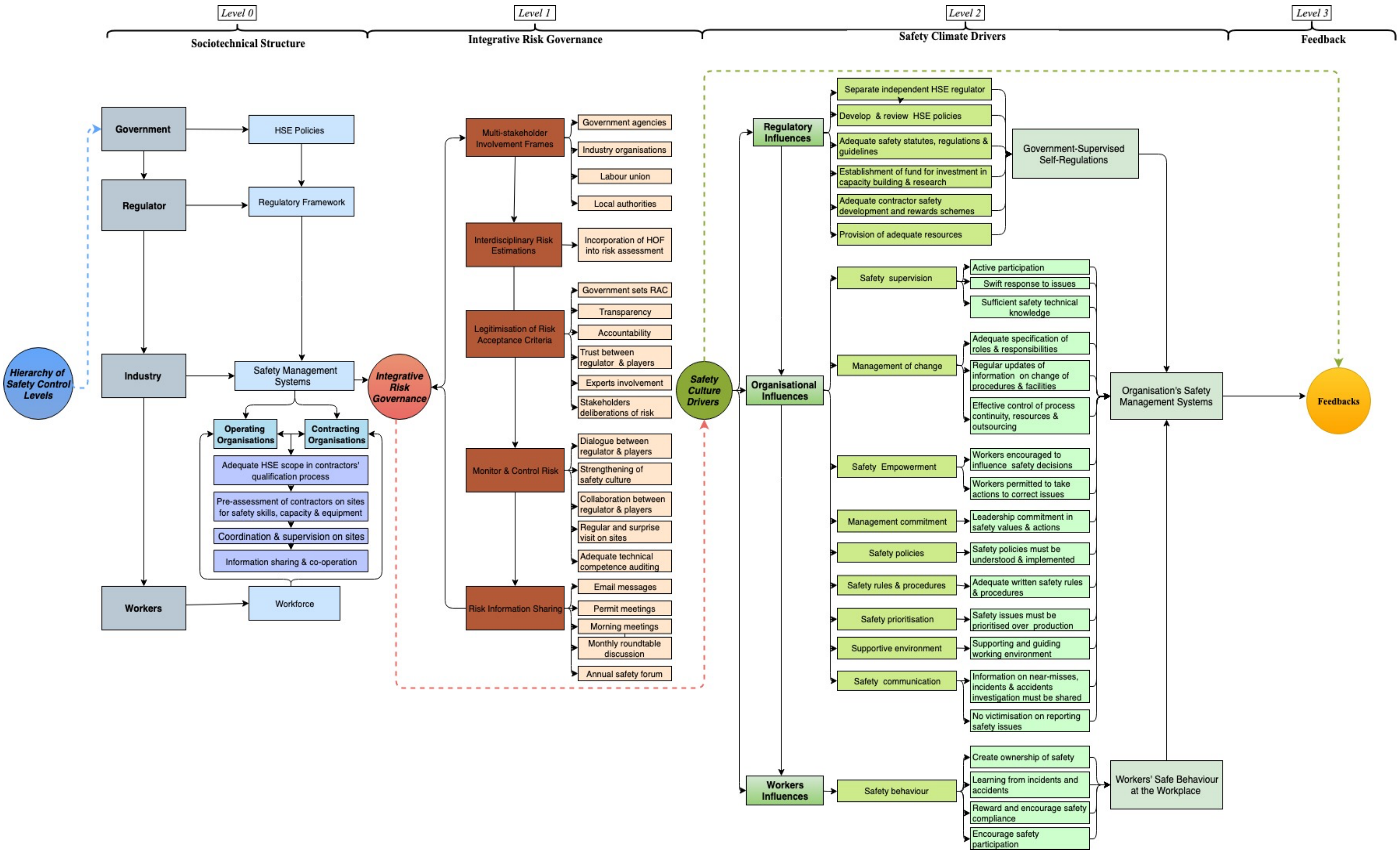


Fig. 4. 5 Initial proposed conceptual framework for robust safety management

4.5 Stage 4: Evaluating the Framework

The previous section (section 4.4) presented stage 3 of the DSR activity, which developed a framework to be utilised as a practical tool to robustly manage safety in Ghana's upstream oil and gas industry. The current section presents the final stage of the DSR activity. The purpose of this section is to determine how well the initial proposed conceptual framework addresses the explicated problem (section 4.2) and to what extent it fulfils the defined requirements (section 4.3) of the study. It establishes the evaluation criteria and strategies, validates the initial proposed conceptual framework through a focus group of industry professionals and presents the refinement of the final proposed conceptual framework.

5.5.1 Evaluation Criteria and Strategy

According to Elragal and Haddara (2019), the stage of evaluating DSR artefact is challenging as there exist several different evaluation techniques to provide the suitable interpretations of the problem and the feedback to improve the quality of the artefact produced. Such diversity of evaluation techniques poses a more challenge for the process. However, the characteristics of the DSR evaluation on the designed artefacts have to be clearly defined (Pries-Heje et al., 2008). As indicated in chapter 3 (section 3.4.3), a designed artefact can be distinguished between *product* and *process*. In this study, the designed artefact (i.e. initial proposed conceptual framework) focuses on processes in improving safety management.

It adapted the hierarchy evaluation criteria developed by Prat et al. (2014) from their review of the DSR literature. As shown in figure 4.8, the evaluation criteria were derived from five main dimensions of a system: goal, environment, structure, activity and evolution. An artefact must have a broader goal to accomplish. The generality of goal forms the first criterion to validate the framework. The second dimension of an artefact is its environment. According to the literature, the environment of a DSR artefact must reflect a sociotechnical system. Given this, people understanding of the artefact function and its consistency with application to the organisation is important to be assessed. The third dimension of an artefact is its structure. The structure of the artefact can be assessed based on the level of details of the constructs and its clarity. The fourth dimension is the activity of the artefact. In this study, the consistency of the artefact in the safety activities is assessed. The final dimension of an artefact is its evolution which must be assessed by its robustness and learning capability. The evaluation strategy adopted by this study was the *Ex ante evaluation* which assessed in a *naturalistic* setting. Ex ante evaluation allows the proposed framework to be validated without being used or even being fully developed. Because this artefact is a process type, it requires that its users validate it in a real-world setting without laboratory evaluation. It speeds up the evaluation process. It allows the proposed framework, which is the initially developed framework to be assessed quickly and inexpensively to elicit feedbacks for further improvement.

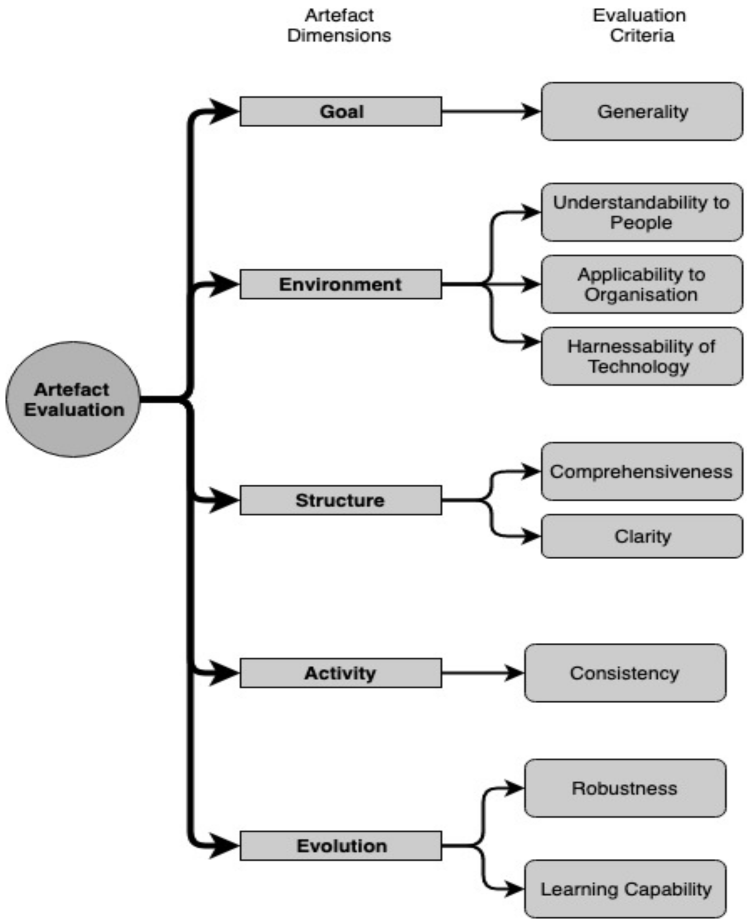


Fig. 4. 6 Hierarchy of evaluation criteria used to validate the proposed framework

Source: Adapted from Prat et al. (2014)

5.5.2 Framework Validation through Focus Group

The evaluation of the framework was carried out through a focus group of industry professionals who participated in the earlier stages of establishing awareness of the problem (section 4.2.1.4.1) and defining the requirements of the framework (section 4.3.1). It must be indicated that nine professionals out of fourteen were available for the participation of the focus group. These participants held safety managerial, supervisory, compliance monitoring and management positions from their regulatory institutions, operating and contracting companies. The focus group was important to be carried out to allow the industry professionals to contribute to the assessment of the relevance of the framework to their respective organisations. The focus group guide is provided in appendix J of this study. The researcher commenced by presenting the framework, which was on a powerpoint presentation to the participants. The researcher presented the literature and empirical findings of the study and explained how the framework was developed. The main theories and concepts and their relationships, which underpinned the development of the framework were clearly explained to the participants. The researcher elicited participants' opinions on the assessment criteria indicated in section 5.5.1. The main feedback and ideas for improvement on the framework were recorded for the analysis. The time duration for this validation activity was 45 minutes.

Figure 4.9 presents the responses of the focus group participants on the validation of the framework. The researcher assessed the general goal of the framework. The framework seeks to provide a practical guide to improve the handling of risk complexity, uncertainty and ambiguity associated with the managing safety in Ghana's upstream oil and gas industry. In terms of the goal dimension of the framework, the results indicated that 50% of the participants agreed to a high extent that this framework fulfils the generality of the safety goal. However, 10% reported the need to improve it further. Given the environmental dimension of the framework, it is required to reflect the sociotechnical features of the frameworks such as its understandability to the industry professionals, applicability to their organisations and the harnessability of technology. The results have shown that 45% agreed that this framework was very well understood. But, 22% of them pointed out the need for further explanation on the framework. 78% of the participants agreed that the framework is highly applicable to their organisation. However, 11% indicated that the framework needs further changes. Whereas 70% of the participants agreed that the framework could be harnessed to improve technological systems safety, 10% disagreed. The structure dimension of the framework was assessed in terms of its comprehensiveness and clarity. 56% of the participants thought that the framework captured more details of the mechanisms to improve safety in Ghana's upstream oil and gas industry. Nonetheless, 33% pointed out the need to incorporate further minor details to the framework. 45% of the participants agreed to a high extent that the structure of the framework is clarified. However, 22% were on the contrary view that the structure required a few further clarifications. The activity dimension of the framework was evaluated on the basis of its consistency. Whilst 45% of the participants thought that the framework was consistent with upstream oil and gas activities, 33% expressed the contrary view that it needed minor improvement. The evolution dimension of the framework was assessed on its robustness and learning capability. The results show that 45% of the participants agreed to some extent that the framework reflects some features of robustness. However, 33% pointed out that the framework needed a minor change. In terms of its learning capability, only 22% agreed that the framework reflects learning capability features. Majority of the participants indicated that the framework needs major improvement on its learning capability. The researcher took note of all the areas that needed to be improved, and this was addressed in the refinement of the framework.

Fig. 4. 7 Responses of the focus group participants on the validation of the proposed framework

5.5.3 Refinement of the Framework

After the validation of the initial proposed conceptual framework, some participants indicated additional comments that needed to be addressed to improve the relevance of the proposed framework. Most of these comments were related to the sociotechnical structure (Level 0), the feedbacks definition and links (Level 3) and the requirement for additional creation of a level purposely to address the element of continuous improvement (i.e. Level 4). At *Level 0*, some participants indicated that the initial proposed framework failed to specify the primary role of the regulator. Some comments by the participants were related to the need to define the rule making and rule enforcement roles of the regulator. Others suggested that the industry also relied on international safety standards as well as a national regulatory framework which have to be captured. At *Level 3*, some participants indicated that the feedback must be well defined and linked to further improvement. Many comments were related to the need to incorporate continuous improvement of the feedback. These comments were considered in the final framework. However, the feedback component (*levels 3*) was removed from the right-hand position and repositioned at the bottom of the final framework. The feedback component was linked to all aspects of the final framework which included the new component, *Continuous Improvement*. The *Sociotechnical Structure* (Hierarchy of safety control levels), *Integrative Risk Governance* and *Safety Culture Drivers* have been linked to the *Feedback* component. The feedback in each level of the final framework is to be improved continuously. Therefore, the feedback and continuous improvement components were linked to all aspects of the final framework.

The primary roles of the regulator were clearly defined to include safety rules making and safety rules enforcement. In the safety rules making, the regulator is required to provide an integrated regulatory framework that must capture both the national safety regulatory framework and international industry standards. The national safety regulatory framework must provide for safety statutes, safety regulations and safety guidelines. Both the national safety regulatory framework and international industry standards must be enforced in the industry.

5.5.4 Description of the Refined Framework

Figure 10 presents the refined conceptual framework for robust safety management in Ghana's upstream oil and gas industry. This framework aims at providing a practical tool to guide policymakers, regulatory agencies and safety managers or supervisors to identify the hierarchical sociotechnical structure for safety control (Level 0), follow an integrative governance process to address complexity, uncertainty and ambiguity of risk-related issues (Level 1), strengthen the safety culture by driving existing safety climate through regulatory, organisational and workers' influences (Level 2), provide feedback on safety statistics and safety climate and ensure continuous improvement of the safety indicators in all aspects of the framework. The refined framework comprises three levels: the sociotechnical structure (Level 0), integrative risk governance (Level 1) and safety culture drivers (Level 2). Each of these levels was linked to the feedback and continuous improvement components. The thicker dotted arrow lines connect one level to another in their respective colours. The arrow lines show the direction of components consideration and the construct dependency. The red thickest dotted double arrows cyclically link the feedback and continuous improvement components to all aspects of the framework.

Level 0: This level allows organisations or practitioners to identify the hierarchical safety control levels in managing safety in the upstream oil and gas industry. The idea behind the identification of this sociotechnical structure is that there are technological, human interfaces and organisational processes involved in the complexity of the upstream oil and gas operations. Each of these safety control levels has a role to play in term of the interaction of technology, human and organisational influences in the system operations. For safety management, all the levels and their component must be identified for control. The first level of the hierarchical sociotechnical structure is the government. The government considers the safety policies component. That is, the government through the ministry of energy is required to develop safety policies to ensure that its implementation protects human lives, facilities and the environment from unacceptable risks of the upstream oil and gas activities. The next safety control level of the hierarchical sociotechnical structure is the regulator. The regulator is a state agency established through an act of parliament with the primary responsibility of making and enforcing safety rules. In this case, the regulator considers two main components: enactment of safety rules and enforcement of safety rules. In terms of its safety rules making component, it is required to provide an integrated regulatory framework that must reflect both national and international regulatory characteristics. The national regulatory framework covers the safety statutes, safety regulations and safety guidelines. The international industry standards are required to be incorporated since the designs of the technology reflect global context. This integrated regulatory framework is enforced in the industry by the regulator. The next level of the sociotechnical structure is the industry. The industry is required to implement safety management systems. The respective operating and contracting organisations perform safety management systems. Because the operating companies most times outsource some of their activities due to limited expertise, they must ensure the following: contractors demonstrate sufficient HSE scope during tender process; pre-assessment of contractors' safety skills, capacity and equipment on sites; provision of an effective co-ordination, supervision, communication and co-operation of the activities of the contractor on sites. The final level of safety control on the sociotechnical structure is the workers. Workers' activities for both operating and contracting organisations are identified and controlled. The feedback from the sociotechnical system must be continuously improved and this is indicated by the red thickest dotted double arrows. Level 0 is connected to Level 1 by the blue thicker dotted arrow lines.

Level 1: After the identification of the hierarchical safety control levels within the sociotechnical system, it follows an integrative risk governance process as shown by the blue thicker dotted arrow line. The purpose of this integrative risk governance is to purposely address the complexity, uncertainty and ambiguity of risk-related issues associated with the upstream oil and gas operations. This integrative risk governance considers these components: multi-stakeholder involvement frames, interdisciplinary risk estimation, the legitimisation of risk acceptance criteria, monitoring and controlling of risk and risk information sharing. The multi-stakeholder involvement frames depend on government agencies, industry organisations, labour union and the local authorities. The interdisciplinary risk estimation relies on the incorporation of human and organisational factors into the risk assessment. The legitimisation of risk acceptance criteria is dependent on government setting up the RAC, transparency, accountability, trust, expert involvement and stakeholders' deliberation of the risk associated with the upstream oil and gas operations, the monitoring and controlling of risk depends on dialogue, strengthening of the safety culture, collaboration, regular and surprise visit on sites and adequate technical competence in auditing. The final component of the integrative risk governance is the risk information sharing which depends on emails massages, permit meetings, morning meetings, monthly roundtable discussion and annual safety forum. The integrative risk governance leads to strengthening the safety culture drivers through the thicker brown dotted arrow line. The feedback from the integrative risk governance must be continuously improved and this is indicated by the red thickest dotted double arrows.

Level 2: After the incorporation of the integrative risk governance level, the next level is the safety climate. As indicated in the literature that safety climate was the manifestation of the safety culture, it was driven by three main components: regulatory, organisational and workers' influences. The regulatory influences were dependent on the following: separate independent safety regulator; develop and review safety policies; adequate safety statutes, regulations and guidelines; establishment of a fund for investment in capacity building and research; appropriate contractor safety development and reward schemes; and provision of adequate resources. These regulatory influences may improve robustness of the government-supervised self-regulations in the industry. The organisational influences considered these components: safety supervision, management of change, safety empowerment, management commitment, safety policies, safety rules and procedures, safety prioritisation, supportive environment and safety communication. Safety supervision depends on active participation, swift responses to safety issues and enough safety technical knowledge. The management of change depended on the precise specification of roles and responsibilities, regular updates of information relative to the change of procedures and facilities, and effective control of process continuity, resources and outsourcing. The safety empowerment was depended on workers' encouragement to influence safety decisions and workers permitted to take actions to correct issues. The management commitment component depended clearly on leadership commitment to safety values and actions. Safety policies must be understood and well implemented. There must be adequate, written safety rules and procedures. Safety issues must be prioritised against production. There must be a supportive and guiding environment. Safety communication was depended on information sharing relative to investigative reports on near-misses, incidents and accidents. These influences must drive towards the robust implementation of organisational safety management systems in the industry. The workers' influences were driven by their safety behaviour which must be depended on the creation of ownership of safety, learning from incidents and accidents, reward and encouragement of safety compliance, and encouragement of safety participation. These influences must contribute to workers' safe behaviour in the workplace. The feedback from the safety culture must be continuously improved and this is indicated by the red thickest dotted double arrows.

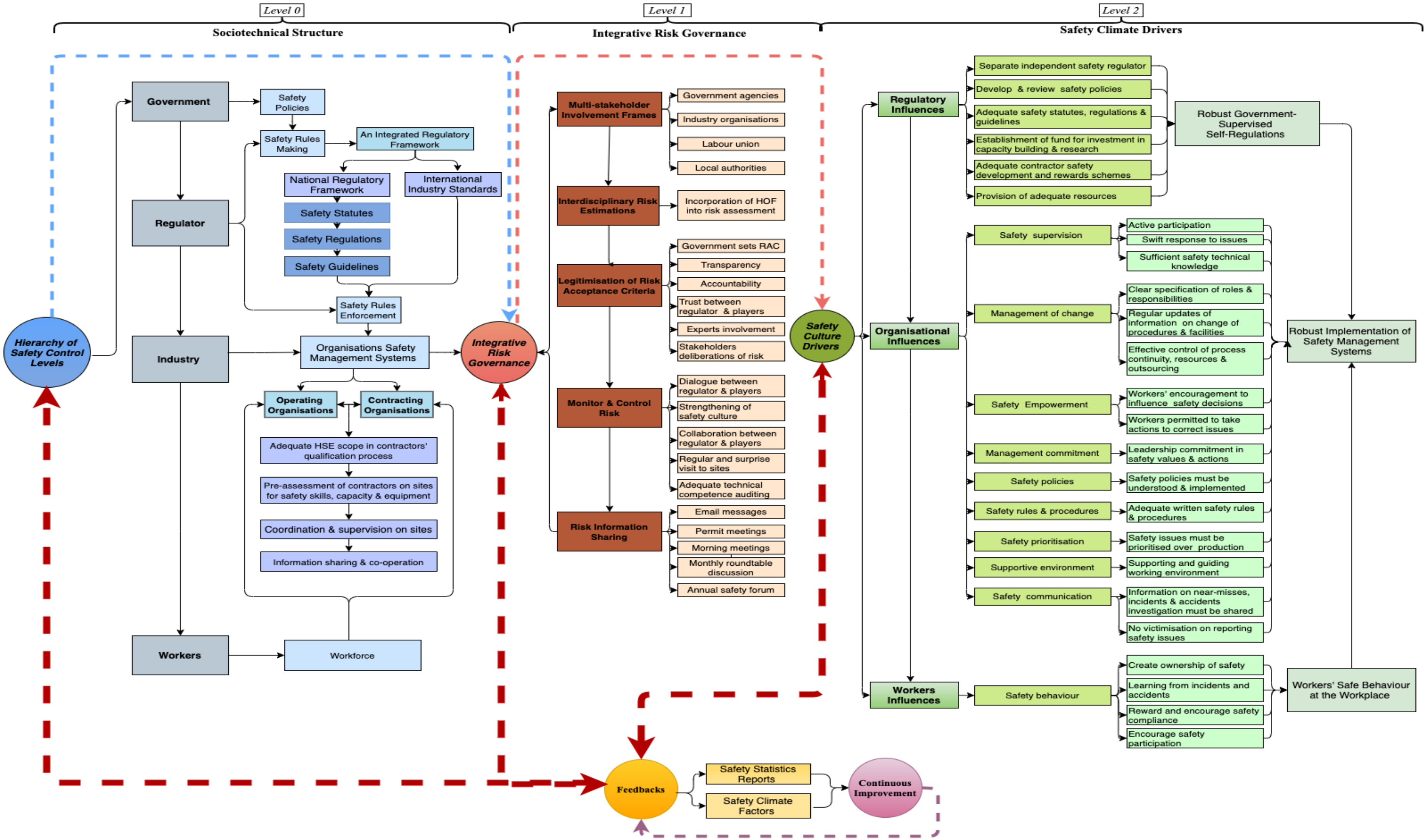


Fig. 4. 8 Refined framework for robust safety management

4.6 Summary

This chapter presented the data analysis and the research findings of the four stages of the DSR activities adopted for the study. Stage 1 established the awareness of the problem through the data analysis of the documents on existing safety statutes and regulations relevant to Ghana's upstream oil and gas industry, quantitative safety data, questionnaire surveys and semi-structured interviews. The main findings indicated several regulatory gaps, increasing incidents trends, poor safety culture practices and inadequate integrative risk governance.

Stage 2 defined the requirements of the framework which outlined the regulatory influences, adequate integrative risk governance and the safety culture drivers. In terms of the regulatory influences, the following were suggested to improve government-enforced self-regulations: a separate independent HSE regulator, government establishing national HSE policies, a unified safety regulatory framework, government setting up fund for investment in safety capacity building and research, establishment of adequate contractors' safety development and reward schemes and provision of enough resources. The following were suggested to address the inadequacy of the current risk governance: the need for multi-stakeholder involvement frames (i.e. government agencies, industry organisations, labour union and local authorities), interdisciplinary risk estimation where human and organisational factors are incorporated in the risk assessment, legitimisation of the risk acceptance criteria (emphasising on government setting the risk acceptance criteria, transparency, accountability, trust, expert involvement, and stakeholders deliberations of the risk), monitoring and controlling of risk (requiring dialogue, strengthening of safety culture, collaboration, regular and surprise visits to sites and adequate development of technical competence in auditing) and risk information sharing (requiring email messages, permit meetings, morning meetings, monthly roundtable discussion and annual safety forum). The following were suggested to drive safety culture: investment safety training and development, behavioural change, leadership commitment to both safety values and actions, effective change management, active participation and involvement in safety, effective communication channels both 'top-down' and 'bottom-up' approaches, positive supporting and guiding working environment, effective change management, reward packages, learning from incidents and accidents and continuous improvement.

Stage 3 developed a conceptual framework based on the literature and empirical research findings. Stage 4 presented the proposed conceptual framework for the participants for evaluation. The validation of the initial proposed framework was done through a focus group.

The feedbacks and additional comments from the focus group were addressed to refine the proposed framework.

CHAPTER 5: DISCUSSION

5.1 Introduction

The previous chapter presented the data analysis and the key findings of the participants. It followed the DSR process to establish the problem of the study, which was a foundation of the formulation of the requirements for the development of a conceptual framework to address it. The conceptual framework was evaluated through validation by the participants. The purpose of the current chapter is to bridge the gap between the literature findings (chapter 2) and the empirical findings (chapter 4) of the study. It mainly discusses the results of the literature relating to the risk governance issues and the key findings of the data analysis. The discussion is structured into two parts: problem facing safety management and solution to address the problem.

5.2 Part One: Safety Management Problem in the Industry

As indicated from the beginning of the study, safety management is a control problem. This means that an improvement of the governance of risk would help to address the issues of complexity, uncertainty and ambiguity in operations. In this regard, the complex manner to coordinate the regulatory processes for collective decision making relative to risk becomes a critical matter. The consequences of upstream oil and gas operation affect human lives, facilities and the environment. This requires institutional structure and the policy process that must guide and check the activities of individuals, companies and the public. Hazard incident risks continue to show a rising trend in the industry which point to inadequacies in existing control systems in the industry.

5.2.1 The Rising Trend of Hazard Incidents in the Industry

The safety performance indicators measure the safety outcomes of the systems. It covers near misses, incidents, accidents and safety (Guo & Yiu, 2015). The analysis of available statistical data has indicated a continuous rising trend of near-misses and incidents since Ghana's upstream oil and gas operations. The near-misses are those unplanned or uncontrolled events that have not resulted in recordable injury or physical damage or environmental damage but have the potential to do so in other situations. From Heinrich's accident Triangle theory (Heinrich, 1931), it points out that near-misses may have no or fewer consequences but can rise to result in major accidents. The research findings indicated the main rising incident categories to include struck by or impact, hydrocarbon releases, falls from height or dropped objects, cut or puncture or scrape, equipment failure and electrical exposure. The struck by or impact, falls from height or dropped objects, cut or puncture or scrape, and electrical exposure are more of occupationally related injury cases. These hazard incident categories are more linked to personal safety domain of the industry. It must be pointed out that different types of hazards have its implications for managing safety in the industry. They have negative health consequences on workers' lives (Broni-Bediako & Amorin, 2010). They have a high frequency in terms of their occurrence but with low consequences to human risks.

Equipment failure and hydrocarbon releases were found in the empirical analysis as the main process-related hazards incidents occurring in Ghana's upstream oil and gas operations. Equipment failure is one of the hazards that cause a major accident in the oil and gas industry. Such accidents may result in multiple consequences, including damage to the facilities (Nivolianitou et al., 2006). Hydrocarbon releases are noted to be the root causes of major hazard precursors on offshore installations (Sklet, 2006; Vinnem et al., 2007; Vinnem et al., 2010; Vinnem, 2012). Much of these hydrocarbon releases occurred in production operations and offtake activities. In all, these incidents appeared more frequent in the following upstream oil and gas related activities: production operations, office, warehouse, lifting, crane, rigging, deck operations, constructions, installation, subsea and transport.

It must be indicated that whether these incident categories reflected personal or process safety domains of the industry, they have potential consequences to human, equipment and environmental risks. As noted in the data analysis (section 4.2.1.2.1.1.2), much of these hazard incidents had critical interfaces with the equipment (70%) and human risk (23%). Near-misses and other hazard incidents may have less severe consequences but point to weaknesses in the system that may contribute to major accidents (Bellamy, 2012; Reason, 2016). These safety performance indicators indicated the inadequacies of the existing safety controls. Although these safety performance indicators are essential in providing valuable information about how the safety controls have performed in the past, they cannot adequately capture the knowledge of the causal links to these safety outcomes. This takes to the next discussion on the key research findings of the questionnaire surveys and the semi-structured interviews.

5.2.2 Safety Climate Influences on Safety Performance in the Industry

The questionnaire surveys assessed workers's perception of safety climate influences on hazard incident risks. These factors were found to have relatively higher extent of predictive influence on safety performance: safety supervision, management of change, safety empowerment and management commitment. Some factors such as safety policies, safety rules and procedures and safety behaviour were found to have relatively high effect on hazard incident risk. However, factors such as safety priority, supportive environment, equipment maintenance and safety communication appeared to have influence on hazard incident risks in the upstream oil and gas operations.

It must be indicated that safety supervisory deficiencies related to unsafer maintenance procedures, lack of swift response towards resolving process safety issues and limitation in discussing process safety related issues between supervisors and workers. These supervision deficiencies may cause major incidents if not resolved. As noted in the review of Bell and Healey (2006), safety supervision had been a key factor in major accidents findings. These deficiencies found in supersory behaviour must be critically considered for remediations. Workers' perceived management of change issues included vague specification of roles and responsibilities, sporadic update of information on change of working procedures and inadequate control of the process of activities continuity, resources and outsourcing arrangement. Changes in technology, chemical processes, equipment and procedures may increase the complexity of the processes and systems operations as well as contributing to the changes in hazards. These may have significant potential consequences to the risk of major industrial incidents (Theophilus et al., 2017; Jain et al., 2018). The research found perceived lack of safety empowerment in the industry. According to Kines et al. (2011), it affects promoting trust and social exchanges at the workplace. Trust and social exchanges need to be created to influence safety performance in the organisations. Workers's perceived lack of management commitment to safety was found to have predictive influence on hazard risks. The key issues here is about leadership value and action towards safety. In most cases, management commitmnent to safety are not linked to their values and actions at the workplace. The link between leadership and workplace accidents is evident that most managers' behaviour at the various levels of the organisations influence safety performance (Willis et al., 2017; Stiles et al., 2018). Leaders must drive safety improvement through their values and actions.

Furthermore, safety policies in various organisations were not well understood by the workers Safety policies are meant to commit the management in various levels of the organisations to follow the expressed safety decisions. When such safety policies are not well understood by the workers, it affects implementation of the safety management systems. This is because safety policies are key aspects of the organisations' safety management systems. Safety rules and procedures were perceived to have influence in hazard incident risks in the upstream oil and gas operations. These influences related to inadequacy, short-cut and infrequent compliance to written operating procedures at the workplace. The design of safety rules and procedures are meant to provide a chronological sequence of needed actions that must be followed to accomplish safe operations. They are indispensable elements of safety management, particularly for high-risk industries. However, factors such as safety priority, supportive environment, equipment maintenance and safety communication were found to have relatively limited influence on safety performance. These factors must be given an attention as they have influence in causing accidents at the workplace (Cox & Cheyne, 2000; Konstantinidou, 2012; Okoh & Haugen, 2013; Amiri et al., 2015). Safety behaviour was perceived to influence safety perofmance in the industry. Conditions at the workplace made workers sometimes ignored safety rules and procedures, take short cuts, non-compliance to code of practice and lack of participation in safety related activities. Such behaviours at the workplaces influence safety performance at the workplace. These safety behavioural practices confirmed the earlier literature that indicated poor safety culture practices in the Ghanaian industrial working environment (Donkoh & Aboagye-Nimo, 2017; Agyekum & Simons, 2018).

Having regarded accident as an emergent property, the critical characteristic of the complex interactions of its components parts is the joint optimisation. It is a dynamic state which is continuously subjected to changes and influenced by both organisational internal and external factors. Safety climate measures this joint optimistion (Brian et al., 2015). The multilevel measurement which was reflected in the various categories of workers from different level of organization that constituted the sample gives more credence to the safety climate findings. For example, the samples included engineering professionals, maintenance or craft technicians, operations management, contractors, maintenance management and other workers. The safety climate measure captured the shared perception of the human and organisational issues from various levels of the upstream oil and gas operations. The measure indicated several weaknesses from the complex sociotechnical system in the industry. It reflected the overall status of safety in the industry as perceived by the workers. This means that safety climate is a product of the sociotechnical systems. However, in this study, the external factors related to the issues related to existing regulatory and institutional framework which are discussed in the next section.

5.2.3 The Strength of Regulatory and Institutional Frameworks

Government has the primary responsibility to control the hazardous activity of the industry. This goal must be expressed in policy form which must be reflected in the existing regulatory framework. The empirical findings (section 4.2.1.4.2.4) indicated a lack of national safety policies. Safety policies contribute to influencing the safety climate of the industry (Mearns et al. (2003; Petitta et al., 2017). These safety policies commit the actors involved in the upstream oil and gas operations. It defines the tasks, responsibilities, and how decisions are to be carried out or made towards fulfilling the requirement of protecting workers, facilities and the environment from unacceptable risks. The practice in the country is that various organisations may have their safety policies which are followed throughout in their operations. However, when the state lacks a policy direction in controlling the hazardous activities of the oil and gas resources, organisations may result in compromising safety for production most times. Ghana was not prepared in terms of how to control the hazardous activities in the industry and for that matter that state safety management role was left to the industry where various companies have adopted their internal safety controls since the country's first oil and gas production.

However, existing regulatory and institutional framework before the first oil and gas production could have managed the industry without the reliance on the companies' internal safety control frameworks. The simple reason is that existing regulatory and institutional frameworks are weak and therefore, depending on them could result in several inadequacies in managing major hazard risks associated with the upstream oil and gas operations. Annan et al. (2015) and Norman et al. (2015) noted the general increasing trends of industrial accidents in Ghana. This evidence gives more credence to the ineffectiveness of existing risk governance in Ghana. The research findings in both the documents (section 4.2.1.1) and semi-structured interviews (section 4.2.1.4.2.1) revealed several issues associated with the governance of risk in Ghana's upstream oil and gas industry. The research findings on the review of the documents containing existing safety statutes and regulations relevant to the industry indicated incoherence and limited scope of the existing regulatory properties. Hence, there is the need for this framework. The literature (Dagg et al., 2011; Mendes et al., 2014; Burton et al., 2017; Acheampong & Akumperigya, 2018) pointed out the importance of regulatory properties in determining the efficacy of existing safety regulatory regime in the industry. These safety statutes and regulations must reflect the safety of workers, facilities and the environment. They are required to cover employment standards and work environment, emergency planning, oil spill response and liability for accidents. Much of these regulatory properties are captured in different statutes. *Petroleum (Exploration and Production) Act* and *Petroleum (Exploration and Production) HSE Regulations* have limited scope in covering the regulatory properties. This means that various pieces of regulatory features have to be coordinated to fulfil the safety functions. This may affect the efficacy of the existing regulatory regime. However, in terms of ensuring the coordination and effectiveness of the various regulatory properties, an integrated approach is required to provide a '*single window'* to the regulatory regime. The research findings from the workshop (section 4.3.1.1.1) indicated the need to develop an integrated framework to capture all the regulatory properties. This confirms the literature findings of the importance of regulatory features in the determination of the efficacy of a regulatory regime.

The institutional framework plays a critical role in risk governance. Generally, the process of making and implementing collective safety decisions requires institutions. Such an analysis of the institutional framework is much placed in terms of its regulatory approach. In other words, the roles of institutions in risk governance are influenced by its regime style. The power to control the risks of industrial activities is exercised by the sovereignty of the state, which is usually conferred to a public institution through a legislative means. In this case, an institution represents a vehicle and an outcome of a decision. Existing safety regulatory regime in Ghana before the industry commenced in 2010 was the prescriptive approach. This approach has several limitations in controlling hazardous activities. This is because the boundaries between the state and private organisations, and between the business interests and the regulatory needs of the society are all vague (Renn, 2014). The performance-based regime has become one of the regulatory regimes to regulate safety. This requires an effective and independent public regulatory authority to control the risk of industrial activities in the country. The empirical findings indicated that the PC lacked independence and performs dual roles in terms of regulating the licensing of the petroleum exploration and production activities as well as ensuring safe operations. This confirms earlier literature (Addulai, 2016; Acheampong & Akumperigya, 2018). Ghana's safety case is a performance-based regime that focuses on ensuring companies reduce the risk associated with their operations as low as possible. This regime approach requires a collaboration between government agencies and the industry. The industry has several organisations that contribute to the risks of the operations

5.2 Part Two: Manage Safety in the Industry

This section discusses the ways to address the safety management problem in the industry. The ways to manage safety in the industry are based on five areas such as identification of the hierarchical sociotechnical structure for safety control, requirement for an integrative governance process to address complexity, uncertainty and ambiguity of risk-related issues, strengthen the safety culture by driving existing safety climate through regulatory, organisational and workers' influences, provide feedbacks on safety performance and ensure continuous safety improvement.

As pointed out from the literature, safety management is a control problem. Therefore, to manage safety robustly, it requires all the hierarchical safety control levels to be identified. The main reason for identifying the safety control levels in the upstream oil and gas operations is to address the complexity issue. The main concern associated with complexity in the safety management context is because there is inadequate knowledge at the overall system level. The complexity of a system arises when there is insufficient knowledge about the consequences of the system, although there is a strong knowledge about the consequences of its sub-systems (Jensen & Aven, 2018). The use of probability-based risk assessment approach, which underpins the current safety management in the industry increases the complexity issue in operations. Those probability risk estimates do not adequately capture the background knowledge linked to the risk. This results in uncertainties of knowledge and potential surprises in the industry. One critical approach to address the complexity issue is to adopt sociotechnical thinking. Given this performance variability in the systems as associated with the complex upstream oil and gas operations, the roles of the government, regulatory agency, industry and the workforce towards achieving the safety functions must be identified. In this regard, a hierarchical sociotechnical structure is provided to identify all the levels where technology, humans and organisational processes interact to influence safety outcomes. Government becomes the first level of the sociotechnical structure that must develop the national safety policies to reflect the broader safety goals of the industry. The second level is the regulatory authority that must integrate the HSE regulatory framework for the industry. As indicated in the research findings (section 4.2.1.1.1.1), the current regulatory framework for Ghana's upstream oil and gas industry lacks coherence and adequacy relative to the scope of the regulatory properties. This regulatory framework must capture the relevant national safety statutes, regulations, guidelines, as well as the international standards and industry best practices. The regulator must enforce this regulatory framework. It must be indicated that statutory and regulatory influences major accidents in the industry. A typical example is the *Deepwater Horizon* disaster which, among other factors, included national and international regulatory deficiencies (Theophilus et al., 2017).

The industry constitutes the next safety control level that is required to implement the safety management systems. The key actors in this context that have a direct influence on the safety performance of the industry are the operating organisations and their vendors (i.e. contracting companies). Both the operating and contracting organisations are required by the regulator to carry out their activities in a safe manner. Ghana's safety case regime requires both operating and contracting organisations to adopt internal safety controls to ensure that their activities do not expose humans, facilities and the environment to unacceptable risks. Although the adoption of the internal safety controls, including best industry practices, are mainly required by the existing regulatory framework, they have to be justified by the companies and approved by the regulator. However, the research findings (section 4.2.1.4.2.5) indicated lack of knowledge gap in the HSE requirements among local contractors in Ghana's upstream industry. It is imperative that operating organisations when outsourcing, must stress the requirement for an adequate HSE scope in contractors' qualification process, pre-assessment of contractors' safety skills, capacity and equipment used for their work. These strategies may help to understand the safety gaps of the contracting organisations. They are necessary because as indicated by Bianchini et al. (2017), investment in safety management systems are considered as unprofitable by small companies. This is because such companies have no real perceptions of the accident risk and also the economic benefits are not clear to them in the short run of their activities. In a country with a poor safety culture where its regime emphasised local content mandatory requirements, the local companies' safety management needed a critical attention in the industry. The increasing growth of construction-related activities in the upstream oil and gas operations makes local companies more relevant in the industry (Misiti & Hebert, 2016; Popat et al., 2018). These local companies may be found in the supply of supports, fabrications, maintenance and repair of equipment, demolitions, waste management and fabrication activities. However, the literature revealed that several Ghanaian companies lack the prerequisites to carry out activities that fulfil the standards required in the industry (Ackah & Mohammed, 2018). The operating companies must support their local clients (local companies) to implement safety management systems. The last safety control level of the sociotechnical structure is the Workers. Workers' unsafe acts influence safety performance in the industry. The quality of human performance relative to interaction with technology and organisational processes is critical to improve safety performance. Technical training and competence influence safety performance but are not only sufficient to assure operational integrity (SPE, 2014). The right safety behaviours of workers in operating and contracting companies are important to assure the operational integrity of the industry.

The findings of the literature review indicated that the requirement for integrative risk governance is a vital feature to drive robustness of a safety regime. It contributes to addressing the issue of complexity, uncertainty and ambiguity of risk-related issues associated with upstream oil and gas operations. The empirical research findings (section 2.4.2.1 and section 4.3.1.1.2.1) highlighted poor risk governance in the Ghanaian upstream oil and gas industry. A multi-stakeholder approach is required in the implementation of all the steps involved in the governance of risk in the industry. Given the influence of several actors in the risk characterisation in the upstream industry, a multi-stakeholder approach which captures several government agencies, industry actors, labour union and the local government authority would help to conceptualise the risk issues of the operations. An inadequate risk framing may affect the risk assessment of the upstream oil and gas operations (Renn, 2014). The framing structure must take into consideration the identification of all relevant stakeholders that may influence the risk of the upstream oil and gas industry. The research findings of the workshop suggested the need to have interdisciplinary risk estimation, which must incorporate human and organisational factors to the QRA. QRA is an aspect of safety engineering that requires a probabilistic risk assessment. Such probabilities are limited in terms of incorporating those background knowledges to the hazard risks. This requires companies to employ qualitative assessment of the issues that are linked to the hazards. Those perceptions are critical in decision making of the risk (Aven & Ylönen, 2016). The risk evaluation requires to be instituted with the legitimisation process with the government setting up the RAC. This reinforces the argument made by Abrahamsen and Aven (2012). This is because the authority to control the risk of upstream oil and gas activities is inherent in the sovereignty of the state. Therefore, the government must take the responsibility to set the RAC for the companies. However, this must be done in terms of providing procedures that defined transparency, accountability, trust, the involvement of experts and stakeholders in the deliberation of the risk. This would contribute to reducing ambiguity issues associated with the risk evaluations between the regulator and the industry players. It has been noted that existing regulatory authority responsible for safety compliance monitoring lacks the capacity of this role. Given the nature of the government-enforced self-governance of the industry, elements such as dialogue, strengthening of safety culture, collaboration, regular surprise sites visitation and capacity building would help to control the risk associated with the upstream activities. Such a partnership role between the government and the industry would boost the reinforcement of trust and accountability in the industry. However, discursive approach in disseminating information about risk must be emphasised along with the traditional strategies for communication.

Strengthening the safety culture in the industry is a key feature to drive robust safety management. In the oil and gas industry, safety culture has been a long journey. Strengthening safety culture helps to improve human and organisational factors influencing safety performance. Human and organisational factors still continue to contribute to many of these hazard incidents and process failures today (Pariyani & Reniers, 2018). Strengthening the culture of the oil and gas industry must cover the regulatory agencies, companies and the individual workers. It must be noted that both the literature (section 2.3.1.2) and the empirical findings of this study (section 4.2.1.4.2.5) revealed weak safety culture in the Ghanaian industrial environment including local companies involved in the upstream oil and gas industry. Strengthening the safety culture of the regulatory agencies would help to improve safety performance in the upstream oil and gas industry (NASEM, 2016). The regulatory authority must go beyond compliance monitoring approach to develop its competency. A safety case regime only functions well when there are a competent, independent, well-resourced regulator and a high level of expertise (Hopkins, 2012). In this view, the existing regulatory authority must be a separate and independent body. The national safety policies relating to the upstream oil and gas operations must be developed and reviewed to meet the safety standards required in the industry. The regulator must develop an adequate safety statutes, regulations and guidelines required in the industry. It must invest in the capacity building of its staff and research as wells as developing supporting stimuli scheme for its local companies in view of addressing the challenges found in the local content implementation in the industry. In driving organisational safety climate in the industry, existing safety supervision, management of change, safety empowerment, leadership commitment to safety, safety policies, safety rules, safety prioritisation, supportive environment and communication must be improved to strengthening existing safety culture in the industry. However, workers' safety behaviour can be improved by making the employees own the safety of their operations, learn from incidents and accidents motivation and encouraging them to participate in safety at the workplace. These elements would help to contribute to strengthening the existing safety culture.

An effective feedback mechanism from safety performance is critical for the industry to learn from its failures. Safety performance involves safety outcomes and safety behaviours (Christian et al., 2009). Provision of feedback mechanism must address the safety outcomes and safety behaviours. The safety outcomes are related to the reported information on safety performance indicators that including incidents, accidents, injuries and fatalities. Safety outcomes are necessary for two main reasons: to determine appropriate strategic responses and act as a warning or 'prodromes' of future accidents (Fink, 1986). Safety behaviours are related to safety compliance and safety participation. A safe behaviour at the workplace can be promoted through a positive organisational safety climate. The feedback mechanism improves the learning capability of the safety management framework that is relevant for the reinforcement of continuous improvement of safety performance in Ghana's upstream oil and gas industry. The feature of continuous safety improvement reinforces the learning capability of the regime. Continuous improvement is part of the change that is required in the upstream to adapt to the dynamism in technology, human actions organisational processes (Pasmore et al., 2019). It strengthens the learning capability of a sociotechnical system. This continuous safety improvement must go back to each level of the framework.

5.4 Summary

This chapter discussed the main research findings of the study. It highlighted the safety management problem in the Ghanaian oil and gas industry and how safety must be managed to minimize the complexity, uncertainty and the ambiguity of the risk-related issues. It indicated how it has contributed to bridging the safety research gap in the Ghanaian upstream oil and gas industry.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This study started with the discussion and synthesis of the critical issues of safety management in the upstream oil and gas industry in a comprehensive review of the literature, as presented in chapter two. It was followed by a research methodological framework which indicated the philosophical position, adoption of DSR as the research approach, research methods which defined the various data collection and data analysis techniques used for the study were presented in chapter three. Chapter four presented the data analysis and research findings for each step of the DSR process. Chapter five presented a discussion on the research findings. The current chapter provides a conclusion of the research by summarising the key results for all the research objectives, contribution to knowledge and presentation of the research limitations and further research.

6.2 Synthesis on the Research Objectives

As indicated in chapter one, the aim of this study was to develop a framework for robust safety management in the upstream oil and gas industry in Ghana. In achieving this aim, six research objectives were set. The first objective was to assess the robustness of existing safety regulatory regime. This was achieved by way of review of current safety statutory and regulatory documents as well as semi-structured interviews of industry professionals. The second research objective was to identify the safety regulatory issues influencing the upstream oil and gas operations, and the semi-structured interviews of industry professionals addressed this. The third research objective was to examine the safety performance indicators in the industry, which was achieved by the safety statistical data. The fourth research objective was to assess workers' perception of the safety climate influence on hazard risks which was addressed by way of questionnaire surveys. The fifth research objective explored the drivers and barriers to a robust implementation of safety management systems in the industry. Semi-structured interviews of the industry professionals addressed this. The final research objective was to develop and refine a framework for robust safety management in Ghana's upstream oil and gas industry. This was addressed by the findings of the literature review, findings of the review of existing safety statutory and regulatory documents, questionnaire surveys of workers, semi-structured interviews, workshop and the focus group of the industry professionals. The main findings of each research objectives of this study are presented and summarised in the next sections.

6.2.1 Research Objective 1: Assess the Robustness of Existing Safety Regulatory Regime

As the literature review findings indicated (section 2.4), robustness has become an important concept which, in many cases, realised as an 'official solution' for dealing with potential policy issues. As noted in the literature review (section 2.3.1.2), there are pres-existing weaknesses of risk governance in the Ghanaian industrial environment before the emergence of the upstream oil and gas industry. Given the inherent hazardous nature of the industry coupled with the complexity, uncertainty and ambiguity risk challenges, a theoretical framework defining robustness features was reviewed to assess Ghana's safety regulatory regime. The main findings of the documents (section 4.2.1.1.1.1) and the semi-structured interviews (section 4.2.1.4.2) indicated incoherent and limited scope of the existing regulatory properties, critical characteristics of integrative risk governance were not addressed in the current safety case regime, insufficient engagement of stakeholders in implementing the safety case approach, existing self-regulatory regime had not been sustained for a longer period and the learning capability of the regime reflects more reactiveness as there was limited engagement of the stakeholders in changes to facilities. These findings are indicative that Ghana's safety regulatory regime does not demonstrate the ability to sustain the principal characteristics of the government enforced-self-regulatory regime with adequate learning capabilities. Therefore, Ghana's safety regulatory regime lacks robustness.

6.2.2 Research Objective 2: Identify the safety regulatory issues

The literature indicated the importance of safety regulatory influences on major accidents in the global oil and gas industry. Incidents or accidents goes beyond organisational failures; it involves national and international industry and its governance. It can be indicated that any deficiency in the national and international regulatory framework may influence safety performance. The semi-structured interviews revealed several regulatory issues in the industry.

The main findings include the lack of national safety policies and guidelines, lack of independence of the regulator, lack of policies for investment in safety training and development, scattered safety laws, insufficient resources, inadequate safety requirements in procurement for local contractors and corruption. These issues are critical to influence regulatory failure in the industry.

6.2.3 Research Objective 3: Examine the safety performance indicators

As indicated in the literature review (section 2.5), safety performance indicators are critical because they can monitor system performance. They identify and report on incidents with the purpose to check the adequacy of existing safety controls. Therefore, they indicate the safety outcomes of the control systems. As noted in the literature, no adequate safety performance indicators had been examined since the emergence of Ghana's upstream oil and gas industry. This study examined the safety performance indicators in the industry. The main findings of the safety statistics indicated rising trends of near-misses and incidents in the industry. The critical incident categories driving this rise include struck by or impact, hydrocarbon releases, falls from height or dropped objects, cut or puncture or scrape, equipment failure, and electrical exposure. These incidents mainly occurred during the following upstream oil and gas related activities: production operations, office, warehouse, lifting, crane, rigging, deck operations, constructions, installation, subsea and transport. However, these hazard incidents had interfaced with humans, equipment and the environment dimensions of risk. The results indicated that these incidents had relatively the highest interfaces with equipment risk. They had some interfaces with human risk as well. However, these incidents had relatively less contribution to environmental risk as cases in water leaks and spills related cases were barely low. The safety performance indicators in the industry have been driven by increasing trends of near-misses and incidents.

6.2.4 Research Objective 4: Assess workers' perceptions of the influence of safety climate on hazard risks

As noted in the literature review findings (section 2.3.1.2), Ghana had a poor safety culture in its industrial environment before the emergence of the upstream oil and gas industry. For some years of upstream oil and gas operation, the safety culture in the industry has to be assessed through safety climate measures. The study evaluated workers' perceptions of the influence of safety climate on hazard risks in upstream oil and gas operations. The safety climate has become a key concept that reflects and manifests the organisational safety cultural assumptions. It measures the shared workers' perceptions about the relative importance of safe conduct in their workplace behaviour. As indicated in the literature review findings, it provides early warning indications on the performance of the system as it relates more to active monitoring of risk control systems to provide feedback on performance before an incident occurs. However, the study found that safety climate perceptions have a predictive influence on hazard risks in Ghana's upstream oil and gas operations. Factors such as safety supervision, management of change and safety empowerment have a relatively higher predictive effect on hazard risks. It indicated that safety policies, safety rules and procedures and safety behaviour have a relatively high predictive effect on hazard incident risk. Factors such as safety priority, supportive environment, equipment maintenance and safety communication had some influence on hazard risks. Given the rising tof near-misses and incidents in the upstream oil and gas operations, these factors give the impression for a critical need to improve the safety culture in the industry.

6.2.5 Research Objective 5: Explore the drivers and barriers to a robust implementation of safety management systems

This study investigated the issues associated with the implementation of safety management systems in Ghana's upstream oil and gas industry. As indicated in the literature review (section 2.7.2.1), it is as a rationalised management system that defines the policies, procedures, tactical guidelines and practices for achieving the safety function. For control of risk and fulfilment of regulatory requirements, organisations in the industry are required to implement them. The study found safety culture as the primary construct that drives a robust implementation of safety management systems. However, the empirical findings (section 4.2.1.4.2.5) indicated several barriers that influenced a robust implementation of safety management systems in the industry. They include poor safety culture, knowledge gap, inadequate safety involvement, lack of supporting environment, inadequate communication, insufficient monitoring, lack of awareness creation, lack of awareness creation, poor contractor safety management and limited resources. These barriers are more related to safety climate issues. Therefore, the existing safety culture in the upstream oil and gas industry needs to be strengthened to improve safety performance.

6.2.6 Research Objective 6: Develop and refine a framework for robust safety management

The final research objective was to develop and refine a framework for robust safety management in Ghana's upstream oil and gas operations. Having established the awareness of the problem confronting safety management in Ghana's upstream oil and gas industry, it was imperative to outline the requirements to address the problem in the industry. The problem was defined by way of review of safety statutory and regulatory documents (section 4.2.1.1), statistical analysis of quantitative safety data (section 4.2.1.2), assessment of safety climate influences through questionnaire surveys (section 4.2.1.3) and investigation of the issues through semi-structured interviews of industry professionals (section 4.2.1.4). The study elicited suggestions from the industry professionals to address the problem (section 4.3.1). However, a conceptual framework was developed based on the empirical findings of the problem and requirements definitions and theoretical findings of the study (section 2.8). The framework was developed based on the theory of sociotechnical systems that defined the hierarchical safety control levels of the industry, integrative risk governance model that addresses the issues of uncertainties and ambiguities of risk in the industry, the safety culture that defines the drivers of the regulatory authority, industry organisations and the workers, and the learning capability concept that establishes the feedback mechanisms. However, the framework was refined through a focus group validation by industry professionals. The key findings of the focus group included the following: the majority of the participants agreed that the framework fulfils the generality of the safety goal, understandable to practitioners, applicable to their industry, harnessable of technology, structure comprehensive and clarified, consistent with the upstream oil and activities and sustainable. However, in terms of its learning capability, the participants disagreed. The comments suggested by the participants were addressed in the refined framework. This framework provides a practical guide to practioners, policy makers and researchers on how to manage safety robustly in Ghana's upstream oil and gas industry.

In short, the main conclusions of this study are presented as follows:

- The safety management regime for Ghana's upstream oil and gas industry does not reflect the robustness thinking development.

- Existing safety regulatory regime for Ghana's upstream oil and gas industry is limited in terms of national safety policy directions and guidelines, coherence and independence of the regulatory authority, capacity development and leadership commitment.
- There is an increasing trend of incidents in the industry dominated by struck by or impact, hydrocarbon releases, falls from height or dropped objects, cut or puncture or scrape, equipment failure, and electrical exposures. These incidents had relatively the highest interfaces with equipment and human risks.
- Safety climate perceptions have a predictive influence on hazard risks in Ghana's upstream oil and gas operations.
- Safety culture influences the robust implementation of the organisations' safety management systems in the industry.
- There is the need for the upstream oil and gas industry to focus on robustness thinking in safety management which must be characterised with an integration of the perspectives of sociotechnical systems, integrative risk governance, safety culture and learning capability**.**

6.3 Contribution to Knowledge

The study identified a gap in the current body of knowledge in safety management of Ghana’s upstream oil and gas industry. There was no adequate empirical research that has defined the safety management problem confronting Ghana’s upstream oil and gas industry. This study used several different research methods to define the safety management problem in the Ghanaian upstream oil and gas industry. The improvement of the research rigour helped to provide a deeper understanding of the issues facing safety management problem in the industry. This study has contributed to bridging the gap identified in the literature and offered prescriptive knowledge underpinned by relevant integrated concepts and theories to address the needs of the industry that would benefit policymakers, industry practitioners and researchers. This study specifically contributed to theoretical and practical knowledge.

6.3.1 Theoretical Contribution

Given the gap of knowledge related to safety management in Ghana’s upstream oil and gas industry, this study collected and analysed primary data to define the safety problem facing the industry. In other words, the analysis of the primary data helped to establish the true picture of the safety performance and the robustness of the existing safety management of the industry which is hitherto unknown. The study established a continuous rising trend of hazard incidents and near-misses, and existing safety management lack robustness. It is important to indicate that various pieces of principle and method are provided to guide decision-making on risk in the industry. This study contributed to bridging the knowledge gap by providing an integrative research that offered broader views of managing safety in the upstream oil and gas industry. It merged the principles of sociotechnical systems, integrative risk governance, safety culture, feedback and continuous improvement into a framework. This integrated research helps to provide a better understanding of safety management in a complex system like the upstream oil and gas industry.

6.3.2 Practical Contribution

DSR is well developed in information systems; its application in safety management in the upstream oil and gas industry remains unclarified. Following the DSR process, this study has contributed to bridging the gap between research and relevance of knowledge in the industry. It has established that DSR is more applicable to safety management field in the upstream oil and gas industry as characters of DSR projects such as prescription of knowledge, tailored to management research, multi-dimensionality, continuous improvement, and systemic driven have reflected in the current conceptual framework developed to improving safety management. Every stage of the research involved multiple stakeholders' participation of industry professionals. This helped to fulfil the needs of the stakeholders in the industry in addressing the safety management problem. Overall, this study developed a framework that can be used as a practical tool to guide policymakers, industry practitioners and researchers on how to carry out a robust safety management in the Ghana's upstream oil and gas industry.

6.4 Limitation of the Research

The findings of this study are associated with some research limitations. Firstly, the analysis of the questionnaire data did not differentiate between operating workers and contracting workers relative to the perception of safety climate influences on hazard risks. An indication was made in semi-structured interviews that it was the upstream oil and gas industry that is largely driving the safety culture in the country. An empirical analysis of the differences in safety climates influences between operating and contracting workers would provide some evidence to this position.

Secondly, the upstream oil and gas industry is a globalised environment where both technology and foreign companies are an integral part of the operations. National culture plays a critical role in terms of safety performance in the oil and gas industry. This study did not investigate the influence of national culture on safety performance. It can be recommended that further research examine the impact of national culture on safety performance in Ghana's upstream oil and gas industry.

Thirdly, the study did not provide an analysis on the *Expected Utility theory* on why the need for government to set the risk acceptance criteria for the industry. Although this study argued for the state to set the risk for the industry, there was no empirical analysis of the expected utility model to reinforce this position. Empirical research is required to strengthen this argument further.

Finally, the analysis of the incident cases covered only two years periods (from 2017 to 2018) of Ghana's upstream oil and gas operations. This obscures the full picture of the trends of the occurrence of the incident in the industry. Due to the challenge of obtaining a comprehensive safety performance data in the industry, this analysis was limited to two years period. A further study is needed to provide an updated review of the incidents for the whole periods of Ghana upstream oil and gas industry. This will help to identify the trends of occurrence of incidents categories in the industry.

6.5 Recommendations to Policy Makers

This study offers some recommendations to improve risk governance in the upstream oil and gas industry in Ghana. The recommendations include the following:

1. There is currently no national comprehensive health and safety policies in the country that control major hazards operations. Given the state obligation to control the risk of hazardous industrial activities in the country, a new national comprehensive safety for major hazardous control must be developed.
2. The current regulatory body for the upstream oil and gas industry plays two critical roles: licencing and safety compliance monitoring. There is a need for a separate

independent safety regulatory authority to provide an effective risk control of major hazardous operations of the industry.

3. Guidelines are developed to help fulfilling those safety statutory and regulatory responsibilities in the industry. They provide an understanding of how the safety statutory and regulatory requirements can be achieved. There are no national safety guidelines for critical operations of the industry currently. This study suggests that the government must develop a national safety guideline for the safety regulatory framework, management regulations, information duty regulations, facilities regulations and activities regulations.
4. Because of the dynamic nature of the upstream oil and gas operations, this study suggests that government through its regulatory agency must establish a special fund for specific investment in safety capacity development and research for the industry.
5. Given the introduction of the local content policies in the upstream oil and gas industry, it is suggested that special incentive interventions must be provided to local employees and companies towards improving their capacity and safety standards that are required in the industry.
6. There is a general challenge in terms of safety behaviour in the Ghanaian industries. This study recommends the development of safety behaviour change strategies that would improve employees' attitudes towards safety at the workplace.

6.6 Summary

This chapter summarised the key findings of the research obtained from the review of the safety statutory and regulatory documents, statistical analysis of qauntitative safety data, questionnaire surveys, semi-structured interviews, workshop and the focus group. The research aim and objectives of the study were achieved. The study contributed to bridging the gap between safety management research and industry relevance.

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APPENDICES

Appendix A

Lists of Conference Papers Prior to the Submission of this Thesis

Horbah, F., Pathirage, C.P., & Kulatunga, U. (2017). Assessing the safety climate in Ghana's upstream oil and gas sector. In: *13th International Postgraduate Research Conference (IPGRC)*, 14-15 September 2017, University of Salford, UK.

Horbah, F., & Pathirage, C.P. (2018). The influence of management of change, workforce involvement and safety climate on risk perception: a study of workers in Ghana's oil and gas industry. In: *1st International Conference on Construction Futures (ICCF),* 19-20 December 2018, University of Wolverhampton, UK.
[*This paper received Springfield Award for the best paper on research methodology*]

Appendix B1: Ethical Approval

Research, Innovation and Academic Engagement Ethical Approval Panel

Research Centres Support Team
G0.3 Joule House
University of Salford
M5 4WT

T +44(0)161 295 5278

www.salford.ac.uk/

28 October 2016

Dear Francis,

RE: ETHICS APPLICATION ST16/132 – Improving Health and Safety Management in the Oil and Gas Industry in Ghana.

Based on the information you provided, I am pleased to inform you that your application ST16/132 has been approved.

If there are any changes to the project and/ or its methodology, please inform the Panel as soon as possible by contacting S&T-ResearchEthics@salford.ac.uk

Yours sincerely,

Prof Mohammed Arif
Chair of the Science & Technology Research Ethics Panel
Professor of Sustainability and Process Management
School of Built Environment
University of Salford
Maxwell Building, The Crescent
Greater Manchester, UK M5 4WT
Phone: + 44 161 295 6829
Email: m.arif@salford.ac.uk

Appendix B2: Questionnaire Survey Invitation Letter

Francis Horbah, PhD Candidate
Room 324a
School of the Built Environment
3rd Floor, Maxwell Building,
University of Salford,
M5 4WT

16th March 2017

Dear Sir/Madam,

INVITATION TO PARTICIPATE IN SAFETY STUDY

I am currently conducting a research as part of my PhD study in the area of Disaster Management at the School of the Built Environment, University of Salford, UK. The research focuses on developing a framework for robust safety management in Ghana's upstream oil and gas industry.

I would like to invite you to participate in this survey. The survey is designed to elicit your response on safety perception in the upstream oil and gas operations. The survey is expected to take approximately 30-45 minutes to complete. Ethical approval has been granted for this study by the Ethics Committee of University of Salford.

I would like to emphasize that, any information provided for this survey will be kept strictly confidential and will only be used for the purpose of this research.

If you decide to participate, please see the attached Participant Information Sheet and Consent Form. If you have any questions or concerns about the study, please contact me on:

- **Researcher** [Tel: +233547134644; Email: f.horbah@edu.salford.ac.uk]
- **Supervisor** [Tel: +44161 295 4016; Email: c.p.pathirage@salford.ac.uk]

Your participation is highly appreciated.

Yours sincerely,

………………………..

Francis Horbah
(PhD Candidate)

Appendix C: Questionnaires Instrument

<u>Section A: Demographic Information</u>

(Please Tick only one box)

1. What is your gender?

- Male
- Female

2. What is your age?

- Under 25
- 25-29
- 30-39
- 40-49
- 50 or above

3. What is your nationality?

- Ghanaian
- Other national

4. What is your highest education qualification?

- SSCE
- Diploma
- Bachelor degree
- Master degree
- Doctorate degree

5. Are you employed by:

- An operating company
- A contracting company

6. Where is your work taking place?

- Onshore
- Offshore

7. What is your job category?

- Engineering Professionals
- Maintenance/Craft Technicians
- Operations Management
- Contractors
- Maintenance Management
- Other

9. How many years have you worked on installation before your current job?

- None
- 1-2 years

- 3-5 years
- 6-10 years
- 10 or more years

10. How many years have you worked with this company?

- Less than 1 year
- 1-2 years
- 3-5 years
- 5-10 years
- 10 or more years

Section B: Workers' Safety Climate Perceptions

Please review each statement below and select the number from 1 to 5 that best expresses your response to the statement.

1 = Strongly disagree

2 = Disagree

3 = Undecided

4 = Agree

5 = Strongly agree

	1.	2.	3.	4.	5
Safety Policy					
11. I have read my company's health and safety policy.	☐	☐	☐	☐	☐
12. I do not understand what the policy requires me to do in my workplace	☐	☐	☐	☐	☐
13. I am not even aware if there is existence of health and safety policy at the workplace.	☐	☐	☐	☐	☐
Safety Priority					
14. When there is high operational cost we are not allowed to follow safety procedures to get the job done.	☐	☐	☐	☐	☐
15. Manager/supervisor would not stop us working if there are safety concerns.	☐	☐	☐	☐	☐
16. In my work group, process safety concerns are secondary to achieving production goals.	☐	☐	☐	☐	☐

17. Management puts a high priority on process safety through actions and not just empty slogans.	☐	☐	☐	☐	☐
Safety Training					
18. The training that I have received does not provide me with a clear understanding of the process safety risks at my workplace.	☐	☐	☐	☐	☐
19. This company provides adequate training on hazard identification, control and reporting.	☐	☐	☐	☐	☐
20. New workers receive the necessary process safety training to do their job safely.	☐	☐	☐	☐	☐
21. Experienced workers receive the necessary process safety training to do their job safely.	☐	☐	☐	☐	☐
22. I know how to use safety equipment and standard work procedures.	☐	☐	☐	☐	☐
23. I am not adequately trained to response to emergency situations in my workplace.	☐	☐	☐	☐	☐
24. The process safety training that I have received allows me to recognize when a process should be shut down if safety critical interlocks, alarms or other process-safety devices fail or become unavailable during operation.	☐	☐	☐	☐	☐
25. The process safety training that workers receive at my workplace is adequate to prevent process- relate incidents, accidents and near misses.	☐	☐	☐	☐	☐
Safety Rules and Procedures					
26. The safety rules and procedures followed in my workplace are not adequate to prevent incidents occurring.	☐	☐	☐	☐	☐
27. Written operating procedures are regularly followed and kept up to date.	☐	☐	☐	☐	☐
28. The safety procedures and practices at the workplace are not useful and effective.	☐	☐	☐	☐	☐

29. Creating unapproved shortcuts around process safety. is not tolerated at my workplace.	☐	☐	☐	☐	☐
Management Commitment to Safety					
30. After a process-related incident, accident, or near miss, management is more concerned with correcting hazards than assigning blame or issuing discipline.	☐	☐	☐	☐	☐
31. In this company, process safety improvement is a long-term commitment that is not compromised by short-term financial goals.	☐	☐	☐	☐	☐
32. In my workplace managers/supervisors do not show interest in the safety of workers.	☐	☐	☐	☐	☐
33. When near-miss accidents are reported, management acts quickly to solve the problems.	☐	☐	☐	☐	☐
34. When there is pressure for production, management allow us to compromise on safety for increasing production.	☐	☐	☐	☐	☐
Equipment Maintenance					
35. Interlocks, alarms, and other process safety-related devices are regularly tested and maintained.	☐	☐	☐	☐	☐
36. Maintenance checklists and procedures are easy to understanding and use.	☐	☐	☐	☐	☐
37. Process equipment is not regularly tested and Maintained.	☐	☐	☐	☐	☐
38. In order to ensure process safety at my workplace, inspection and maintenance are made high priorities.	☐	☐	☐	☐	☐
Safety Communication					
39. I do not hesitate to report actions or conditions that raise major hazards concern, even when a co-worker is involved.	☐	☐	☐	☐	☐
40. In general, workers don't bother to report minor process-related incidents, accidents, or near misses.	☐	☐	☐	☐	☐
41. I can report hazardous conditions without fear of negative consequences.	☐	☐	☐	☐	☐

42. I believe a culture exists at the workplace that encourages raising process safety concerns.	☐ ☐ ☐ ☐ ☐
43. I can report hazardous conditions without fear of negative consequences.	☐ ☐ ☐ ☐ ☐
44. My line manager/supervisor does not always inform me of current concerns and issues of safety.	☐ ☐ ☐ ☐ ☐
45. I do not always inform my line manager/supervisor about safety issues I encounter at the workplace	☐ ☐ ☐ ☐ ☐
46. Workers are informed about the results of process related incident, accident, and near miss investigations.	☐ ☐ ☐ ☐ ☐
Supportive Environment	
47. When people ignore safety procedures here, I feel it is none of my business.	☐ ☐ ☐ ☐ ☐
48. Employees here are not encouraged to raise safety Concerns.	☐ ☐ ☐ ☐ ☐
49. Co-workers often give tips to each other on how to work safety.	☐ ☐ ☐ ☐ ☐
50. I am strongly encouraged to report unsafe behaviour at the workplace.	☐ ☐ ☐ ☐ ☐
51. A no-blame approach is used to persuade people acting unsafely that their behaviour is inappropriate.	☐ ☐ ☐ ☐ ☐
Safety Involvement	
52. Workers sometimes work around process safety. concerns rather than report them.	☐ ☐ ☐ ☐ ☐
53. I voluntarily carry out tasks or activities that help to improve workplace safety.	☐ ☐ ☐ ☐ ☐
54. Management do not involve us in updating, revising and reviewing the policy.	☐ ☐ ☐ ☐ ☐
55. I involved in informing management of important safety issues.	☐ ☐ ☐ ☐ ☐
Safety Empowerment	
56. Workers at all levels in my company actively participate in hazard reviews and assessments.	☐ ☐ ☐ ☐ ☐

57. Workers at all levels of my workplace actively participate in incident and accident investigations.	☐	☐	☐	☐	☐
58. I feel that I can influence the process safety policies implemented at this company.	☐	☐	☐	☐	☐
59. Workers are empowered to take corrective action as soon as possible (including shutting down when appropriate) if process safety related devices fail or become unavailable during operation.	☐	☐	☐	☐	☐
60. When a process safety issue is involved, I can challenge decisions made by management/supervisor. without fear of negative consequence.	☐	☐	☐	☐	☐
61. I feel free to refuse to participate in work activities that are unsafe.	☐	☐	☐	☐	☐
Management of Change					
62. Where there is a change in working procedures workers are always kept fully up to date.	☐	☐	☐	☐	☐
63. When there is a change in the facilities here you are always kept up to date.	☐	☐	☐	☐	☐
64. Management always implement changes efficiently.	☐	☐	☐	☐	☐
Safety Supervision					
65. My supervisor makes sure that procedures relating to maintenance is safe before such activities are initiated.	☐	☐	☐	☐	☐
66. My supervisor takes appropriate action in response to my suggestions for process safety improvements.	☐	☐	☐	☐	☐
67. My supervisor informs us about process safety related information frequently.	☐	☐	☐	☐	☐
68. We are freely allowed to discuss any process related safety issue with our supervisors.	☐	☐	☐	☐	☐
69. My supervisor takes a swift action when a worker engages in a poor safety practice.	☐	☐	☐	☐	☐
70. Persons with appropriate supervisory authority and expertise participate in hazardous. process-related activities, such as start-up.	☐	☐	☐	☐	☐

Safety Motivation					
71. I feel that I can influence the process safety policies implemented at this company.	☐	☐	☐	☐	☐
72. I feel that it is necessary to put efforts to reduce accidents and incidents at the workplace.	☐	☐	☐	☐	☐
73. I feel that it is important to encourage co-workers to use safe practices.					
Safety Behaviour					
74. Conditions at the workplace makes me ignore safety regulations to get the job done.	☐	☐	☐	☐	☐
75. I take shortcuts which involves little or no risk.	☐	☐	☐	☐	☐
76. I do not adhere to codes of practice when under pressure.	☐	☐	☐	☐	☐
77. I willingly participate in safety related activities	☐	☐	☐	☐	☐

<u>Section C: Workers' Experience of hazard Risks</u>

Everybody assesses their level of safety at the workplace differently depending on the individual and on the hazard in question, how safe do you feel from the occurrence of the following events?

Please select the number from 1 to 5 that best expresses your response to each hazard.

1 = Very unsafe

2 = Unsafe

3 = Undecided

4 = Safe

5 = Very safe

	1	**2**	**3**	**4**	**5**
78. Slips/trips	☐	☐	☐	☐	☐
79. Falls from height/dropped object	☐	☐	☐	☐	☐
80. Cut/puncture/scrape	☐	☐	☐	☐	☐
81. Medical malaria/gastric/food poisoning	☐	☐	☐	☐	☐
82. Overexertion/strains	☐	☐	☐	☐	☐
83 Struck by/impact	☐	☐	☐	☐	☐

84. Confined space	☐	☐	☐	☐	☐
85. Asset damage	☐	☐	☐	☐	☐
86. Caught in/under/between	☐	☐	☐	☐	☐
87. Exposure noise/chemical, biological/vibration	☐	☐	☐	☐	☐
88. Electrical explosure	☐	☐	☐	☐	☐
89. Diving accident	☐	☐	☐	☐	☐
90. Fire/explosion/burn	☐	☐	☐	☐	☐
91. Equipment failure	☐	☐	☐	☐	☐
92. Releases (i.e. oil, gas, chemicals)	☐	☐	☐	☐	☐
93. Water leakes	☐	☐	☐	☐	☐
94. Spills	☐	☐	☐	☐	☐
95. Weather and wind conditions	☐	☐	☐	☐	☐
96. Transport accidents (e.g. car, helicopter crashing)	☐	☐	☐	☐	☐
97. Vessel interruptions	☐	☐	☐	☐	☐
98. Sabotage act	☐	☐	☐	☐	☐
99. Other hazards	☐	☐	☐	☐	☐

Please provide any other comments you might have regarding safety at your workplace in the space below.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

Thank you for completing the survey.

Appendix D: Review of Existing Safety Statutory and Regulatory Documents Relevant to Ghana's Upsteam Oil and Gas Insutry

Criteria	Key Elements Assessed	Assessemt	Findings
Scope of Legislative and administrative regulatory framework governing upstream oil and gas operation	*Safety and health protection of personnel and facilities.*	The safety and health protection of personnel and facilities in Ghana's upstream oil and gas industry are primarily governed by the *Petroleum Commission Act*, the *Petroleum (Exploration & Production) Act*, and the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations*. The Article 3(d)(i) of the *Petroleum Commission Act* provides for an enforcement role of the regulator to ensure compliance with health, safety and environmental standards. Articles 73 to 80 of the *Petroleum (Exploration & Production) Act* provide for the safety requirements and standards by operators, contractors and sub-contractors to conduct safe operations. The *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations* is the main regulation that basically focuses on providing health, safety and environmental requirements for the Ghana's upstream oil and gas operations. There are other statutes and regulations of general application that governs workplace health and safety of personnel and facilities in Ghana such as the *Factories, Offices, and Shops Act*, the *Labour Act* and the *Ghana Shipping (Protection of Offshore Operations and Assets) Regulations*. They are not mainly specific to the upstream oil and gas industry. These safety laws are incoherent and limited in scope.	Present in both legislations and Regulation

		In Article 94 of the *Petroleum (Exploration & Production) Act*, it mandates the minister to make regulations to give effect to the requirements in this Act. Currently, there is only one regulation that regulates the safety of personnel, properties and the environment.	
	Environmental protection.	The environmental protection in upstream oil and gas industry are specifically governed by the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations*. Articles 81 to 84 of this regulation provides for environmental principles and protection, environmental impact assessment, liability for pollution damage and compensation for pollution damage in upstream oil and gas operation. There is another legislation of general application (i.e. *Environmental Protection Agency Act)* that requires environmental protection in all activities undertaking in the country. This Act provides for the principal regulatory authority responsible for environmental protection compliance. The *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations* provided limited scope of the environmental protection of the upstream oil and gas operations.	Present in both legislations and Regulation
	Employment standards and work environment.	The employment standards for the upstream oil and gas industry are regulated in the *Petroleum (Exploration & Production) Act.* This legislation requires operators, contractors, sub-contractors or the state entity to ensure that workers recruited at the various level of activities in the upstream oil and gas industry have the requisite expertise or qualifications and must be	Present in both legislations and Regulation

		employed in accordance with applicable laws, the terms and conditions of the petroleum agreement, licence or the petroleum sub-contract. There is other legislation of general application. The *Labour Act* provides a general statutory duty that imposes on all employers to ensure that every employee work under satisfactory safety and health conditions. This legislation imposes responsibility on workers to use the safety protective equipment provided by their employers in compliance with the employers' instructions. However, it limits the liability of employers to the extent that an employer shall not be liable for injury suffered by a worker who contravenes his duty to use safety protective equipment and who suffers injury solely by his or her non-compliance of the legislation. The regulation of the health and safety of the *Work Environment* in the upstream oil and gas industry is governed by Articles 116 to 146 of the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations*. This regulation requires the operators, contractors and sub-contractors to take steps to promote occupational health management; organisation of work to prevent physical and psychological strains on workers, hazardous exposure and reduce the probability of errors that could result to emergence of hazards and accidents; establishment of minimum age, working hours; and establishment and coordination of working environment committees.	

	Emergency planning.	Emergency planning in the upstream oil and gas operations is regulated in the *Petroleum (Exploration & Production) Act* and the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations.* Articles 75 and 76 of the *Petroleum (Exploration & Production) Act* requires anyone conducting operations to ensure efficiency emergency plans to prevent, control and reduce accidents and emergencies that may result to fatality or injury, major damage to property and environmental pollutions. This Act also requires operators, contractors, sub-contractors or state entity to implement emergency preparedness plan against deliberate attacks. Articles 157 to 160 of the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations* requires operators, contractors as well as sub-contractors to set up emergency preparedness plan to deal with hazards, pollutions and accident situations. The Act requires the setting up of a robust emergency preparedness organisation which is capable to deal with hazards and accidents situations. It further requires the operator to coordinate and notify through telephone and electronic email the regulator on potential near-misses, pollutions, hazards and accident situations.	Present in both legislation and regulation
	Oil spill preparedness requirements.	There are current no legislations or regulations that specifically deal with the oil spill preparedness requirements. Thus, there are no specific requirements on the following: spill preparedness plan, roles and responsibilities in spill response, and capacity for response. As was the case in the *Deep Horizon*	Absent in both legislation and regulation

		Disaster where the regulator failed to require adequate oil spill response plan (see Bratspies, 2011). Article 81 of the *Petroleum (Exploration & Production) Act* only provided environmental principles and protection that require the setting up and implementation of effective safety systems to dispose and treat waste and prevent pollution. The legal requirements in this Act to handle and manage oil spill response are not adequate to handle major oil spill response.	
	Liability for accident.	Liability for accident is not clearly specified in the existing safety legislation and regulation. Article 59 of the *Petroleum (Exploration & Production) Act* provides for liability for damage. Major accident occurrence may lead to pollution damage. In view of this, Article 83 of this Act provides for liability for pollution damage. It requires operators, contractors, sub-contractors including the state entity undertaking activities in the upstream oil and gas industry to be strictly liable for pollution damage caused. In the case of joint operations by parties, in the failure by any party to pay its share of the cost of the damage, its participating interest are used to pay for the pollution damage. In the other legislation of general application such as the *Labour Act*, there is limitation in terms of the liability of employers as they are not liable for injury suffered by a worker who contravenes his or her duty to use safety	Not clearly specified in the legislation. Absent in the regulation. Existing safety regulatory regime is not adequate to deal with liability.

		protective equipment and who suffers injury solely by his non-compliance of the legislation.	
	Management system requirements with clear responsibilities.	The regulatory requirement for a management system is provided in the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations*. Article 3 of this Regulation requires the operators, contractors, sub-contractors as well as the state entity undertaking activities in the upstream oil and gas industry to develop, maintain and implement a management system to comply with the safety regulations. The management system is shaped by the regulatory approach: prescriptive-based regulation and performance-based regulation: Ghana's management system for the upstream oil and gas industry is shaped by its performance-based regulatory approach. This performance-based approach sets the safety goals and requires applicants for permit to demonstrate and prove to the regulator that their submitted safety plans and procedures can meet the safety goals. In other words, the management systems are not developed by the regulator but rather developed in the creation of the safety plan (*Safety Case*) by the applicants and submission to the regulator. It requires operators, contractors, sub-contractors or the state entity to communicate the management system in their safety plan to the workers and their representatives as wells as ensuring that they participate in the HSE matters including monitoring and	Present in the regulation with no clearly defined responsibilities.

		continuous improvement of the process. This regulation does not specify the responsibilities underlying the implementation of the management system.	
	Regulatory approach.	The safety regulatory approach for Ghana's upstream oil and gas industry is based on performance-based or goal-setting that requires oil and gas organizations to show that they can take measures to reduce risk 'As Low Reasonably Practicable'. Article 10 of the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations* requires the operators, contractors, sub-contractors and the state entity to submit a *Safety Case* to the regulator for approval in not less than six months before beginning upstream oil and gas operation and decommissioning. The *Safety Case* must indicate the following: description of the facility, technical and control measures, risk analysis, emergency preparedness analysis including emergency preparedness plan, and information on the management systems that is in compliance with existing safety legislation and regulations.	Present in regulation
	Framing emphasisng a complex actor-network involvement in capturing all the issues.	Existing legislations and regulations do not explicitly provide for procedures for setting up the risk frame that emphasises a complex actor-network involvement in capturing all the hazards, threats and issues in Ghana's upstream oil and gas operations. Both the *Petroleum (Exploration & Production) Act* and the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations* require every participating organisation to submit a risk assessment to the regulator. How this risk	Absent in both safety statutes and regulations.

		assessment captures all the safety issues from a complex actor-network involvement in the operations is not clearly provided in the existing safety laws. Existing safety laws only emphasises the *Safety Case* that requires the operators, contractors or the state entity to demonstrate that the system and process that have been adopted are safe in terms of ensuring the health and safety of the personnel, facilities and the environment.	
	Emphasis on incorporation of human and organizational factors in the risk estimations	Existing safety regulation requires the operators, contractors or any entity undertaking upstream oil and gas activities to perform a risk analysis in accordance with best industry practice. Articles 155 to 156 of the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations* provide general requirements for risk analysis. In terms of risk assessment, organisations are required to establish their own critera for assessing risks which takes into effect identification of hazards and accident situations, risk of deliberate attacks and threats, the possible causes of hazards and incidents, and their potential consequences. Ghana's *Safey Case* regime which is underpinned by the goal setting approach is mainly characterised with engineering frame that requires Quantitivate Risk Analysis (QRA) to be conducted to identify the risks. In view of the inexperience of Ghana's upstream oil and gas industry, the involvement of specialist consultants had been a practice since the development of its offshore oil and gas resources.	Absence in safety statutes but limited in HSE regulations.

		QRA in some cases are contracted to consultants. QRA are limited in terms of incorporation of human and organisational factors.	
	Legitimization of the methods and processes on the judgement of risk evaluation.	The risk evaluation approach underpinning the existing safety regulatory regime for Ghana's upstream oil and gas industry is captured in Article 9 of the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations*. This regulation provides for 'Risk Acceptability or Tolerability Criteria' that requires operators, contractors or any entity undertaking upstream oil and gas activities to identify and minimize risk to a level as "low as possible". The requirement for application of this risk reduction principle, *As Low As Reasonably Achievable* has its own challenges as its outcome is derived from probability base. The main issue is that the industry mainly focuses on satisfying the minimum requirements for risk acceptability or tolerability criteria. However, it is challenging to realized significant improvement in safety so far as there is existence of such minimum criteria. The current risk evaluation approach is rooted in probability risk-based application. This requires the indication of the methods and processes to assess the knowledge on which these probabilities can be based including the strength of the knowledge. This requires to be legitimised to provide transparent and democratic process on the judgement of risk evaluation. However, this legitimisation of the methods and processes	Absence in both existing safety statutes and regulations.

		on the judgement of risk evaluation is not provided in the existing safety statutes and regulations.	
	Monitoring and controlling of risk through cooperation, adequate resources and separate competent regulator.	The monitoring and controlling of risk are captured in Article 110 of the *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations*. It requires the operators, contractors or any entity undertaking upstream oil and gas activities to ensure that relevant technical, operational and organisational factors are duly kept under control at all times. In Article 51 of the *Petroleum (Exploration & Production) Act* provides for collaboration with relevant authorities of the state in supervision and inspection of safety standards in the upstream oil and gas industry. In Article 3 (d) of the *Petroleum Commission Act* requires the operators, contractors or any entity undertaking upstream oil and gas activities to ensure compliance with the health, safety and environmental standards. However, there appeared to be limited emphasis on the regulatory requirement for cooperation among the various stakeholders in monitoring and controlling of risk in the industry. The Petroleum Commission, which is the regulator for Ghana's upstream oil and gas industry performs a dual role: *petroleum licensing* and *safety compliance monitoring.* This raises critical issue of its independence in ensuring compliance monitoring of health, safety, and environment standards. The regulator provides the resources required for its compliance activities. The usual resource challenges associated with state	Absence in all the safety statutes and regulations.

		agencies may also affect its capacity to provide adequate resources for its safety enforcement activities. The traditional compliance monitoring tools used by the regulator may be associated with lack of adequate technical competence in ensuring safety performance.	
	Communication strategies emphasizing inclusion of all relevant actors in the deliberation of the risk issues	Article 22 of the *Petroleum (Exploration & Production) Health, Safety* and *Environmental Regulations* requires provision of communication equipment that must be based on operational needs, the activity type as well as the established hazard and accident situations. It further requires at least two independent means of notification that must be set up specifically employing permanent communication links (e.g. telephone and email). In the same regulation, Article 133 requires operators, contractors or any entity undertaking upstream oil and gas activities to share information on risk during their course of the operation. The regulation requires that the findings of risk assessment, analysis, measurement as well as the mappings of the causes of work-related health issues and investigation of accidents, incidents and near-misses be submitted to the regulator within one month. In relation to communication in risk governance, multiple actors' involvement is critical in risk deliberations. Involvment of people in risk-related decision helps to make them gain ownership of the process. There is no requirement in existing Ghana's *Safety Case* regime to incorporate procedures to facilitate discourses among the varuous stakeholders that emanate from different background in	No requirement in existing *Safety Case* regime that incorporates procedures to facilitate discourses among the varuous actors.

		view of promoting meaningful interactions towards confrontation of uncertianities.	
	Sustainability of the functionality of the system	The current principal functional characteristics of Ghana's safety regulatory regime for its upstream oil and gas industry have lasted less than ten years. Ghana's safety regulatory regime operates under the goal setting approach driven by *Safety Case* that uses QRA to identify the hazards and accident situations for decision making. Its *Safety Case* has not survived for many years with detailed modifications because the development of its existing statutes and regulations relevant to the upstream oil and gas operations commenced several years after the maiden production of oil and gas resources. The balance of interests of different actors appears less effective as there had not been established procedures for the development of an open and transparent dialogue in addressing uncertainties from the existing complexity of operations. Currently, there is no safety guidelines developed for the upstream oil and gas industry. Despite the current safety regulatory regime has not been challenged with major accidents, one cannot conclude that its robust because there had not been mobilisation of forces and discourses to maintain its principal functional characteristics.	The *Safety Case* has not survived for many years with detailed modifications to preserve its principal functional characteristics.
	Adaptability to changed situations	The *Petroleum (Exploration & Production) Health, Safety and Environmental Regulations* reflected this feature of *adaptability to changed situations*. In articles 73-82 require standards for blowout preventers in the	Present in only existing safety regulation, but

		areas of drilling and well systems. This regulation provided for the requirement of operators, contractors or any entity undertaking upstream oil and gas activities to ensure that the there is a well control equipment designed to have the capacity to ensure barrier integrity and well control. The need for regulatory regime to reflect this requirement for standards for blowout preventers became a lesson learnt from the *Deep Horizon Disaster* in 2010. Ghana incorporated this lesson to its current safety regulation. Although the passage of this safety regulation came after the disaster which made its convenient for this adjustment. The true determination of this feature of *aadaptability to changed situations* can be assessed in existing safety guidelines designed by the regulator. There are currently no safety guidelines designed by the regulator for the upstream oil and gas industry. Such safety guidelines need to be designed to reflect this element of adjustment in changed situations.	no detailed adjustments have been made as there are no existing safety guidelines for the change management regime

Appendix E: Results of the Factor Analysis

Component Matrix[a]

	Component				
	1	2	3	4	5
Management of change	.855	.218			
Safety empowerment	.852	.174			
Safety supervision	.844	.157	.217		
Management Commitment	.681		-.221	.159	-.129
Safety involvement	.576	.182			.275
Safety motivation	.508	-.116	.432		.163
Safety policies	.465	-.697		-.194	-.296
Safety rules & procedures	-.433	.643	-.188	-.338	.191
Safety behaviour	-.332	-.591	.240	.339	.201
Equipment maintenance	.260	-.178	-.571	.293	.410
Supportive Environment	-.291	.236	.553	.213	.375
Safety Training		.229	-.356	.609	-.370
Safety Priority		.304	.427	.583	-.294
Safety communication	.324	-.106	-.139	.294	.546

Extraction Method: Principal Component Analysis.

a. 5 components extracted.

Component Transformation Matrix

Component	1	2	3	4	5
1	.920	.261	-.206	.207	.009
2	.332	-.841	.249	-.181	.296
3	.191	.318	.750	-.491	-.243
4	-.082	.275	.412	.394	.770
5	-.006	-.219	.405	.727	-.510

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Appendix F: Results of the Monte Carlo PCA for Paralle Analysis

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Monte Carlo PCA for Parallel Analysis
Version 2.3


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Number of variables:     14
Number of subjects:     212
Number of replications: 100

++++++++++++++++++++++++++++++++++++++++++++++++++++++
Eigenvalue #     Random Eigenvalue     Standard Dev
++++++++++++++++++++++++++++++++++++++++++++++++++++++
      1              1.4543               .0630
      2              1.3407               .0452
      3              1.2617               .0345
      4              1.1900               .0303
      5              1.1254               .0274
      6              1.0674               .0271
      7              1.0087               .0265
      8              0.9525               .0272
      9              0.9005               .0267
     10              0.8481               .0266
     11              0.7981               .0253
     12              0.7451               .0291
     13              0.6871               .0326
     14              0.6203               .0449
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Monte Carlo PCA for Parallel Analysis
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Appendix G: Results of the Multiple Regression Analysis

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	REGR factor score 5 for analysis 2, REGR factor score 4 for analysis 2, REGR factor score 3 for analysis 2, REGR factor score 2 for analysis 2, REGR factor score 1 for analysis 2[b]	.	Enter

a. Dependent Variable: Incidents Risk

b. All requested variables entered.

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6.981	5	1.396	6.937	.000[b]
	Residual	41.464	206	.201		
	Total	48.445	211			

a. Dependent Variable: Incidents Risk

b. Predictors: (Constant), REGR factor score 5 for analysis 2, REGR factor score 4 for analysis 2, REGR factor score 3 for analysis 2, REGR factor score 2 for analysis 2, REGR factor score 1 for analysis 2

Coefficients[a]						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.583	.031		51.383	.000
	REGR factor score 1 for analysis 2	.101	.031	.210	3.266	.001
	REGR factor score 2 for analysis 2	-.093	.031	-.194	-3.011	.003
	REGR factor score 3 for analysis 2	.078	.031	.163	2.527	.012
	REGR factor score 4 for analysis 2	-.078	.031	-.163	-2.522	.012
	REGR factor score 5 for analysis 2	-.046	.031	-.096	-1.487	.139

a. Dependent Variable: Incident Risks

Appendix H1: Participant Information Sheet

Research Title: "***Developing a framework for Robust Safety Management in Ghana's Upstream Oil and Gas industry***".

You are being invited to take part in this study being undertaken as a part of doctoral research project. This information sheet is intended to provide you with information about the research and your participation. The interview will take approximately 45-60 minutes to complete.

Aim of the Study:
The research aims at developing a framework for robust safety management in Ghana's upstream oil and gas industry.

Why have I been chosen?
Your knowledge and professional experience in the upstream oil and gas industry make you an ideal person for this study to solicit your views about the current understanding of the issues confronting safety management in Ghana's upstream oil and gas industry

Do I have to take part?
Taking part in this research is entirely voluntary; it is fully upon your discretion to decide whether or not to participate. You may choose not to participate, however due to the relevance of your participation for this research, you are encouraged to take part in these interviews. The researcher can provide more information if it helps in making your decision to participate and will ask you to grant your consent for participation in this study. You are free to withdraw at any time, without giving a reason.

Will my taking part in this study be kept confidential?
All of the data and information obtained from you will be kept confidential and secured and will be used in maintaining anonymity. No personal information of participants will be used as codes and numbers will be allocated. Information gathered from the interviews will be anonymously processed. After the study, all of the data would be destroyed securely to comply with data protection and maintaining confidentiality.

What are the potential benefits of participating?

There would be no financial reward for your participation in this research as it is completely voluntary. However, your knowledgeability and professional experience will make crucial contribution to the development of a framework for robust afety management in the upstream oil and gas industry industry.

Is there any risk involved?

Due to the nature of the study, the participant will not be exposed to any type of risk.

Contact details:

If you have any questions about this study, you can contact the person(s) below:

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Appendix H2: Semi-Structured Interview Protocol

This study seeks to identify the issues confronting safety management in the Ghana's upstream oil and gas industry. It seeks to define the safety management problem in the upstream oil and gas industry. The information elicited from you would help to understand the real safety issues facing the industry.

The interview protocol is made up of two sections:

Section A: Background Information about the interviewee

Section B: The Main Semi-Structured Interview Questions.

The main semi-structured interview questions are based on your current professional experience in the Ghanaian upstream oil and gas industry. The information obtained will remain confidential and will be used for the only purpose of the study.

Thank you in advance for participating in this study. If you have any queries, do not hesitate to contact me.

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Appendix H3: Semi-Structured Interview Questions

A. Background Information about the interviewee

Please can you tell me your background in terms of the following:

- Main position/role in the organisation
- Core functions/operations of your organization
- Location of the activities
- Years of current job experience

B. The Main Semi-structured Interview Questions.

1. To what extent can you say the safety regime in Ghana is robust?

PROBE:

- *Stakeholders involvement in framing risks*
- *Interdisciplinary estimation of risk .*
- *Legitimization of the risk appraisal*
- *Management of risk issues (safety culture and monitoring and controlling of risk)*
- *Strategies for risk information sharing*
- *Sustainabilility of the principal functions of the safety case application*
- *Adaptability to changed situations*

2. What are the Issues influencing safety regulations in Ghana’s upstream oil and gas industry?

3. What are the issues/barriers influencing robust implementation of safety management systems in Ghana’s upstream oil and gas industry?

Please do you have further comments/contribution to make to this study?

Thank you for your time and availability.

Appendix H4: Semi-Structured Interview Transcript

SECTION A: Background Information about the interviewee

R: Please can you tell me your background in terms of your position or role in this organization?
I: Well, I am an HSE compliance monitoring officer. Basically, my work is to enforce HSE in the industry and we are government agency in the industry. We ensure compliance to HSE laws in the upstream industry. Basically, the role of the [*organization name deleted*] is to develop regulations and also ensure that all operators or anyone coming in to operate in the oil and gas space comply to the relevant national regulations first of all and the international standards and conventions. So basically, my role is to support the department to achieve that goal.

R: Please can you tell me about the core functions/operations of your organization?
I: The [*organization name deleted*] was established five to six years ago by an act of parliament and the HSE department is manned by six officers all from varied backgrounds and [*organization name deleted*] is a public sector as by law, like I said in my opening statement we are to ensure compliance to laws and regulations. So, the HSE is just one of those aspects of our work in this institution. We are to ensure compliance to the laws governing the [*organization name deleted*]. Aside the HSE, there are other roles that the [*organization name deleted*] plays that is economic, local content and also cost management so basically those are the areas we focus.

R: Please, can you tell me where your work/operations are located?
I: Yea, we ensure HSE compliance in the upstream oil and gas industry in this country. So, our work covers both offshore and onshore activities. We cover the two, yea!

R: Please can you tell me about the years of experience with your current job?
I: Well, year, years of experience in terms of health and safety? I have say, six years working with the [organization name deleted]. I have had work experiences that are not relevant to health and safety but specifically to health and safety, it’s six years and I work here at the [*organization name deleted*] as an HSE officer.

SECTION B: The Main Semi-structured Interview Questions.

R: To what extent can you say the safety regime in Ghana is robust?

I: Before 2016, the whole oil and gas industry in Ghana was governed by the various petroleum agreements between the government of Ghana and the International Oil Companies. After the repealing of these laws, a new petroleum law was enacted that contained the HSE laws. Within this laws that the current HSE regulation was developed. As you know what the safety is about, it was originally from UK and subsequently adopted by the Norwegian oil and gas industry and now Ghana has also adopted it. It requires that any organisation applying to undertake oil and gas activities has to demonstrate convincingly to the regulator that the management system put in place is adequate to ensure safety operations. Our safety case is a derived regime which already has an international acceptance. It is a self-regulation region. However, it has to be adopted to a Ghanaian law so that there is a liability in the state and not international laws. Although our laws allow the industry to also consider international best practices. On robustness, our HSE law allows you to submit a safety case and safety plan according to the specifications of our MODUS requirements. Every facility has already a safety case document which we ask them to amend to reflect international laws that reliability as I mentioned earlier exists. So, for the safety case you are required to put in place all the requirements for all the various risks in your operations like for examples fire risk, blow-out risk, hydrocarbon releases risk, emergency response risk. That aside, the HSE law requires you to submit an HSE plan for the project which will include the safety case document. There are various requirements in the plan that you are supposed to demonstrate to us before you are given our consent to undertake your activities. And if you we are not satisfied with your document or assurance and in most cases the contractors management systems which is mandatory requirements, we don't give out our consent. So, we are very sure.

R: To what extent are stakeholders involved in the framing of risks?

I: With the safety case regime, it is self-assessment thing. So, it is you assessing the risk associated with your facility and you are telling us that you have put in place adequate measures to reduce the risk as low as possible. You do it out of the state engagement. However, prior to the starting of the facilities, we have what we called the Endurance Test Operation where your safety case is tested at its full working operations. There is no need to have stakeholders' engagement on safety case document when it is pre-produced. However, since there are local risks, like the fishing activities, malaria, weather, you have to submit this to the commission.

R: Is there adoption of interdisciplinary approach in estimation of the risks?
I: There is quite extensive work they do that mostly covers health, safety, environmental, economic risks. Most often they meet the requirements. With the risk assessment, the IOCs are quite well vested in that given their vast experience of that. They do internal risk engagement for hazard identification which is a big engagement activates where they engage large crowd to perform the risk assessment for various risks they could have encountered with the project. So, for that sense, the likelihood that they would mis risks in their operations for risk assessment they had done for over 15 years is very low. So, for risk assessment I will say they are will vested. However, there is always the need to incorporate the local risks I mentioned earlier. Beyond the weather and the fishing activities that had been a problem in the offshore environment, salinity in salt, which is causing most of the facilities, causing rust. Some of these risks are to be identified in Ghana. Most of our risk analyses are quantitative risk assessment. For qualitative risk I say big no, hardly! We don't do most of these qualitative risk assessments. We have a lot of drilling analysis. We rely on assessment that you can measure immediately. So, it is quantitative way. There is always the need to incorporate the local risks I mentioned earlier. Beyond that the weather had been a problem in the offshore environment, salinity in salt, which is causing most of the facilities, causing rust. Some of these risks are to be identified in Ghana. Most of our risk analyses are Quantitative Risk Assessment (QRA). For qualitative risk I say big no, hardly! We don't do most of these qualitative risk assessments. We have a lot of drilling analysis. We rely on assessment that you can measure immediately. So, it is quantitative way.

R: What procedures are used for the risk evaluation?
I: We have the filling modes, HAZID, HAZOP, Bowtie. These are some of the tools they use in the risk evaluation process because we are dealing with the process and not the occupational nature. It is more process oriented. So, the failure modes, effects and criticality analysis (FMECA) are the most preferred tools being used in the risk evaluation so far.

R: How is the monitoring and controlling of risk done in the industry?
For monitory, the expectation is that the IOCs who are contracting have to have assurance from their contractors but they themselves have periodic audit of the contracting activities and engage the regulator on the course of the year. Active monitoring is what we critically need to employ using the Observation cards, the permit work system. There are things that are auditable

even if you at the offshore you continuously monitor the facilities performance. We come to organisational behaviour, they behaviour are from the management. The culture here is the seriousness of the management. With the IOCs in terms of their financial loan regimes from the IFCs, there are high expectations of environmental and safety sensitivity. So culturally their sides continue to improve. The challenge has always been the local environment where the Ghanaian safety performance is quite low. The average Ghanaian does not consider safety as a major threat to our existence. The challenge has always been to transfer the corporate perception to the local contractors. The difficult has been to get them to a level where the need to accept to operate in a safe manner. This has always been a challenge for the industry. The local workforce does in the Ghanaian way where they don't understand they are always required to work in a safe way. They don't accept to work in a safe manner!

R: How is risk information shared in the industry?

I: The IOCs use the bulletin system where they share information about incidents across the operations. They submit report to us, and we also share with the other actors within the petroleum space. The internal communication has always been the bulletin system. Where I sit, it is down! Communication is down! They use emails, letters and meetings. So, incidents report goes through these techniques. These techniques have been used by the IOCs to the contractors too. Communications are in two ways: one teaching you and one accepting. If you come to education, most of our offshore workers at the lower units are not adequately. You understand? I am talking about the riggers, the cleaners etc. The lower hanging jobs don't have a requirement to have a degree for those jobs. These are the workers that are more risk and they need to be trained. So, training gap for those going for the offshore activities. That is a key challenge.

R: To what extent can you say the existing principal characteristics of the safety regime are sustainable?

I: As I said it earlier, the safety case regime is tested and proven before. With the functional features of the safety case, it is accepted generally, and I don't think the Ghanaian risks is higher than the southern American risk or the North Sea risks. It is the same risk we all use the same safety case. It is appropriate and exhaustive. So, it is appropriate! However, it requires a lot more engagement from the stakeholders. This is where there is challenge particularly engagement of the regulator, contracting parties, state agencies and the implementation of all these requirements in the safety case. This comes to periodic audits and unfortunately there is a gap in our national agenda as it is not a high priority. We need the support of the leadership for the HSE department to ensure that operating companies put their things in order to ensure safety operations in our industry.

R: To what extent is the industry adapted to changed situations?

I: Management of change regime exists in the HSE regulations that should in case there is a major change in the facilities, they should be brought to the attention and engagement of the regulator. So, in that sense it is reactive. It is reactive in the sense that in case of any major change in the facility, you have to react to the regulator for engagement where you are required to submit a risk assessment on that change for approval by the regulator. There have been some few experiences where those earlier operating companies had changes in their facilities, and they had to engage us on how to implement that on their management systems and we went through and it was accepted by the regulator. In these days of our operations, we have not had such engagement for this management of change situations.

R: What are the issues influencing safety regulations in Ghana's upstream oil and gas industry?

I: Like I said we have laws scattered, we have the factory inspectorate, we have the environmental protection regulations, health and safety regulations for the upstream sector, so these pieces of regulation are those that governing the sector as of today. Aside that the sector is highly regulated by international standards and international organizations, so there are a number of standards and principles that as a country we are signatories to so by default those standards become abiding principles for the industry so basically that it. we also have a guideline that EPA issued in 2010 governing the environmental protection and management in the absence of that so those are key guideline plus the regulations I mentioned early on; the environmental protection regulation, health and safety regulation that I said as of today 22nd of December is a law and also the standards.

R: What are the issues/barriers influencing robust implementation of safety management systems in Ghana's upstream oil and gas industry?

I: I will say it's going to be an issue of culture and mindset {interruption} and I must say that it is difficult changing the way people perceive and respond to things. But you cannot say you will not do anything because that how people are. I believe that continuous engagement, training… people or reorientation would help to get people to change their attitude and also helping people see the result of their effort. For instance, when you implement or introduce a particular safety program and you achieve some result, positive result for that matter, it is important to communicate that to people as a form of encouragement for them to know that their efforts are yielding results. Another way is to established some sort of reward system to encourage good practices and entrenched it in people so those are ways of ensuring improvement but when you don't do do that people begin to become resistance because there is no difference between those who are complying and those who are not complying or those who yielding result and the vice versa then complacency set in so there should be some reward

Appendix I: Workshop Guide

Main Theme: "*Robustness Thinking in Safety Management: How DO We improve the Issues in Ghana's Upstream Oil and Gas Industry***"**

Time Duration: 1.30 hrs
Moderator: Researcher

- Researcher welcomes participants
- Introduction and roll call of participants
- Moderator briefs participants on the research information, ethics, assurance of confidentiality of data and requirement for consents.
- Taking of participants' consents
- Procedures for the session
    1. Moderator introduces the issues and elicits suggestions for improvement.
    2. Every participant is given opportunity to provide his or her suggestions.
    3. Participant's submissions should not exceed three munites for each submission.

Session Commencement

Moderator highlights the main issues identified from the earlier studies by the researcher.

<u>**Key Issues:**</u>

A: *Inadequate integrative risk goveranace framework:*

1. Risk framing
2. Risk estimation
3. Risk evaluation
4. Risk management
5. Risk information sharing

B: *Regulatory Influences:*

1. Lack of national safety policies
2. Lack of safety guidelines

3. Lack of independence of the regulatory body
4. Lack of policies for investment in safety training and development
5. Scattered safety laws
6. Insufficient Resources
7. Inadequate safety requirements in procurement for local contractors

C: *Poor safety culture*

Mechanisms/interventions to address the issues:

Moderator provides summary of the suggestions for each issue outlined.

Thanksgiving

Closure of workshop

Appendix J: Focus Group Guide

Time Duration: 45 Munites

Researcher briefs participants on the research information and requires for consents for the validation study.

Researcher presents the conceptual framework to the group

Explain the structure of the conceptual framework to the participants:

- Underpinning theories
- Key concepts
- Relationships
- Importance of the framework

Validation Questions

Goal
1. To what extent does this conceptual framework fulfil the general goal of safety management in the upstream oil and gas industry?

2. Environment
To what extent is this conceptual framework Understandable to professionals?

To what extent is this conceptual framework consistent to organizations' safety management guidelines?

3. Structure
To what extent is the structure of this conceptual framework covers the level of details of safety management?

4. Activity
To what extent is this conceptual framework consistent in addressing the safety activities in the industry?

5. Evolution
To what extent is this conceptual framework consistent with the requirement of robustness in addressing complexity, uncertainty and ambiguity of risk related issues in the industry?

To what extent is this conceptual framework consistent with the requirement of learning from its experience?

Thanksgiving