Master's degree thesis

LOG950 Logistics

Implications of Data Collection Tools and Practices by Oil and Gas Sector in Ghana: An Exploratory Analysis

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Preface

This master thesis is my final academic work leading to the award of MSc. Degree in Logistics at Molde University College – Specialized University in Logistics. The entire program lasted for two years and my experience has been tremendous. It was both challenging and rewarding and this being my first-time stepping foot from my country Ghana made it more fun and intriguing. This program has taught me valuable lessons such as independent thinking, working with others and respecting their views and meeting strict deadlines; which are core values needed to excel in the business world.

This work spring from my own effort and understanding of data collection tools and analysis in the oil and gas industry. However, its successful completion would not have been possible without the guidance, co-operation and support of some people, I am thereby particularly indebted to:

My supervisor and Rector of the University Professor Steinar Kristoffersen for his suggestions and constructive criticisms.

The co-supervisor, Professor Alok Mishra for providing guidance into the technical areas of the work.

Management of Front Group AS for the suggested topic and support which has given me the occasion to increase my knowledge of the workings in the oil and gas industry.

Finally, to the Almighty God for His continual providence in my life.

Samuel Elorm Kofi Somone

Molde, Norway.

May, 2020

Summary

The introduction of Information Technology (IT) has transformed any industries and the oil and gas sector is no exception. Nowadays the major innovations in the oil and gas industry are the field of IT and it promises to improve not just the operational and financial performance but also Health and Safety issues which is a major concern in the sector. It is estimated that, workers in the oil and gas industry are over seven (7) times more likely to be injured then in other sectors. Adding these issues with the environmental concerns caused by the industry has made it necessary to look for sustainable solutions.

This work identified 7 factors impacting HSE issues in the industry and they formed the basis for hypotheses. Questionnaires were developed, distributed and results were analyzed using frequencies, percentages, correlations and regression analysis. Five of the 7 hypothesis were found to positively impact organizational HSE performance. These are; geographical location of the company, nature of business and activities performed, supervisory bodies frequency of visit, use of Big Data Analytics and frequent meetings. The remaining two hypothesis; tools for collecting data and investment in HSE improvement were rejected as lack of evidences were found to suggest that they improve HSE performance.

The outcome of this work is expected to help both academia and the corporate world alike to know the interplay between the core elements impacting HSE performance and developed for informed strategies to improve it.

Key words: Health, Safety and Environment (HSE), Oil and Gas, Data Collection tools, Big Data, Internet of Things.

Contents

CHAPTER 1

1.0 INTRODUCTION

1.1 Background of the Study

The introduction of information technology (IT) to any industry has the potential to improve and transform it rapidly. It is therefore not surprising that the past three decades has seen many organizations automating their processes in an attempt to achieve what is known as the paperless office (Davidson, 2013; Milliken, 2015). Progresses made in information technology has also changed how data is collected and it has impacted monitoring and evaluation (M&E) of organizations that utilizes it. An example of these applications is Mobile Data Collection (MDC).

MDC is the use of already existing IT products such as smartphones, tablets, computers and software to collect data instead of recording data on a paper with pen or pencil and then manually entering it into a database or keeping it on a shelve. With the new technology, data can be exported directly into a centralized database automatically. This saves time and avoids data entry errors. Despite these benefits, it is still common to see organizations using paper-based data collection tools (Muthii, 2017). Main reasons for this include its low overhead cost, lack of infrastructure, little or no training required, potentially higher reach and no technical glitches (Jha, 2015). Interestingly, paper-based methods for monitoring task performance are still common in the energy industry. Due to the hazardous environment that oil and gas are usually produced, the introduction of electronic devices have to go through strict requirement to prevent explosion and other types of dangers. This is especially true for the processing plants area which requires only certified devices (Heyer, 2010). For durability, mobile devices are encapsulated with quality materials thus making them heavier and bigger than they are supposed to be. It therefore makes it unsuitable for use in the hazardous oil and gas industry since they can limit the movement of its users (Blauhut and Seip, 2017).

It must be noted that any decision taken based on the analysis of data is only as good as the data itself, as such the importance of data accuracy cannot be overemphasis (Jha, 2015). It is therefore not surprising that the oil and gas industry is making much progress in information technology since it promises more benefits than paper-based methods. When talking of innovations in the oil and gas industry, many will suppose it is about hardware such as, bigger, faster, deeper drilling; more powerful pumping equipment; bigger transport, hydraulic fracturing, horizontal drilling, and other enhanced oil recovery (EOR) techniques. This is however not the case, similar to other process industry that generates lots of data, where optimization is important and data error can be costly, the bulk of the innovation in the oil and gas industry has been in the area of data science, predictive analytics, machine learning, advances in digital imaging and processing. These is what has driven innovation and created a rich and disruptive movement among oil and gas companies and their suppliers. It is rightly so because, the oil and gas industry probably values efficiency and accuracy more than any other industry. A conservative estimation of a typical well is over ten million dollars and slight errors can lead to losses and at the same time even little improvement in efficiency and productivity can be a huge cost saving (Cowles, 2015). IT tools are used to monitor the equipment which ensure higher productivity.

1.2 Mode of Data Collection

1.2.1 Paper-Based Surveys

Although IT products have greater advantages over paper based by making work easier and faster, it is still common to see paper base data collection in used in the oil and gas industry. A simple checklist is printed on a paper or book and engineers notes down what they see on the field whist working or during inspection on an equipment.

Pros:

- **Low overhead cost**: The overhead cost of paper-based data collection is low and also organizations do not have to worry about the initial investment as in the case with modern IT products and Apps.
- **Little or no training required**: Since people are used to writing on paper with pen or pencil, just a little guidance is enough to get them working.
- **Potentially higher reach**: Can be taken and used in remote sites even where there is no electricity since there will be no issue of battery running out.
- **No technical glitches**: The fear of electromagnetic interference which may distort the data collected does not apply to paper-based methods.
- **Convenience:** Due to the protective clothing worn by inspection team, using pen and paper is much easier to record since it can be used even with the gloves on (Jha, 2015; Biscardini, et al., 2018).

Cons

- **Time-consuming**: Since it is a manual process, it requires more time to administer and transfer to a database than digital forms which can be automatically uploaded.
- **Data entry**: Inputting man-made data into a computerized database system is more prone to errors than when collected with a digital tool.
- **Retaining records:** Deciding on what to do with the paper after collecting data and transferring it into the database is not very easy. Decision has to be made on whether to stored it for future crosschecking which will require large storage areas or to discard it (Jha, 2015; Biscardini, et al., 2018).

1.2.2 Digital Tools

In the developed world, many people are used to digital tools in their daily lives so field workers will only require very little training. This might however not be true in the developing world.

Pros

- **Opportunity for data analysis**: Data captured using IT products can be easily transfers to the database without any problem. This makes analysis faster and more accurate.
- **Economies of scale**: Though it requires high overhead cost, unlike paper-based that needs to be replaced frequently, the same IT product can be used for years and might even be cheaper in the long run.
- **Flexibility to modify survey**: Based on what is found during the data collection period, IT products allows for easy modification.
- **Saves Space**: Paper-based requires storehouse where they are kept for future reference in case of errors. With time, this can take huge space from the room, a problem which is absent in the case of digital data collection.
- **Multiple functions**: IT products performs many other functions which paper-based system cannot do. Such as sensors to monitor the equipment 24/7 and report error when one occurs.

Cons

- **Infrastructure limitations**: When in a location where there is no electricity to charge the device when the battery runs out, it can be difficult to complete data capturing in time. Those that requires signal before they work will result in data lost when signal is lost.
- **Unfamiliarity with digital tools**: Requires training of workers to be comfortable to use it. It is also more inconvenient to use since the workers are mostly dressed with gloves.
- **Specialized Devices**: Due to the hazardous nature of the environment, not all IT products are acceptable and getting the right one requires huge financial commitment (Jha, 2015; Biscardini, et al., 2018).
- **Security issues**: Online devices can be hacked thereby exposure of business intelligence.

1.2.3 Adopting or Implementing a New System

1.2.3.1 People, Process and Technology

In the late 1990's Bruce Schneier popularized the concept of "people, process & technology". However, it has been in usage long before then and was even at the core of ITIL (Information Technology Infrastructure Library) in the 1980's. This concept has been referred to as the "golden triangle", the 3 keys to successful project implementations and organizational change, and a back-to-basics approach to solving complex business problems. These three components are crucial because for the efficient successful completion of an operation, the relationship between people, process and technology has to be optimized. An omission of one creates an imbalance and the technology might not solve its purpose.
For instance, a company may rightly identify a particular technology as a panacea to their problems and decide to adopt or buy it. What they fail to realize is that they need the right processes around it and their employees needs to buy into the idea or should be able to use it efficiency; otherwise, it will be a waste (Banks, 2016).

1.2.3.2 Getting the Right Balance

People

People should always be the first consideration. One need to identify the most vital people and what are their expertise? This is to know what to include in the new system. Since the project cannot be embarked upon without the approval of top-level management, it is important to sell your idea to them. Finally, one must have a complete team with the needed skills, experience and attitude to help deliver value.

Process

Once the people have been identified and are involved, the next step is to consider the process. Business process simply is a structured set of activities or series of actions that must be done to complete a task. Before implementing a new system, it is important to consider what need to be done to achieve the end result in mind. The main steps or the broader picture should be identified first, then the detailed or sub steps can follow. As such the process variations, rules, interdependencies and supporting process should follow. Once the processes have been decided, it is important to discuss and assess them with the various stakeholders and get their feedback.

Technology

The final stage is the technology. After having the people and process in place, it now becomes easier to know the right technology to adopt. This way the people will feel part of it which makes learning and usage much easier. The supplier of the technology needs to build rapport and demonstrate credibility to the buyer to be acceptable (Banks, 2016; Markin, 2018).

1.3 Statement of Problem

Data form the basis of decision making and in an industry such as the oil and gas that generates huge among of data daily, they require quick and accurate means of capturing and recording it for analysis and quick decision making. Unlike other professional industries, the oil and gas sector is characterized by extreme weather condition of where process plants are located, loud noise and other dangers (Blauhut and Seip, 2017). In the US, it is reported that workers in the oil industry are seven times more likely to die from work related incidents than in other industries (Schleifstein, 2013). Between the years 2008-2017, about 1,566 died trying to extract oil. This number is equivalent to the number of US soldiers that died at war in Afghanistan (Morris, 2018). This situation repeats itself around the globe. Data collected from field and records of these incidents needs to be identified quickly to prevent them from reoccurring.

Many oil and gas companies have it has a goal to reduce the number of incidents to the lowest possible and digital tools is playing a pivotal role in this regard. Though most of these companies operate internationally and try to maintain their culture, different regions have unique challenges and will require unique solutions. Most research conducted has been in the developed world and their experiences may differ from sub-Saharan Africa. Sub-Saharan Africa has relatively lower development of telecommunication infrastructure and is mostly developing or underdeveloped. These companies will therefore need to find more specific innovative means to capture, analyze and use the processed data. This is because even with the experiences they had from other fields, they may not be applicable in sub-Saharan Africa and will therefore mean they have to create new data from their experience in the sub-region. This background therefore forms the basis of the study, to know the mode or tool of data collection by oil and gas companies in Ghana, the data collected, how they are analyzed or processed, how they are stored and retrieved for decision making, mainly, health, safety and environment (HSE) decision. The study will also look at the constraints they face in the tool being used to collect data.

1.4 Research Question

At the end of the study, I hope to answer the following question.

- What is the state-of-the-art data collection and analyzing tool used in the oil and gas industry and how do they affect HSE performance?

1.5 Significance of the Study

This study will look into the various types of data collection tools used by oil and gas companies in Ghana and the underlining reason behind their choice. It will also focus on how captured data is used, whether it is integrated into their database or otherwise and how it affects decisions.

A successful completion of the study should point out to management of the strength and weaknesses of a particular choice of data collection and other practices. It will also help management of oil companies in developing countries on the best options to monitor the performance of their equipment. Since very little work exist in this field that focus on developing countries, this study will serve as one of the foundations for future studies in the developing world.

1.6 Organization of the Study

The study is broken down into seven different chapters;

Chapter one (Introduction) contains the background of the study, where an overview of the issues relating to data collection in the oil and gas industry were discussed.

Chapter two (Literature review) begins the literature review and examined relevant studies in HSE issues, data collection including new technologies used and data quality.

Chapter three (context of the study) outlines the context of the study as it pertains to Ghana as a country.

Chapter four (methodology) illustrate the methods used to achieve the objective of the study.

Chapter five (**Research Model**), other literatures were discussed which formed the basis for developing hypotheses.

Chapter six (analysis and discussion), includes the analysis and discussion of the work.

Chapter seven (conclusion and recommendation) concludes the work and made the necessary recommendations.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Safety Climate in Ghana

Research into industrial safety in Ghana shows an increasing rate of incidents resulting in injuries, fatalities and loss of assets (Norman et al., 2015; Bayire, 2016). Industrial accidents cost the nation about $16 million annually (Norman et al., 2015). The oil and gas sector in Ghana is not exempted from the increasing rate of incidents (Ocloo, 2017; Tetteh, 2017). Studies indicate that although the industry is already highly risky, the many technological, human errors and environmental challenges makes it even worse (Amorin 2013; Hystad et al., 2014; Horbah, Pathirage and Kulatunga, 2017).

2.2 Health, Safety and Environment

2.2.1 Environmental Impacts

Epstein and Selber (2002) identified the environmental impact of some key activities conducted by the oil and gas industry in their lifecycle analysis. The activities studied were; exploration, drilling, production, transportation, refining and combustion. Table 2.1 shows the summary of their findings. As seen in the table, upstream operations by oil and gas companies potentially leads to deforestation and disturbance to the aquatic ecosystem. It also results in the disruption of natural habitat of animals, environmental degradation, livestock destruction, physical fouling and oil spillage.

For instance, the Exxon Valdez oil spill that occurred in 1989, affected animals and birds immediately. It is reported that 250,000 seabirds, 2,800 otters, 300 harbor seals, 247 bald eagles, and 22 orcas (killer whales) were killed (History.com, 2018). Three main reasons were given as the cause of the spillage. (1) Exxon not fixing the malfunctioning radar, (2) Ignoring reports that the ship captain Hazelwood, had been drinking for three years prior to the accident which even resulted in his driver's license being revoked, and (3) Exxon not having adequate equipment to handle oil spills (Study.com, 2019).

In just over two decades, a worse oil spillage almost 20 times that of Exxon Valdez occurred in the Gulf of Mexico. BP- Deepwater Horizon in 2010 which is now the largest marine oil spill in history which also caused major damages to marine life (Hartsig and Robbins, 2018).

Table 2.1: Effects of Oil and Gas Industrial Activities on the Environment (Epstein and Selber, 2002).

Stage	Effect	Subcategory
Exploration	Deforestation and disturbance of aquatic ecosystems	Infectious diseases
Drilling and extraction	Chronic environmental degradation	• Discharges of hydrocarbons, water and mud • Increased concentrations of naturally occurring radioactive materials increasing the chances of occurrence of cancer
	Physical Fouling	• Reduction of fisheries • Reduced air quality resulting from flaring and evaporation • Soils contamination • Morbidity and mortality of seabirds, marine mammals and sea turtles
	Habitat Disruption	• Noise effects on animals • Pipeline channeling through estuaries • Artificial islands
	Livestock Destruction	
Transport	Oil spills	• Destruction of farmland, terrestrial and coastal marine communities • Contamination of groundwater • Death of vegetation • Disruption of food chain
Combustion	Air pollution	• Particulates • Ground level ozone
	Acid rain	• NOx, SOx • Acidification of soil • Eutrophication; aquatic and coastal marine
	Climate change	• Global warming and extreme weather events, with associated impacts on agriculture, infrastructure, and human health

Even before Epstein and Selber (2002) work, The Exploration & Production (E & P) Forum in a joint study with UNEP jointly, in 1997 identified a number of adverse effects of oil production on the environment. They categorized the impacts as; humans, social and cultural which includes how the use of land has changed. Effect on the atmosphere as a result of venting, combusting, flaring and purging gas and these results in air pollution, acid rain and climate change. Impact on aquatic life as a result of oil spillage and leakages, poor disposal of chemicals and disposal of drilling fluids. Noise from construction sites, solid waste disposal, ecosystem impacts which leads to habitat disruption were categorized under terrestrial impacts. These shows the massive dangers oil and gas industries can cause to the environment.

2.2.2 Preventive Mechanism for HSE Issues

In order to reduce the negative impact to the barest minimum of the frequency of HSE issues, oil and gas companies employ a number of strategies. Since safety of employees is of paramount importance, companies put in effort to hire the highly competent people and train them frequently on HSE issues. They also have regular medical checks, monitoring of the working environment and creates awareness to keep employees safe, healthy and alert. New and improved technology are also ways they use to improve HSE performance as seen in table 2.2 (Schneider et al., 2013).

Table 2.2: HSE Issues in the Oil and Gas Industry and their Control Mechanisms (Schneider et al., 2013)

EHS	Issues	Controls
Environment	Managing Hazardous and Non-Hazardous Waste	1. Monthly waste analysis plan; 2. Inspection and audits; 3. Train the workforce.
	Managing air emissions	1. Eliminate continuous flaring processes and replace them with on-demand flaring technologies; 2. Setup controls that capture the co2 and sulfur dioxide emissions.
	Spills	1. Storage of chemicals in free of damage recipients; 2. Provision of secondary containment for tanks and storage recipients; 3. Emergency preparedness plans for the spills & training of personnel.
Health	Industrial hygiene monitoring	1. Baseline industrial hygiene survey for all activities. To determine workplace hazardous. 2. Mandatory medical check every year or before resuming work from an accident; 3. Monitoring and controlling workplace conditions (noise, heat, etc.); 4. Awareness of employees about specific health issues resulting from each activity; 5. Use of personal protective equipment.
Safety	Human injuries and incidents	1. Automation of highly hazardous tasks; 2. Setting up safety barriers on the hazardous parts of the processes; 3. Restriction of access into hazardous areas for unnecessary/ unauthorized workers; 4. Training and supervision of workforce; 5. Use of personal protective equipment.
	Training of the workforce (lack of follow up)	1. Planning a training program that incorporates all workforce in individual facilities, and training refreshment 2. Implementation of competency assessment program that assess among many things, the effectiveness of training on the worker's performance using different methods of assessment (observation, simulation, written assessment, etc.
	Energy and Process Control Issues (Process safety issue)	1. Safety instrumented systems (engineering), 2. Logout tagout program 3. Training (admin), supervision

2.2.3 HSE Management

The disturbing trends of incidents and their associated effects on health, safety and environment around the globe and Ghana in particular, is enough to compel the Ghanaian government to enact laws that compels oil and gas companies to perform routine safety audit. They should also be made to train specialist to serve us external auditors of the safety procedures. The current safety audit, in the Petroleum Model Agreement requires the investors to perform HSE audit under the supervision or assistance of Environmental Protection Agency (EPA). It will be helpful if the government also strengthens the archaic factories, offices and shops. The laws such as Act 1970 (Act 328) and Workmen's Compensation Law 1987 (P.N.D.C.L. 187) should be revised and enforced. The National Occupational Health Unit should also be given the needed resources to provide health service for workers.

The E&P Forum and UNEP (1997), states that oil and gas companies needs to develop and implement their HSE management system even as government tries to understand their underlining working conditions to enact laws.

Some companies such as Tullow Ghana has developed their own comprehensive HSE policy manual to guide their operations.

E&P Forum and UNEP (1997), suggested certain conditions which is required for the government to effectively implement its environmental legislation. They are;

- International and national laws, regulations and guidelines should be appropriate
- A well aligned procedures for making decision on projects/activities
- Have a legislation that unambiguously spells out the responsibilities of each party and liabilities due them
- Operational standards should be enforceable
- A well-defined and fitting monitoring procedures and protocols
- Clear channels or means of reporting performance
- Resourceful and well-motivated enforcement authorities
- Established or existence of enough consultation and appeal procedures
- Should be empowered to a applied the appropriate sanctions

The E&P Forum and UNEP (1997) also listed some infrastructure needed to ensure a smooth environmental protection. They are;

- Policy and regulations should be formulated

- Baseline environmental surveys
- Procedures for assessment and approvals
- Inspection, monitoring and enforcement
- Services - water, power and waste disposal
- Ready emergency response
- Logistics and transportation
- External supplies/services - construction, materials, engineering, consultants, etc.
- Technical services—laboratories, laboratory supplies, and equipment
- Training institutions, standards associations.

The following should also be in place; risk assessment/management, occupational health services, provision of health insurance, holding counseling session for accident victims, safety training. They should liaise with the EPA, Fee Zone Board and Factories Inspectorate together with the National Fire Service and National Occupational Health Unit to come up with a Health and Safety Performance Framework for periodic workplace safety audits and inspections.

The current safety management procedures in Ghana is based on the prevailing culture which may not be very useful for managing a hazardous climate like the oil and gas industry (Oppong S., 2014). Having seen the drive of the international bodies and issues pertaining to the oil and gas industry, Ghana as a nation needs to adopt and implement virtually all the above suggested conditions and infrastructure to be able to effectively manage the HSE risk in the oil and gas upstream sector.

2.2.4 Challenges in Finding Solutions to Incidents

The fatality rate of oil and gas workers is about 7.6 times above the national average (King, 2013). Getting to the bottom of the problem to prevent health, safety and environmental (HSE) issues requires detailed measurement of the past events (Veley, 2002). Past efforts to identify the patterns of these core causalities has proven futile due to three main factors. Firstly, even though a number of the HSE data has been coded and grouped as numerical data, such as lost-time incident statistics, a good amount of them were captured as written responses that were later converted to text (Campbell et al., 2012). Secondly, high proportion of the past records are held in highly customized applications with unique data structure making it incompatible with new data. They are therefore difficult to analyzed with conventional tools (DeVol, 2004). Finally, as a result of the uniqueness and fragmented nature of HSE data, many of the captured data are unused and are just kept in the archives. Others too are difficult to access and analyzed for decision making (Akoum and Mahjoub, 2013). Big Data and its applications can be used to harness these data to make informed HSE decisions.

2.2.5 Applications of Big Data and other Digital Technologies to Improve HSE Performance

Many industries have been able to use Big Data to analyze their large data sets captured by digital technologies to increase operational efficiency, make inform strategic decision such as identifying and serving new market and increase customer value by creating new products (Demirkan and Delen, 2013; Fulgoni, 2013; Lohr, 2012a).

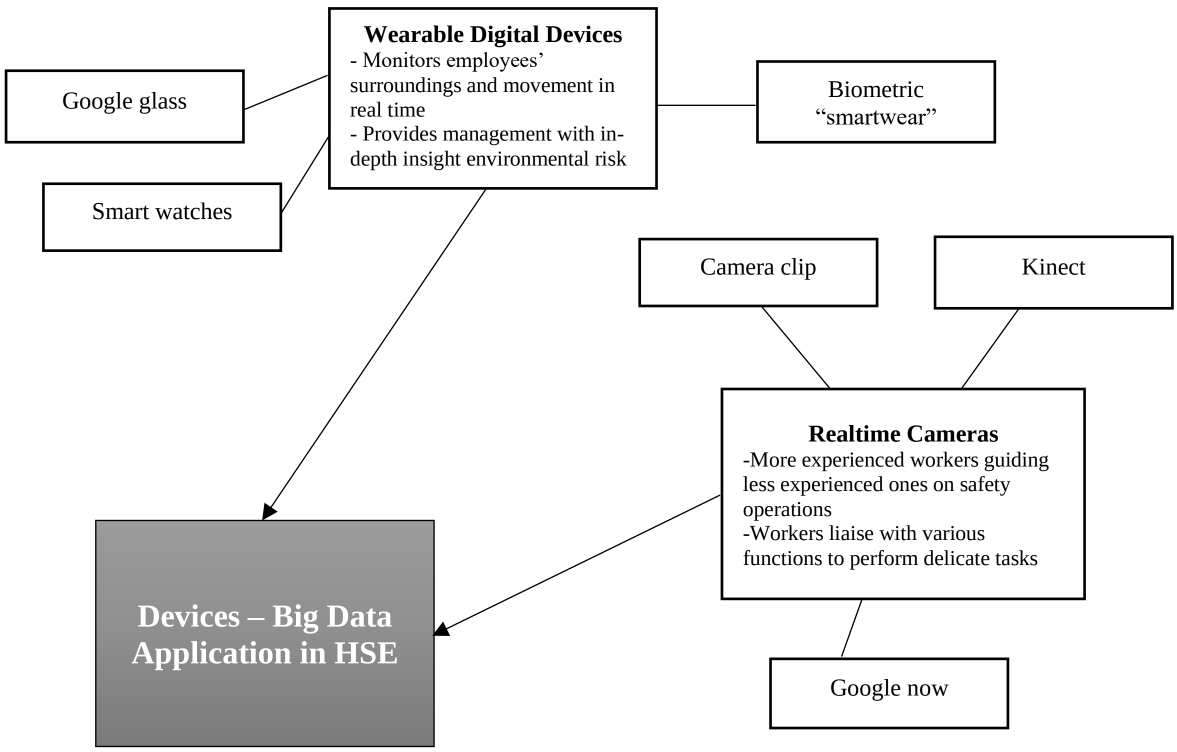
The oil and gas industry is well known as a high risk sector. Management have identified Big Data with its related technologies as a tool that can be utilized to improve health, safety, and environmental (HSE) performance (Cowles, 2015) as well as reduce damages caused to infrastructure and also reduce industrial operational and supply chain risk. This is seen as a timely invention, especially as demand for energy keeps rising which has led many players of the oil and gas industry to explore new and deeper waters, more unpredictable and hazardous environment making it riskier to issues related to HSE. Most companies are therefore being proactive to identify and address these issues. They analyze historical records to predict future incidents. Interestingly, new areas such as earthquakes, soil, air and water pollution have become a source of problem to the industry. Big Data and its related technologies can also be employed to reduce the negative effects of these unconventional hazards (Cowles, 2015).

Other technologies exist in the industry as Griffith (2014), identified; workers in oil and gas industry can follow hands-free checklist, as they assemble equipment. This process saves time and also reduces risk as a result of mistakes. Emerging wearable devices such as glasses, watches and rings are also playing a huge role to mitigate risk in the oil fields Griffith, 2014). Adopting these devices will enable experts provide detail guidance to less experience staffs around the globe. For instance, by wearing glasses which are equipped with camera, microphone, speaker and wireless antenna, an inexperience worker can have real-time direct access to an expert who can see their surroundings and guide them should they need their assistance (Tan et al., 2016).

The applications of devices such as those portrayed in figure 5, can be harness to improve HSE statistics. However, accidents in the oil and gas industry are usually caused by humans and are as such classified, making it more difficult to know the root causes of the accident (Frenzel, 2003; Lasprogata et al., 2004). It is also likely that other non-personnel data may be useful in preventing future accidents, however since most accidents results from human factors human resources data is the obvious and most preferred source of data lined to HSE issues (Gordon, 1998).

Attempts had been made to know the link between HSE-related investments and level of safety (Zacharatos et al., 2005); and to also find out if some investment strategies guarantees higher safety performance than others. Since Big Data can be used to analyze data of different types, it is used to find patterns of investment types and their resulting safety (Tan et al., 2016).

Figure 2.1: Big Data Device for HSE (Tan et al., 2016)



2.2.6 Standards in Offshore Production

Each country has its body in charge of health, safety and environmental issues. For instance, the USA has American Petroleum Institute (API), Ireland has Health and Safety Authority, Ghana has Petroleum Commission Ghana and Norway has Norwegian petroleum directorate. In their study of ten major oil and gas companies, Schneider et al. (2013); noted that most companies based their HSE standards on recommendations made by International Petroleum Industry Environmental Conservation Association (IPIECA), the International Oil and Gas Producers Association (OGP) and the American Petroleum Institute (API) Oil and Gas Industry Guidance on Voluntary Sustainability Reporting (2010). Other guidelines were adopted from the Global Reporting Initiative (GRI) G3.1 and Sustainability Reporting Guidelines (GRI 2011). Also, the International Organization for Standardization (ISO), have a number of standards which guides operations in the oil and gas sector.

Some ISOs for the oil and gas industry are; ISO 17776:2016 which regulates offshore production installations, with a focus on how to manage major accident hazard during the design of new installations. To effectively manage hazards the company needs to have the engineering expertise and knowhow to be able to meet their set targets. The company must also have the needed tools to evaluate and determine the possibility and consequences of the occurrence of a major accident (ISO 17776. 2016).

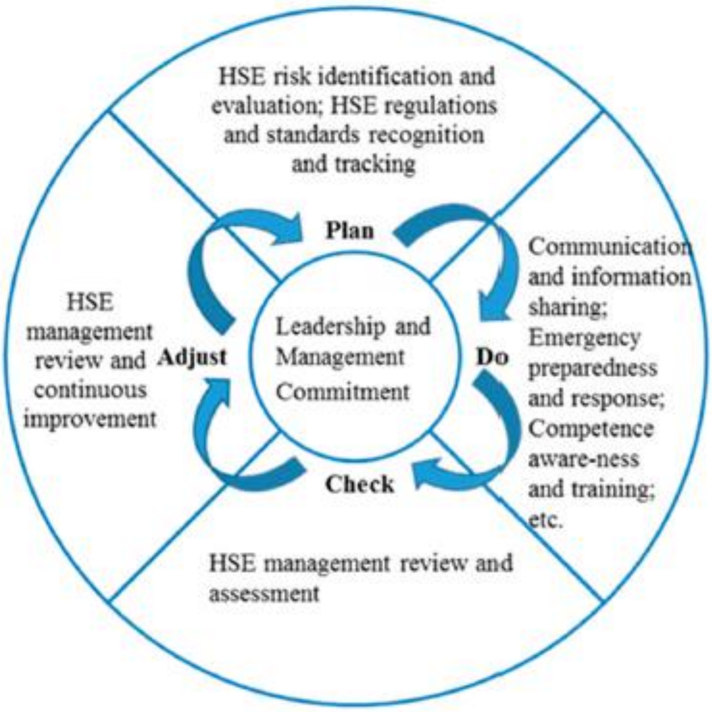
The ISO 35101:2017; looks into the working environment of the Arctic region. It gives a general guideline on how to design and operate both fixed and floating oil and gas facilities either onshore or offshore. This regulation aims at promoting optimal health, safety, human performance and decision-making conditions for oil and gas workers in the artic region (ISO 35101:2017). ISO 13702:2015(en); provides guidelines for controlling and mitigating of fires and explosions on offshore production installations which are used to produce hydrocarbon resources. ISO 15544:2000(en); detailed procedures on how to response to emergency during offshore production installations for hydrocarbon resources.

2.2.7 Regulating HSE Management System for Offshore Operations

Some of these standards includes; the ISO 9000 series for quality management and the ISO 14000 series for environmental management systems. Also, OHSAS 18001 which deals with Occupational Health and Safety Assessment Series but has now been replaced by ISO 45001 which is concerned with occupational Health and safety management. In Ghana Petroleum (Exploration and Production) (Health, Safety and Environment) Regulations, is guided by the Legislative Instrument 2258 that was passed in 2017 (L.I 2258) and all exploratory and production companies in the country must abide by it. These standards when followed will help the offshore oil and gas companies to establish an HSE management system (HSEMS) without compromise to safe and health and the environment (Sun and Wang, 2006).

This system can be designed to function in a circular procedure, to include planning organizational structure and HSE work, implementing HSE plan, checking HSE performance and adjusting relevant processes (Figure 2.2).

Figure 2.2. HSE Management System (Sun and Wang, 2006).



HSEMS is generally a tool that is built to ensure that to HSE policy and principles are always applied in offshore operations. Upon installation, HSEMS is able to perform quantitative risk assessment (QRA) after collecting human and organizational data to evaluate and ensure safety operations.

2.2.8 General Regulations in Oil and Gas Industry

Below are some of the HSE regulations and guidelines the Oil & Gas industry is challenged with:

Health:

- Educate employees about health issues and assist them on how to reenter the office buildings after an accident or illness.
- Ensure that employees working in hazardous department are well trained on the use of Personal Protective Equipment (PPE)

- Have a well-defined procedure to ensure control in loud noise area
- Ensuring employees have access to protective clothing such as heat or cold resistant
- Ensure employees follow all the precautions when working in hazardous areas

Safety:

- Have a continuous training program to keep employees prepared on safety issues in the organization.
- Adopt and encourage employees to have a zero tolerance for incident at the workplace.
- The material safety data sheets (MSDS) should be kept in a single location.
- Capture, record and save all accidents or situations that almost ed to accidents in an incident database that can be analyzed to avoid them.
- Clearly document safety features and display milestones for all employees to see.

Environmental:

- Set a standardized quality performance objective, measure performance with set standards and evaluate to ensure continuous improvement
- Adopt practices that aims at minimizing pollution to the environment
- Implement sustainable waste management

Create constant awareness among employees to keep them abreast with policies, standard programs and performance (Solis O., 2015).

2.3 Types of Mobile Apps in the Oil and Gas Industry

In 2017, many CIO and IT directors considered mobile technology as their main priority and 67% of the CIOs believe mobile technology will lead to an immerse improvement in their operations. However as at that time, only 18% have incorporated mobility strategy in their organization. It is therefore expected that more investment will be made in mobility in the years ahead. Projections for 2018 reveals that Oil and Gas companies will invest $16 Billion on mobile apps and $180 Billion on Enterprise Mobile Application. Enterprise mobility promises to improve data capturing, analysis, communication and collaboration among workers in different units and department.

Since oil and gas consumers are concern about going green it becomes more incumbent on them to investment in IT products for real-time monitoring of new discoveries, oil extraction and transportation. This will improve performance and be cost saving. Many companies have implemented it and benefited from it.

2.3.1 Activity Based Apps

There are many activities in the oil and gas industry and unique apps can be developed for each one.

Health & Safety Apps

Oil and gas workers are the most prone to health and safety hazards. Apps can be developed to record the causes of injuries or death and measures taken to address them. Field workers can take or capture real-time videos or pictures of malfunctions and report them for quick response. These app also do include safety measures to help them take precaution.

Disaster Recovery Apps

Apps are developed that has backup data on all relevant issues about the company for easy retrieval in case of emergency or disaster. It could also include instructions to help employees perform recovery process.

Project Management Apps

Project management apps are also important in the oil and gas field. This can be constantly updated to reflect work in progress and all employees concern can see the cost and state of a given project. This ensures work is done on time and all activities are well synchronized.

Communications Apps

Communication apps allow field workers to connect to each other no matter where they are. Also, in places where there are no internet or other wireless networks. Special apps can be used to enable instant communication with each other.

Reporting Apps

Management needs daily data to keep up with happenings in the company and that is what reporting app does. Capturing data daily and creating reports for decision making. It records data and uploads it automatically into the database and synchronized with other records (Apogaeis, 2017).

2.4 Current and Future Trends of Data Manipulation

Data is invaluable to the oil and gas industry, as Clive Humby (2006) stated, data is the new oil and though it is valuable it cannot be used unless it is well analyzed and processed then can it be profitable to the organization. Since data plays such a vital role it can be concluded that how it is captured is equally important. Due to the massive amount of data generated by oil and gas industries, big data which refers to new technologies in handling and processing these massive datasets, has become quite common. The various units in the oil and gas industry, including the upstream and downstream operations generates large data which makes up the dataset (Wipro and Wipro, 2014; Yang, et al. 2014; Mahfoodh 2017; Perrons and Jensen, 2014; Akoum and Mahjoub, 2013; Ciarlini et al. 2015; Hilgefort, 2018; Sukapradja, 2017). When these are analyzed and well processed it then gives management a more in-depth understanding into the basis of a complex engineering problem.

Survey conducted by General Electric and Accenture in 2017 reveals that 81% of executives of oil and gas companies considers big data as one of their top three priorities for 2018 (Mehta, 2018). They added that, the core purpose of this strategy is to improve the exploration of oil and gas to increase their production efficiency. Interestingly, a survey by IDC Energy in 2012 revealed that 70% of oil and gas executives were unfamiliar with Big Data and how it can be applied in petroleum engineering (Feblowitz, 2013). The wide difference in executives of oil and gas companies' appreciation of big data in just 7 years shows the rising importance of Big data (Mohammadpoor and Torabi, 2018).

As oil and gas industry move towards digitalization, it becomes more important to remember the adage of 'Garbage in, garbage out'. This is because no matter the complexity of IT system they have in place, the resulting analyzes for decision making is dependent on the data that is fed into it. This is where the mode of data captured is essential. With this having a mobile app offers much more assurance of accurate data then paper-based ones (Amery, 2018).

2.5 State of the Art Technology in the Oil and Gas Industry

There are many tools used in gathering information in the oil and gas industry today. These tools have improved performance, made work much easier and improve HSE performance therefore reducing the rate of incidents in the oil and gas industry.

2.5.1 About IIoT

The term Internet of Things (IoT) was coined by Kelvin Ashton in 1999 during his presentation to Proctor & Gamble as a concept for connecting objects or things to the Internet. The application of IoT offers much benefits to healthcare, transportation and infrastructure. It is also expected to revolutionize industries by making them more efficient and for them to have greater control of their operations. This led to the concept of Industrial Internet of Things (IIoT). IIoT enables industries to collect and analyze huge data set for decision making for improved industrial performance. It reduces cost in Capital Expenditures (CapEx) and Operational Expenses (OpEx). Other names for IIoT are Industry 4.0 and Smart Manufacturing. It is concern with the application of advance technologies in industrial processes for optimization through real-time monitoring, efficient management and control (Khan et al. 2018; Rouse, 2019). Since IIoT uses less amount of energy it can bring about a reduction in environmental footprints in oil and gas production by virtually eliminating oil and gas leakages and reduction in carbon emissions.

IIoT is expected to be the future of industries and will bring about Industry 5.0 which aims as narrowing the gap between human and machines. This will further lead to industry 6.0, that will enable massive personalization. By the year 2023, IIoT is expected to yield about 14.2 trillion US dollars in revenue and by 2025 devices connected to the Internet are estimated to reach 70 billion.

2.5.2 Enabling Technologies for IIoT

To achieve its purpose, IIoT requires the use of many technologies such as IoT, big data analytics, cyber physical systems, cloud computing, radio frequency identification (RFID), data fusion, artificial intelligence, virtual reality, augmented reality, sensor technologies, Human-to-Machine (H2M) and Machine-to-Machine (M2M) communication (Khan et al. 2018; Rouse, 2019).

2.5.2.1 Internet of Things

Since IoT is concerned with connecting items in the factory, it is used for real-time data collection and actuation. It is the main component of IIoT and tracks all connected equipment in any part of the world. IoT monitors the entire supply chain to attain considerably lower labor cost. It connects, warehouses to production facilities and distribution centers, as such linking from the raw materials till it reaches the final consumer (Khan et al., 2018). IoT is commonly used in the oil and gas industry for predictive maintenance and asset tracking. The first IoT operating architecture for the oil and gas industry was proposed by Khan et al. (2018). Their model contains three modules; smart object, gateway and control center. Smart objects refer to the sensors installed on the equipment at the site; the gateway serves acts as the bridge between the smart objects and the control center and the control center serves as the interface for monitoring and controlling progress.

2.5.2.2 Blockchain Technology

Blockchain is one of the key enabling technologies for the realization of IIoT (Miller, 2018). Currently, both the industry and the academia are conducting extensive study on blockchain and it is being implemented in finance, supply chain, healthcare and car insurance (Khan et al., 2018). Blockchain technology refers to a pattern that enables peer-to-peer (P2P) networks to use and manage their transactions by a trusted rule which can be traced by all users making it impossible to be forge or tempered with (Andoni et al., 2019; Lu et al., 2019). If two parties agree on a transaction, the data generated in the transaction is converted into variables it is then combined with other transactions within the same time period and used to create new data block. The transaction is encrypted and broadcast to many computers in the P2P mode (Andoni et al., 2019). Afterwards, it is validated by the network members with an algorithm and saved on a single computer, each block is given a unique hash value. If an attempt is made to alter any part of the transaction, it will report an error because the correct hash value cannot be generated. However, if it is correctly done and the block is verified, it will combine with the previous verified transaction to form a blockchain. If both parties confirm the transaction, then it will be recorded as completed. Blockchain technology can be implemented in the oil and gas industry to secure data and create a more transparent transaction.

2.5.2.3 Cloud Computing

As IIoT generates high volume of data, powerful computing systems are needed to manipulate, analyze and store these data. Cloud computing can be used to address all these concerns. All devices or applications that is connected by IIoT is seamlessly interfaced with backend clouds. The cloud service can be configured or modeled as private, public or hybrid. Private cloud services are owned and controlled by a single company, public ones are owned and managed by a third-party cloud vendor and the hybrid is a combination of the features of both private and public. Due to the cost involved in developing and managing data centers and recruitment or training of technical employees, private cloud services are mostly only found in large organizations. They are also the most secure and safe form to prevent industrial espionage (Khan et al., 2018).

2.5.2.4 Artificial Intelligence and Cyber Physical Systems

AI technologies is applied to ensure that IIoT runs with little human control to improve accuracy and efficiency. With the use of complex technologies such as conversational AI and multi-agent systems, IIoT becomes autonomous. The intelligence is embedded at layers in IIoT systems, sensors are then connected to devices to edge servers and cloud data centers and this helps in optimization, predictive algorithms and enables different search. IIoT systems employs various cyber-physical systems (CPS) like industrial robots and manufacturing systems. Onboard embedded IoT devices is the core enabler of CPS that makes various sensors and actuators to operate seamlessly in industrial settings. These embedded devices assist in intelligent data processing for autonomous operation and increase efficiency in operations and even in IIoT and CPS systems.

Shell oil has an intelligent drilling solution know as Shell GeodesicTM, this system collects drilling data in real time and make decisions automatically (Microsoft, 2018). Artificial intelligence is used in predicting and locating oil and gas resource which increase success rates of production.

2.5.2.5 Augmented and Virtual Reality

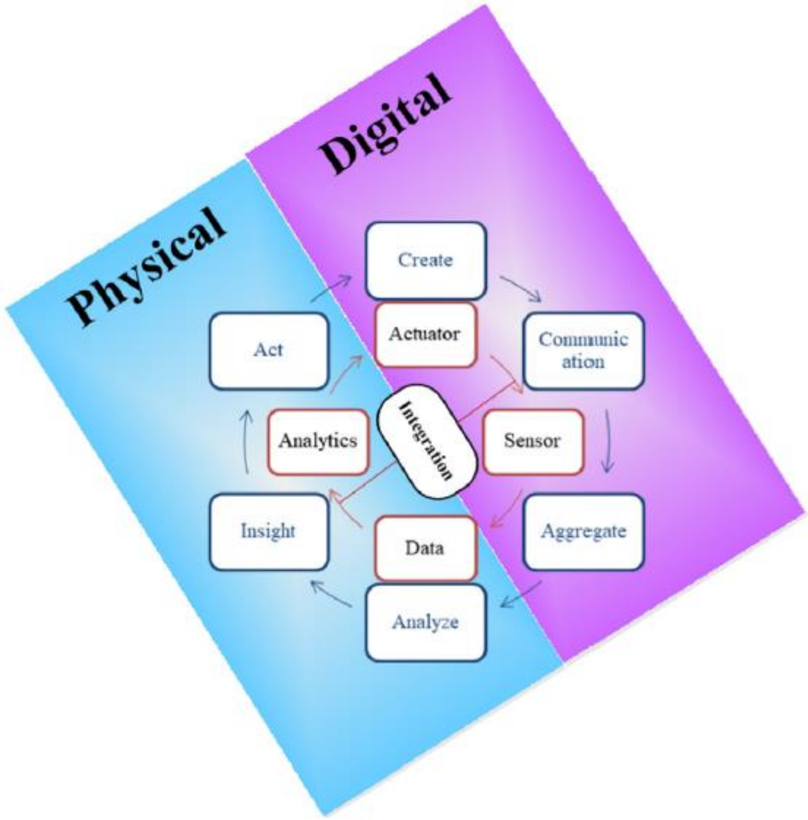
Augmented reality is an interactive experience of the real-world. In augment reality, interactive digital elements or sensory projections such as dazzling visual overlays, somatosensory, olfactory, buzzy haptic feedback, are superimposed into the real-world environments (Huffington Post, 2016; Schueffel, 2017; Chandler, 2019). It is applied when employees need to conduct complex operations such as development of industrial products, assembling/de-assembling machineries and mission critical system. It monitors industrial workers and machines during operations and instantly generate alters or notifications for prompt action to be taken for error minimization.

Virtual Reality (VR) is the use of computer systems to simulate the natural environment or something totally different (Bardi, 2019). It helps industrial workers to visualize the configurations and re- configurations of industrial functions and model it before they are implemented in IIoT systems. This helps reduced the amount of time used in configuration or reconfiguration, avoids errors hence the shut down time or downtime of the industrial machinery is reduced. They are mostly designed with open standards with various CPS and IIoT systems.

2.5.2.6 Digital Twin

Digital twin is a new simulation technology in digitization. It acquires data for mapping an entities lifecycle process in virtual space by using physical models and sensors (Mayani et al., 2018; Poddar, 2018).

Fig. 2.3: Digital Twin Model of the Production Process (Parrott and Warshaw, 2017).



The figure illustrates the production process by digital twin and it represent the cyclical model of the “physical world-digital world-physical world” (Pronier, 2018). It has five elements that drives it, they are; internal loop of sensors, data, analytics, actuators, and integration. An integration technology transmits aggregated data of operational data which are collected by sensors and the organizational data between the physical world and the digital world. It uses analytical techniques in performing algorithm simulation and visualization which helps in the analysis of data, it is then used for troubleshooting equipment.

Baker Hughes has developed a blueprint for digital twin in asset performance management, which includes failure detection, failure prediction, life cycle cost, strategy recommendations, asset status assessment and performance measurement. Digital twin can be used in improving the quality of a product and also improves the efficiency of the company by lower operational cost (Lu et al., 2019).

2.5.2.7 Wireless Communication Technologies

Most oil and gas companies operate in remotes regions and usually have limited access to telecommunication. They must therefore develop their own telecommunication infrastructure such as offshore platforms. Having a good communication technology is an effective tool for cost reduction and improves the overall operational performance. The research firm IHS, forecasted that the oil and gas industry investment in digital platform in 2019 will be about $1 billion (HIS Markit, 2015). The most common wireless communication technologies in used today are; Wi-Fi, ultra-wideband (UWB), RFID, Bluetooth, Zig-Bee, near field communication (NFC), Infrared data association (IrDA) and general packet radio services (GPRS). Wireless communication offers greater benefits than traditional wired ones in offshore projects and are also less expensive. Their application includes the monitoring wellhead during oil and gas development. IIoT has led to a rapid increase of wireless technology, which significantly improves the transmission efficiency of sensor data (Lu et al., 2019).

2.5.2.8 Other Technologies

Other technologies exist that is transforming the oil and gas industry, these includes; robotism, 3D printing and cybersecurity (Lectra, 2016).

Robotism: Robots has been in existent for decades but new improved ones are being developed. The oil and gas industry use multi-functional robots mainly for pipeline and inspection of equipment, such as drones and robots that repairs pipelines (Mashreq, 2019).

3D printing: It is still an emerging field in the oil and gas sector. It is mostly applied in oil and gas equipment manufacturing and in the field of material science (Mashreq, 2019).

Cybersecurity technology: A major issue with wireless system is intrusion or hacking and cybersecurity technology is able to help mitigate it.

System integration: Since there are many components in the oil and gas supply chain, it requires technologies to make integration easier. System integration technologies is used to achieve this need (Lu et al., 2019).

2.5.2.9 Big Data Analytics

2.5.2.9.1 Introduction

The rapid growth in technological progress has resulted in an explosion of datasets in the oil and gas exploration and production industries. Brule (2015) noted that petroleum engineers and geoscientist use more than half of their productive time searching and assembling data. As expected, it is a matter of concern to the management of oil and gas industry and it is their aim to address it. That is where Big Data comes in.

2.5.2.9.2 Big Data Analytics

Big Data is the technologies used in handling, manipulating and processing the huge dataset. The dataset comes in different formats and are generated in the various processes involve in upstream and downstream oil operations. Big data is not only a technology, but also involves people with the appropriate analysis skills, and makes dealing with extreme scale affordable. It was originated as a tag for a class of technology with roots in high-performance computing, as pioneered by Google in the early 2000 (Russom, 2012; Akoum and Mahjoub, 2013; Perrons and Jensen, 2014; Wipro and Wipro, 2014; Yang et al., 2014; Brulé, 2015; Ciarlini, et al., 2015; Bin Mahfoodh, 2017; Sukapradja, 2017; Hilgefort, 2018).

Big Data is also known as Big Data Analytics and includes both unstructured and multi-structured data. Unstructured data refers to data which are not organized and are mainly text, while semi-structured data are different kinds of data format generated as a result of interactions between people and machines (Yang, et al., 2014).

2.5.2.9.3 The Five Characteristics of Big Data

IBM identified three characteristics of big data which are commonly known as three Vs. They are; volume, variety and velocity (Pence, 2015). Recent literature has added two Vs which are veracity and value to complete big data characteristics (Ishwarappa and Anuradha, 2015).

Volume refers to how large the data or information is. Data is collected through sensors or other data collecting tools. Due to limited storage capacity, sustainability and data analysis issues it becomes difficult to handle data as it increases (Trifu and Ivan, 2018). The archives of many oil companies contain large volume of data but they lack the capability to process them. The main purpose of Big Data is to provide the capability to process these data (Ishwarappa and Anuradha, 2015). During the process of exploring, drilling and producing oil and gas, seismic data collected results in huge data which are used to develop 2D and 3D images of the subsurface layers. Narrow-azimuth towed streaming (NATS), uses data gathered from offshore seismic studies to design images of the underlying geology. A newer tool is wide azimuth, it captures more data at greater quality. All these tools results in massive amount of data that must be processed for decision making. There are also new technologies for capturing real time data during drilling process. Examples are logging while drilling (LWD) and measurement while drilling (MWD). Different types of sensors are used together with fiber optics capture some parameters such as temperature, fluid pressure and composition during oil and gas production (Feblowitz, 2013).

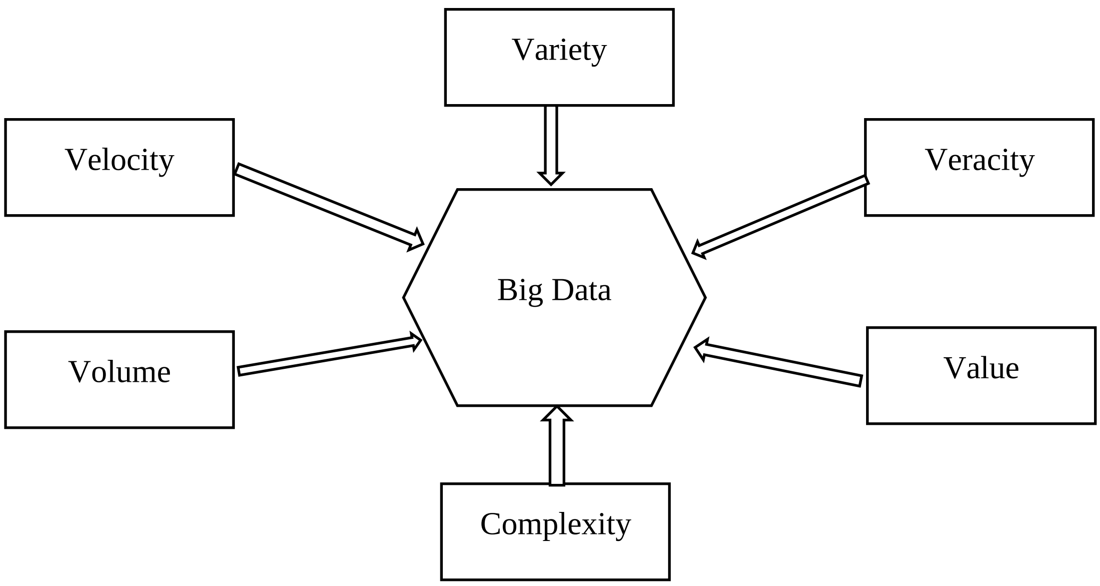
The velocity characteristics of Big Data is concerned with the speed or how fast data is generated, transmitted and processed. More often than not the amount of data generated is higher than the processing capacities. For instance, the velocity of data created in two days is about 5 exabyte which is equivalent to total amount of data humans generated up until 2003 (Sumbal and Tsui, 2016). Since petroleum engineering problems can be complex, it makes the characteristics of velocity more important for the oil and gas industry. It becomes virtually impossible for a single person to process the huge amount of data generated and an attempt to do so leads to delays and uncertainty. In many instances data in the oil and gas industry needs to be gathered in real time and processed quickly. Fast processing becomes necessary when drilling well which can help identify risks and prevent destructive blow-outs efficiently (Feblowitz, 2013).

The variety characteristics is in reference to the different types of data which are generated, stored and analyzed. The sensors and other data collecting tools comes in different forms as such the data formats also varies. These includes; text, image, audio or video. Technically they are classified as structured, semi-structured and unstructured (Sumbal and Tsui, 2016). Ishwarappa and Anuradha, (2015) noted that, an estimated 90% of the data generated are unstructured. That being said, most of the data generated from SCADA systems, surface and subsurface facilities, drilling data, and production data are structured. The data might be time series data that have been recorded over a specific time period. Structured data could also be generated from asset, risk, and project management reports. It could also be gathered from external sources such as weather data and market prices which are needed for forecasting. Unstructured data in the oil and gas industry includes; CAD drawing, well logs and daily report of drilling; whilst modelled and simulated data form semi-structured data (Feblowitz, 2013).

Veracity is concerned with the quality of the data; that is whether is it clean or dirty and how useful it is to be analyzed for decision making. Being assured of the data quality is very important since velocity and accuracy of the analyzed data depends on it. It is vital for the data generated to be professionally and proficiently filtered before it is analyzed else the result will not be accurate and hence cannot be relied upon for decision making (Mohammadpoor and Torabi, 2018). The characteristic of data veracity offers a considerable challenge to players in the oil and gas industry. This is primarily due to the nature of data generated which are mostly from subsurface facilities and as such might contain a level of uncertainty. Another source of problem for data veracity is the mode of data collection, particularly the conventional or manual method of using pen and paper. The fifth characteristics of Big Data is value. Since businesses exit to make profit, it is a vital characteristic. Oil and gas companies considers the financial benefits of big data before investing in its infrastructure. Since big data is able to identify anomaly in large data set, it gives room for engineers to forecast potential risk of a project. The ability to determine the output of an equipment used in operations and knowing in advance potential shortfalls gives the company a competitive advantage which creates value (Mohammadpoor and Torabi, 2018).

Literature also noted that apart from the five Vs there are also other characteristics that should be considered. An example is the complexity of the problem that is to be solved with the date gathered (Khvostichenko and Makarychev-Mikhailov, 2018). Fig 2.4 summarizes the above-mentioned characteristics of Big Data.

Fig 2.4 Big Data Characteristics (Adapted from: Mohammadpoor and Torabi, 2018)



2.6 Big Data Quality

With the growing relevance of big data, the issue of data quality has emerged. With the question, what good is the data collected if it cannot be used? The quality of data is therefore a vital component of big data and it entails more than just the absence of errors, it also includes the usefulness of the data to meet expectations or needs of the user (Eckerson, 2002).

2.6.1 Characteristics of Data Quality

Data Quality has seven attributes, the first five are concern with the content of the data and its structure, they are; Accuracy, Integrity, Consistency, Completeness and Validity. Data lacking any of these attributes is considered poor quality data which usually arises from data entry errors, duplication of records and misapplied business rules. However, data meeting all these requirements is still useless if the industry cannot understand or access it (Wand and Wang, 1996). That is where the remaining two attributes comes in, which are timeliness and accessibility. They are determined by interviewing or conducting a survey of those who use the data.

A quality data should therefore have all seven attributes to aid in reliable decision making.

Accurate: Should be filtered to get rid of errors such as typos, spelling mistakes.

Integrity: Data has not been altered.

Consistency: Similar types are well formatted to be the same or have and should be in line with the rules of the database.

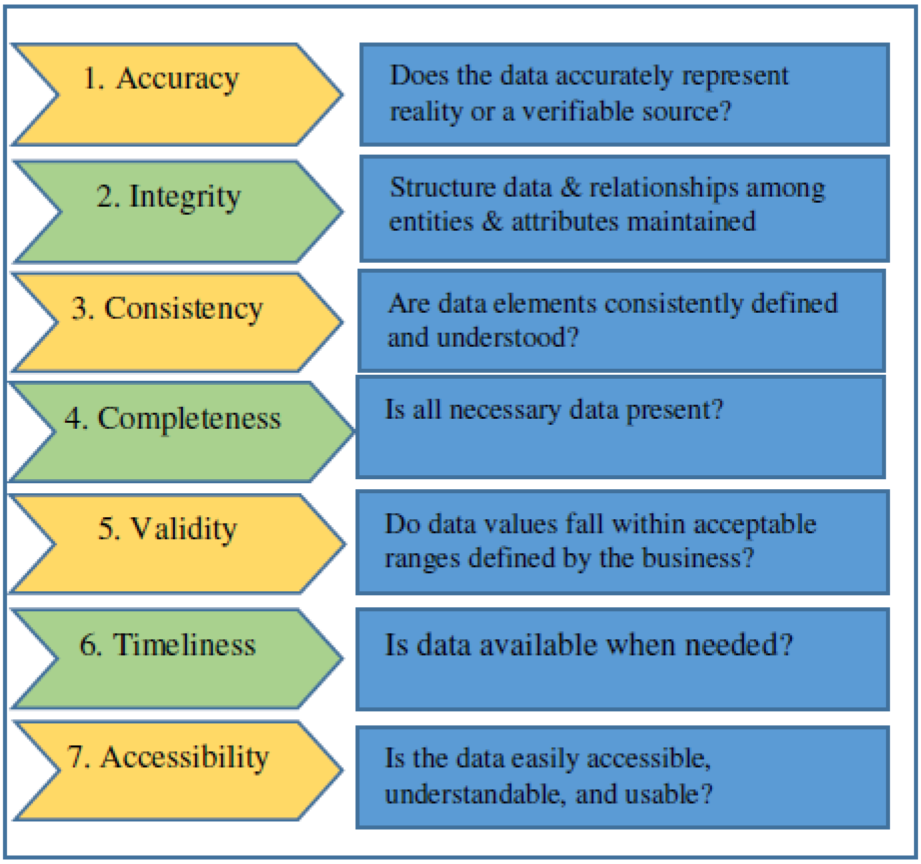
Complete: The data should have all the necessary data; omissions in the data makes it unreliable.

Valid: False data should be avoided.

Timely: The data should be ready when needed and must be current (Sebastian-Coleman, 2012).

Accessible: Users do not have to put in so much effort to acquire and use the data. Manual data should there be computerized to allow quick access (Boyd and Crawford, 2012).

Fig 2.5: Data Quality Attributes (Abdullah et al., 2015)



Apart from the seven data quality issues identified, there exist others that can compromise the quality of data. Data might be valid but incorrect (McGilvray, 2010), lack of validity routine in place (Wang and Strong, 1996), format, structure and syntax not matching (Lee, 2003), unexpected changes in source system and data conversion errors. A Data Quality Survey by TDWI, indicates that about 40% of companies have had problems with their data which resulted in losses or cost to their organization. Another 43% said they are yet to conduct an exercise on the effect of their data (Russom, 2012). In a different study conducted by Abdullah et al. (2015) indicated that; employees regard the extra time needed to reconcile data and dysfunctional system as prime causes of poor data quality.

2.7 Managing Data Quality

Having quality data is a continuous practice. So far as new data is generated and errors or mistakes are made then it means data should be improved for effective decision making. For companies to achieve constant quality data, they must;

1. Have a data quality program

Top level management must see the need of improving their data and make it their goal to implement a quality program.

2. Design a Project Plan

The organization should develop a plan or a number of plans and should include a well-defined scope of activities, estimated cost and benefits, attainable goals and plans to achieve it, monitoring and evaluation.

3. Have a Quality Control Team

Select employees or hire experts to oversee the development or creation of quality data plan. They should perform feasibility studies and implement the monitoring and evaluation plan to maintain high level of quality data always.

Management should establish the Data Quality Team (Madrigal and James, 1999) with regards to the following functions.

Functions of the Data Quality Team

Head of the Team: A person of high ranking in the company whose duties includes data quality and data administration.

Data Steward and Expert: Since data collected or generated is peculiar to specific units within the origination, experts in the various units should be made responsible for ensuring the quality of data.

Data Quality Leader: in charge of creating awareness, cleaning and monitoring and evaluation,

Data Quality Analyst: He or she is in charge of auditing, monitoring, and measuring data daily as well as prompting management of issues with the data and suggesting solutions.

Tools Specialists: Experts in data quality tools who can code data into the system to represent what is required by the organization.

Process Improvement Facilitator: Design procedures to have a well-defined data collection process and tools for improved data quality.

Data Quality Trainer: In charge of developing and delivering data quality materials and training employees.

4. Review Business Processes and Data Architecture

Once top-level managers are satisfied with the data quality plan, there should be in place selected senior managers whose duty will be to review the process of collecting, recording and using data in the organization. Experts can also be hired to develop the architecture to ensure easy input and access to information.

5. Assess Data Quality, Data Auditing.

There need to be a detailed assessment of the data in the organization to determine its quality; it is also known as data auditing or data profiling. This process is important in order identify errors in the data, create criteria or metrics to spot errors when entered and develop rules on how to fix data problems.

6. Clean the Data

Once data auditing is complete it must be cleaned (Sarpong and Arthur, 2013). A key component of quality management is to ensure that defects in the system are identified and corrected close to the source to reduce cost.

Four procedures are identified to clean data (Zhao, Yuan, Peng and Wang, 2002).

Correct: Defective data and records must be cleaned.

Filter: Making sure that only important data is in the system. Missing or meaningless data should be deleted. This should be done with care since some data are linked to others.

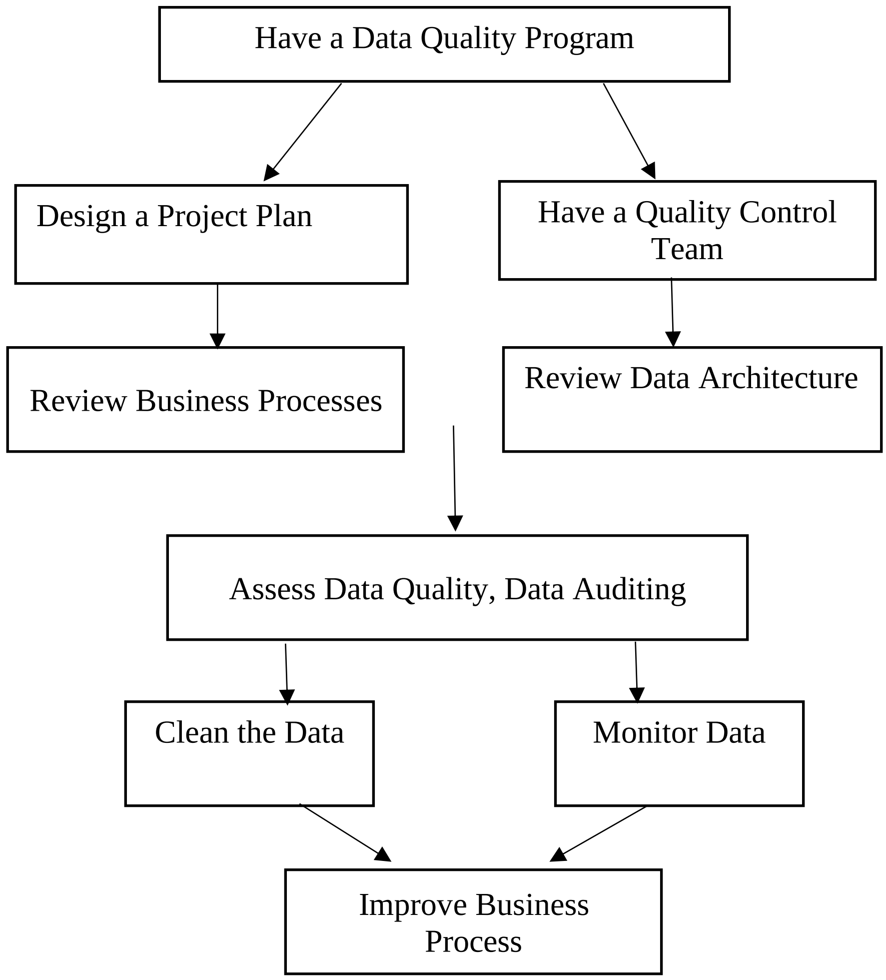
Detect and Report: Defective data should be change if not cost effective.

Prevent: To prevent errors, data entry personal should be well trained and previous mistakes should be addressed. If necessary, system models should be redesigned.

7. Monitor Data

Though it requires a lot of time in preparing data files to be uploaded into a database for the first time, companies need to do it else risk losing the benefits of data preparation efforts by failing to continuously monitor the data quality. Organizations can have a policy to do periodic audit of the data or audit it before and after data is entered. The audit report can serve as a progress report to ascertain if they are achieving the set targets.

Fig 2.6: Steps for Maintaining Data Quality (Abdullah et al., 2015)



2.8 Hazards in the Oil and Gas Industry

The hazardous environment that oil and gas worker operations make them prone to many incidents. Bouti and Allouch (2017) studied about 801 incidents in the oil and gas industry around the world to understand the issues being faced and make recommendations. Their study started in 2014 and ended in 2016, it revealed that most injuries occurred in October, mainly during Springs. North America had the majority of incidents, and about one third occurred in turbine hall area. Only one-quarter occurred in a High-Risk Activity (HRA), also half of the incidents happened when there was no tool being used. Most injuries were minor, such as cut to the finger that requires only first aid treatment. They also noticed that half of the incidents happened due to the hazardous nature of the work with human factors also playing a significant role in the high rate of incidents.

Many records exist on the incidents in the oil and gas industry over the years. Schouwenaars (2008), researched on the major fatal accidents in the industry between 1970 to 2008 which did not only lead to loss of lives but also destruction of equipment. His findings revealed the following. The explosion at a chemical plant near Flixborough in 1974; the industrial accident that occurred in 1976 at a chemical manufacturing plant which affect many towns especially people living in Seveso. The Bhopal disaster which occurred in 1984 due to a linkage of the toxic gas methyl isocyanate (MIC) gas and resulted in a fatality rate of 2,259. It is usually referred to as the worst industrial disaster in the world. Gas explosion in Norco, Louisiana (1988), the explosion that happened in 1988 at Pacific Engineering and Production Company of Nevada (PEPCON) in Henderson, Nevada. The Phillips disaster which happened in 1989 at Pasadena, Texas. The 1988 explosion on the Piper Alpha platform, it led to oil and gas fires that resulted in the death of 167 people. The Esso Longford gas explosion happened in 1998, at the Esso natural gas plant at Longford in Australia. The series of incidents which occurred in 2000 at Grangemouth in Scotland. Humber Oil Refinery explosion in 2001 at South Killingholme in North Lincolnshire, England. The sinking of Petrobras 36 (P-36) in 2001, it was a floating semi-submersible oil platform. The explosion in 2001 AZF, a fertilizer factory at Toulouse. The explosion in 2004 which flattened a large part of the Algerian port of Skikda, killing 30 people. The major fire at the oil storage facility at Buncefield, UK incident in 2005. The Texas City Refinery explosion that occurred in 2005, as a result of a hydrocarbon vapor cloud being ignited and exploded and finally the explosion at Alon USA oil refinery in Big Spring, Texas in 2008.

There has been a number of disasters afterwards. For instance, the British Petroleum Deepwater disaster in 2010 (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, January 2011). Oklahoma Rig Explosion occurred in 2018, in which Red Mountain was the operator of the well (Blum J., 2018).

CHAPTER 3

3.0 CONTEXT OF THE STUDY

3.1 Introduction

Ghana joined the league of oil producing countries when Jubilee oil fields officially came on-stream by late December of 2010 (The Report, 2011). It must however be noted that the search for oil and gas in Ghana started in 1897 (KITE, 2010). A study of the geology of Ghana, especially the rocks suggested to explorers the possibility of oil and gas deposit in commercial quantities. Ghana has four sedimentary basins, they are; Eastern Basin (Accra-Keta Basin), Inland Voltaian Basin, Western Basin (Tano-Cape Three Point Basin) and Central Basin (Saltpond Basin) - (Boateng, 2008). In 2004 Ghana gave licenses to international oil and gas companies for exploration in offshore oil and production. Three years after (2007), oil was discovered in large quantities by Tullow Oil and Kosmos Energy in the Western Region of Ghana, and the area was named Jubilee Fields. They immediately began developing the site and in December 2010 production of oil was officially launched. After the Jubilee Fields, other discovers has been made. Currently, Ghana’s Petroleum Commission has allocated rights to develop 16 new fields. Some of the fields includes, Tweneboa, Enyenra, Ntomme (TEN) and in 2016 hydrocarbon production began there and they are estimated to hold about 300 million barrels of oil and gas which are expected to last for 20 years.

In 2019, Springfield Group a Ghanaian company, made history by becoming the first indigenous African oil and gas company to make deep-water discovery offshore. They now join the likes of Aker Energy, Tullow Oil, Kosmos Energy and ENI as key upstream operators in Ghana (Dokosi M. E., 2019).

Like other developing countries, technological infrastructure is not yet at the advance stage in Ghana. It also does not have constant supply of electrical power. As at 2017, internet penetration rate in Ghana was 37.88%. Though this low, the big cities and towns has much higher rates. Also Jumia discovered that although the population of Ghana is 29 million, there are a total of 34.57 million mobile phones in the country. Which comes to 119% of mobile phone penetration rate, making Ghana one of Africa’s largest mobile market (abusuafmonline.com, 2018).

3.2 Oil Exploration Companies in Ghana

3.2.1 Tullow Oil

Tullow Oil plc is a multinational oil and gas exploration company. It was founded in the year 1985 in a small town in Ireland called Tullow as a gas exploration business in Senegal. Its current headquarters is in London (Tullow oil, 2019). Tullow oil, aim it to create long-term value for all their stakeholders. With the vision of being sustainable, progressive and the leading oil company in Africa by 2030. As at 2019, it has interests in about 80 licenses across 15 countries with 28 producing fields, and an acreage of 195,751 (sq km). Its main exploration works are in Africa and the Atlantic Margins; operating Ghana, Uganda, Kenya and French Guiana (Tullow Oil, 2019).

Tullow oil had interest to explore two oil fields in Ghana since 2006. Upon acquiring the needed licenses, they successfully drilled two wells in 2007 during the exploration phase together with their partners. This led to the discovery of the Jubilee Fields which is located at the Gulf of Guinea in the Tano Basin. The reservoir covered both licenses, which are Deepwater Tano and West Cape Three Points. In October 2008, Tullow was made the official operator the Jubilee Fields with assistance from their partners and in close collaboration with the government of Ghana. The first oil was successfully drilled in November 2010, that was 40 months after oil was discovered which represented a record timeframe for Deepwater Floating Production Storage and Offloading (FPSO) development. The Jubilee Field has been Tullow Group most prized asset as it brings in huge profit margin. Their second major discovery was TEN field (Tweneboa, Enyenra and Ntomme). The approval for development was granted in May 2013 and in August 2016, oil was successfully drilled. Currently, Tullow has 2 licences, 61,000 1H boepd, 2019 production, producing fields and 770 acreage (sq km) (Tullow Oil, 2019).

Tullow oil has a proven record of using new digital technologies to transform operations such as the use of artificial intelligence, machine learning and robotic process automation. In 2019, they created a corporate digital strategy team that will be in charge of developing and managing the realization of a Company-wide digital roadmap. They also have a well-defined Health & Safety system in place that deals with; Crisis and Emergency Management, Occupational Health and Safety, Contractor EHS Management and Process Safety Management (Tullow oil, 2019).

3.2.2 Kosmos Energy

Kosmos Energy is an American Oil and Gas exploration company that was founded in Dallas, Texas in 2003. It has both production and development operation offshore in Ghana, Equatorial Guinea and Gulf of Mexico. Kosmos Energy also has developmental project offshore Mauritania and Senegal and explorations licenses offshore Namibia, São Tomé and Príncipe and Suriname. It helped discovered the Jubilee Fields together with Tullow oil in 2007 which overlaps both West Cape Three Points and Deepwater Tano blocks (Kosmos Energy, 2019; Pai, 2019; Bloomberg, 2019).

Kosmos Energy aim is to create value for their stakeholders by (1) maximizing the value of their producing assets; (2) progressing discoveries toward project sanction and into proven reserves, production, and cash flow through efficient appraisal and development; and (3) adding new resources through a consistently active exploration program (Kosmos Energy, 2019).

Kosmos was made the Technical Operator for Development at Jubilee Field development and in 2010, the first production of oil was made. This led to more discoveries such as the TEN fields which they discovered together with Tullow oil. They found a huge accumulation of gas in 2009 at Tweneboa, later another one was discovered in 2010 at Enyenra then finally at Ntomme field where they found oil and gas condensate at Wawa in 2012. The production at the three fields; Tweneboa, Enyenra, and Ntomme (TEN) began in 2016 (Kosmos Energy, 2019).

3.2.3 Aker Energy

Aker Energy in a Norwegian company that was founded in February 2018 as a part of the Aker Group. Aker Group has a high reputation for oil and gas operations around the globe in over a decade, the recent one being in the Norwegian Continental Shelf, which gives credence to its exploits (Aker Energy, 2019).

Aker Energy aims to become the leading oil and gas operator in Ghana, by growing resources to producing reserves in an efficient, safe and reliable manner (Aker Energy, 2019). As noted on their page, their values are what guide their actions and decisions. Which are, transparent, Safe, Secure and Sustainable, Innovative, Decisive, Respectful and Value Creation (Aker Energy, 2019).

Aker Energy is currently developing the Pecan Field in ultra-deep waters offshore Ghana in close collaboration with Ghanaian authorities. The company will adopt the business model of Aker BP, and as such expects to have flexibility, efficient and an integrated structure for decision making. It also aims at being the leaders in digitalization of oil and gas operations in Ghana. They hold a 50 percent participation interest in the Deepwater Tano Cape Three Points block (“DWT/CTP”), which is about 110 kilometers from the shores of Ghana. It covers about 2,010 square kilometers in an area noted for huge deposits of oil and gas (Aker Energy, 2019).

3.2.4 ENI

ENI - Ente Nazionale Idrocarburi (National Hydrocarbons Authority) is an Italian oil and gas company which was founded in 1953 from an already existing company known as Agip which has been in existence since 1926. It is headquartered in Rome and is one of the seven Supermajor oil companies in the world. It operates in 67 countries and in 2016 was listed as the 11th largest industrial companies in the world (Bloomberg Business Week, 2016; Eni, 2019). Sustainability is at the core of their mission. It aims at creating value by ensuing financial, social and environmental stability. This they envisage to accomplish by being innovative and using technology as a driving force to improve their operations and also implementing the concept of circular economy (Eni, 2019).

Eni came to Ghana in 2009 and operates about 579 square kilometers of the 1,353 square kilometers deep offshore at Cape Three Points Block 4 (OCTP) which represent 42.47%. It also has 44.44% interest of the offshore Cape Three Points (OC TP) permit which is regulated by a concession agreement. In 2018, Eni produced a net of 18 kboe/d from the OCTP project and it was sent onshore to a treatment plant to feed the national grid, making it the only non-associated gas development project in deep water that wholly serves the local market in sub-Saharan Africa. The production is expected to continue for the next 15 years (Enipedia, 2019).

3.2.5 Springfield

Springfield is a Ghanaian oil and gas company that began operations in 2008 as a downstream player in Ghana. It obtained its license in 2010 as a Bulk Distribution Company (BDC) to procure, sell and distribute petroleum products to Oil and Marketing Companies (OMC) and refineries. Mainly selling to neighboring land-locked countries such as Mali and Burkina Faso. It is also the first independent Ghanaian company to lift crude oil from the TEN field in 2016 and 2017 and are into similar operations in the Nigerian downstream oil sector.

In 2011 Springfield obtained the license to provide upstream services to Oil companies in Ghana such as suppling vessels, subsea equipment, oil rigs, marine construction equipment and their maintenance and other logistical services. They also enter into Joint Venture with Aker Energy to enable the production of oil wells in 2015. In 2016, Springfield ventured into the upstream sector of the oil and gas industry and was awarded its pioneer oil and gas asset by the Government of Ghana. Springfield is the operator and majority interest holder in West Cape Three Points Block 2(WCTP2) off shore Ghana with the Ghana National Petroleum Corporation and its Exploration Company (Explorco) holding a minority interest. Springfield is the first wholly Ghanaian owned independent entity to achieve this feat. Springfield has conducted exploration evaluation and appraisal of existing discoveries on WCTP 2 and in 2019, they made history by becoming the first independent indigenous African energy group to discover oil in deep water (Springfield Group, 2017; Pilling 2019; Forbes, 2019).

CHAPTER 4
4.0 METHODOLOGY

4.1 Introduction

Methodology refers to the techniques that are used to conduct research. In a broader view, 'Method' covers the clarification of modes of explanation and understanding the nature of abstraction, research design and methods of analysis. They are the medium and outcome of research practices. Methods must therefore be appropriate to the object being studied and purpose of explanation of the inquiry (Rudestam and Newton, 2007). This chapter discusses the research method used to accomplish the objectives of this study. It describes the research approach and research design adopted. It makes a description of the target population, sample size, sources of data, method of data collection, method of data analysis which aided in answering the research questions and hypothesis.

4.2 Research Approach, Strategy and Design

Sullivan (2001) noted that, the research approach is dependent on;

- The researcher's disposition to human social behavior
- The level of knowledge of the subject area
- Whether there is theoretical understanding of the phenomenon being studied

According to Bryman and Bell (2015), drawing relations between theory and research can be conducted in two different approaches – deductive and inductive. In deductive research, the researcher deduces at least one theoretical hypothesis and use that as basis for conducting an empirical study. In the case of inductive approach, the researcher's uses empirical findings and observation and tries to develop a new theory into an existing one. This is in line with Saunders et al. (2007) view that inductive research aims at generating new theories whilst deductive research test theories.

Bryman and Bell (2015), asserted that there are two categories of research strategies, they are; quantitative research and qualitative. Quantitative strategy aims at quantifying data collected and how it is analyzed whilst qualitative strategy concerns with the detailed description and explanation of a phenomenon. On qualitative research, Guba and Lincoln (1994); noted that it is dependent on the observation, understanding and interpreting how people act and think when encountered with different scenarios and making judgement in a natural setting at that particular time. Qualitative research usually uses inductive methods whilst quantitative research uses deductive methods where hypotheses are formulated and tested (Gabriel, 2013; Rose et al, 2015).

A quantitative research approach was adopted in this study. It was based on the purpose, research questions and hypothesis formulated in the study. According to Hussey and Hussey (1997), when performing a quantitative research, the researcher has the option of choosing longitudinal study, experiment, a survey, a cross-sectional study, or a case study. Other main types of quantitative research are descriptive and correlational study. A combination of survey and correlational research was considered most suitable for this study. This is because surveys are statistical study of a sample population and it represents a very effective and powerful tool for establishing causality. Surveys require the researcher to be familiar with the basic principles and methods of statistical analysis for large data sets (Fink, 2003). Also, in a correlational research the researcher does measure variables and assesses the statistical relationship between them upon observing that the statistical relationship of interest between them is causal (Bryman A., 2006). These two approaches led to the discovery of the underlining reasons for the organizations' choice of data collection tools and then linked them to HSE performance and other issues.

4.3 Data Collection Instruments

The reliability of the outcome of the study will depend on the instrument used in collecting data. Questionnaires was used since it permits the gathering of enough data to make informed analysis and conclusion. The questionnaires were printed and administered to employees of different oil and gas companies in Ghana. A portion was also transmitted via Google forms and filled online. The used questionnaires for the study were 18 printed versions and 12 online forms.

4.4 Types of Data/Sources of Data and Target Population and Data Collection

4.4.1 Types or Sources of Data

The sources of data for the study were both primary and secondary. Primary data came from published governmental information on Ghana oil and gas industry and other documents created by the companies. Others came from the administered questionnaires. Secondary sources of data were obtained from books and journals. Information was also be gathered from reliable websites.

4.4.2 Target Population and Data Collection

In answering the research questions and hypothesis, it was important to know the type of oil and gas companies that will suit the study. There are over 400 oil and gas companies in Ghana but most are into downstream and service provision. There are 5 major upstream operators in Ghana and they are; Aker energy, Tullow oil, Kosmos energy, ENI and Springfield (Petroleum Commission – Ghana, 2020). However there exist other upstream operators who provide services to the big ones. Companies into upstream operation were the most suited for this study and formed the target population. This is because they have firsthand experience of what happens onshore and the incidents that occurs there. They are also usually the largest and have many departments and units to assess the relative risk among each group of employees. I however did send questionnaires to other companies specialized in other areas to get a good balance. This is in line with Spata (2003) who indicated that the population should contain attribute(s) of interest to the research.

4.5 Data Analysis

This work centered on data collection and its related practices by oil and gas companies in Ghana. Relevant literatures were reviewed in order to have a solid understanding of the subject area. These literatures formed the basis of the questionnaire as suggested by Saunders et al. (2007). The 30 questionnaires were coded for easy manipulation and Statistical Package for the Social Sciences (SPSS) was used to analyze it. The analysis was displayed using graphs and charts to give a visual representation for quick understanding. Also, tables were used which showed frequencies, percentages, correlation and regression models to test the validity of the hypothesis.

4.6 Testing of Relationship and Hypothesis

Correlation tests were carried out using both Pearson and Spearman correlation to determine relationship between variables. Pearson coefficient is the most commonly used correlation as Hussey and Hussey, (1997) noted that it has even become synonymous the word correlation. It is mostly associated with interval data; however, it can arguably be applied to ordinal data as well. Spearman coefficient was also calculated to make comparisons. Afterward regression analysis was conducted to see if the relationship is significant which formed the basis for either accepting or rejecting the hypothesis.

This is because, linear regression provides an important way to determination the relationship between dependent and independent variable. It is expressed as $Y = a + bX$;

where, X is the independent variable, Y is the dependent variable, b is the slope of the line and a is the intercept or where the line cuts the y-axis. Linear regression is commonly used in both social and natural science because it is easy to calculate or produce and comprehend.

4.7 Administering Questionnaire

Five (5) questionnaires were sent out for pilot testing and the outcome helped in adjusting some questions which were ambiguous. Fifty (50) questionnaires were printed and sent out and another 50 were sent via Google forms. Of the printed version, 32 were answered and returned and 15 of the Online forms were answered. As such there were a total of 47 responses, representing 47 percent response rate. However, some respondents did not answer some key questions, others too either misunderstood the questions or probably did not read them and ended up selecting opposing or inconsistent choices for different questions. Such responses were eliminated as unusable. This brought me to about 35 questionnaires and I selected 30 making sure most were upstream companies so they can satisfactorily answer the questions. Another important criterion I used in selecting the respondents is making sure I have one response per company in other to eliminate redundancy.

CHAPTER 5
5.0 RESEARCH MODEL

5.1 Introduction

HSE performance in the oil and gas industry is impacted by several factors. Over the years, many researchers have studied these elements to ascertain their level of impact with the result being varied degrees of certainty. This section discusses some of the main factors identified in literature and formulated hypothesis accordingly. For easy understanding, frequencies and percentages in the form of tables and figures were used in data analysis. Where there was a need for an additional testing to prove the validity of a case or hypothesis, correlation and regression analysis was conducted.

5.2 Geographical Location Impact on HSE Performance

Many researchers acknowledge the unique challenges that impact workers in the oil and gas industry base on their geographical location (Zolotukhin, 2019; Bouti and Allouch, 2017). Ahmed (2016), however suggested that these issues can easily be alleviated by sound operational management, biodiversity conservation practices, new technologies and impact mitigation at the beginning of the project design. Thereby making any adverse climatic effect non-problematic.

Employees in the oil and gas industry are exposed to different types of risk depending on which part of the world they operate in. For example, the arctic regions have severe weather conditions such as fog and ice which makes navigation very difficult. The use of icebreakers generates much noise which drives away sealions and since polar bears prey on them it has led to a reduction on their population thereby effecting the balance in the ecosystem (Zolotukhin, 2019). Also, since temperatures in the region easily drops well below freezing points, it creates additional difficulties for ship construction, equipment and systems, and people working there (The Barents observer, 2017, 2019; Shtokman brief history, 2019).

Other cold regions also face similar challenges as Bouti and Allouch (2017) pointed out in the case of North America that most injuries occurred in October, mainly during Springs due to relatively high pollen and workers begin to have seasonal allergies. These challenges are however absent in the tropical regions such as Ghana. The only notable challenge is dusty atmosphere (harmattan) which occurs in late November to early March (Minka and Ayo, 2014). They are therefore expected to have relatively lower rates of incidents.

It is therefore hypothesized that;

H1: The geographical location of an organization impacts its HSE performance.

5.3 Types of Industry or Nature of Work Impact HSE Risk

Much work has been done in the developed world on the risk factors associated with various types of work in the oil and gas industry. Most studies identify offshore engineers as having the highest risk. For example, Alliance Insurance Agency (2018), listed the five main risk facing oil and gas employees. They are; drilling fluids, Hydrogen Sulfide (H_2S) Exposure, transportation risk, fires and explosion and contact injuries. Contact injuries occurs when an equipment or objects fall on or crush an employee. Apart from transportation risk, the remaining four happens in areas where engineers usually work hence putting them at the highest risk. This was also discovered by Schouwenaars (2008) and Bouti and Allouch (2017) who intimated that administrative centers are safer since most of the incidents occurs at turbine halls and High-Risk Activity (HRA) areas. Since these studies were undertook in the developed world, this study aims to find out if the same outcome applies in Sub-Saharan Africa.

From the above statement it is hypothesize that;

H2: Upstream companies or offshore engineers are at a higher risk than other workers.

5.4 Frequency of Visit Impacts HSE Performance

Though frequent supervision is generally viewed positively in relation to the avoidance of incidents at the work place, there is sufficient evidence that shows poor supervision can lead to accidents (Brazier and Ward, 2003; Highways England, 2016). The visiting supervisory bodies must therefore ensure that they provide not just the right guidance and supervision but are themselves well trained to identify malpractices at the work place.

González (2011), suggested that oil companies needs constant supervision to ensure adherence to safety rules which will translate to improved HSE performance. She further stated that apart from the regular supervisory bodies, insurance companies should also be part of the inspection since they usually pay for damages when things go wrong and as such will be more strict resulting in low incidents. In the same vein, Government.no (2018) noted that frequent follow up of supervisors help in ensuring relatively low accidents with regards to HSE issues in the Norwegian petroleum sector. They continued that such exercise facilitates innovation and flexibility in the development and selection of good solutions which improves HSE performance.

A third hypothesis is therefore postulated;

H3: Higher frequent visit of supervisory bodies to enforce standards positively impacts HSE performance.

5.5 Medium of Data Collection Impacts HSE Performance

Traditionally, HSE data were collected on paper which makes them unusable or difficult to process hence making HSE decisions on them is a challenge. Nowadays many oil and gas companies use digital tools to capture data. These digital tools give companies the assurance that critical risks are being captured but analyzing such data to prevent risk is also not guaranteed (Midttun, 2018; Merkazy, 2019). Lloyd's Register noted about 75% of data even when captured, are difficult to analyze (Merkazy, 2019).

The adoption of digital technologies has revolutionized and continues to change the oil and gas industry. The use of mobile apps makes recording of data easier, accurate and fast. IoT is also widely used in the industry and collects real-time data and can be connected to any part of a company's activity thereby ensuring data updation for swift decision making including HSE decision (Khan et al., 2018; Dabbs, 2019).

ENERO (2019) noted that high-speed communication such as IoT can be used to improve workplace safety. Employees working at remote and stranded environments can make use of such applications to report real-time data for others to monitor and take preventive or reactionary measures immediately. These advanced tools offer more efficiency and higher productivity than conventional pen and paper.

From these, it is hypothesized that;

H4: The use of digital technologies positively impacts HSE performance.

5.6 Big Data Analysis Tools Impact HSE Performance

As opposed to traditional methods of analyzing information, today many large companies' decision making is supported by robust analytical tools such as Big Data Analytics. This is due to the huge amount of data they generate that makes it cumbersome when using traditional tools such as spreadsheet (Warner, 2018; Xiffe, 2020). Although Big Data offers numerous benefits such as cost reduction and improved decision making, it also comes with its unique challenges. Authors such as Xiffe (2020) noted that Big Data needs both organized and unorganized data for analysis which makes it difficult to understand. As such, only few people are talented enough to make informed decision from Big Data; thus, leading to the likelihood of non-optimal decision by management.

The use of Big Data to analyze data has however been implemented in several industries with high degrees of success (Demirkan and Delen, 2013). Its implementation in the oil and gas industry has been gradual, but has gained traction lately. The industry is therefore seeing a growing implementation and there are evidences of its usefulness in improving HSE performance. This is because when well processed and understood it gives a more accurate analysis of the accidents and guides management to make better decision (Cowles, 2015). As such, the following hypothesis is postulated;

H5: Application of Big Data to analyze data positively impact HSE performance.

5.7 Rate of Meeting and Proper Time Management Impacts HSE Performance

Meetings serves as a vital practice in the organization where problems and important information are shared among members of the organization. However, if they are not properly done it leads to negative consequence such as creating resentment among employees (Cohen et al., 2011; Yoerger, Crowe, Allen and Jones; 2017). Schell (2010), noted that half of meetings are sub-standard and fails to achieve its objective. In the United States for instance, there are 11 million meeting organized daily. Of these, 63% do not have an agenda and 45% are organized just to give information to staff. It is therefore not surprising why 33.4% of employees, think of meetings as unproductive (Keith, 2015; Minute, 2016). Most literature on meetings focus on good meeting practices and its resulting benefits (Cohen et al., 2011). However there exist a reasonable amount of works that looks into counterproductive meeting behaviors (CMBs) which is the negative attitudes of employees that adversely affect the goal of the meeting (Allen et al., 2015).

Regular healthy meeting at workplaces to discuss safety issues lead to improved HSE performance of the organization. As Health and Safety Executive (2020) stated, doing so lowers accident rates; creates a more positive health and safety climate; results in greater awareness of workplace risks and provide workers better control of risk associated with their work. These benefits they said happens partly because employees get to voice out their opinion on what works best for them or otherwise and they get feedback immediately. They also get to listen to the stories of others and get good counselling. These practices also improve the bottom-line of the organization since there is a positive health and safety culture in place.

With regards to time management, Moran (2018), in his article - Time Management is Safety Management - expounded on 3 points which can help improve safety in the work place. Firstly, the employee should create a list of actions; then define the priorities they care about and finally they must learn to deal with distractions. Following these steps will help workers deal with unforeseen occurrences at the work place. Coming to work on time, observing breaks and closing on time to make sure one is not overworked or fatigued help prevent incidents. Especially since incidents are known to be mostly caused by human errors **(**Horbah, Pathirage and Kulatunga, 2017)**.**

From the above statements, it is hypothesized that;

H6: Frequent meetings and proper time management positively impacts HSE performance.

5.8 Investing into HSE Improvement

Much literature exist that proves the direct benefit of HSE investment resulting in lower injuries, higher productivity, lower insurance cost and reduced absence due to sickness. However not all interventions lead to positive return on investment. Since companies exist to make profit, they are forced to select and implement what is best for both HSE and finance (British Safety Counsel, 2014; Aviva, 2011).

Employers have to be provided and trained on the use of personal protective equipment (PPE) at work (Health and Safety Executive, 2020; Griffith, 2014; Morrish, 2017). PPE is equipment that will protect the user against health or safety risks at work. This includes items such as respiratory protective equipment (RPE), safety helmets, gloves, eye protection, high-visibility clothing, safety footwear and safety harnesses and their likes. This makes employees safe from accidents that might occur at work.

In the same vein, training of workers makes them more prepared to prevent accidents and to administer help or assistance immediately on themselves or their colleague when one occurs. This will reduce the fatality rate or the seriousness of injuries before calling for external help if it becomes necessary (Morgan, 2017; Rospa, 2020).

Having thus said, it is hypothesized that;

H7: Investments made into HSE positivity impacts HSE performance.

5.9 The 7 Hypothesis

H1: The geographical location of an organization impacts its HSE performance

H2: Upstream companies or offshore engineers are at a higher risk than other workers

H3: The higher the frequency of visit by supervising bodies positively impacts HSE performance. H4: The use of digital technologies positively impacts HSE performance.

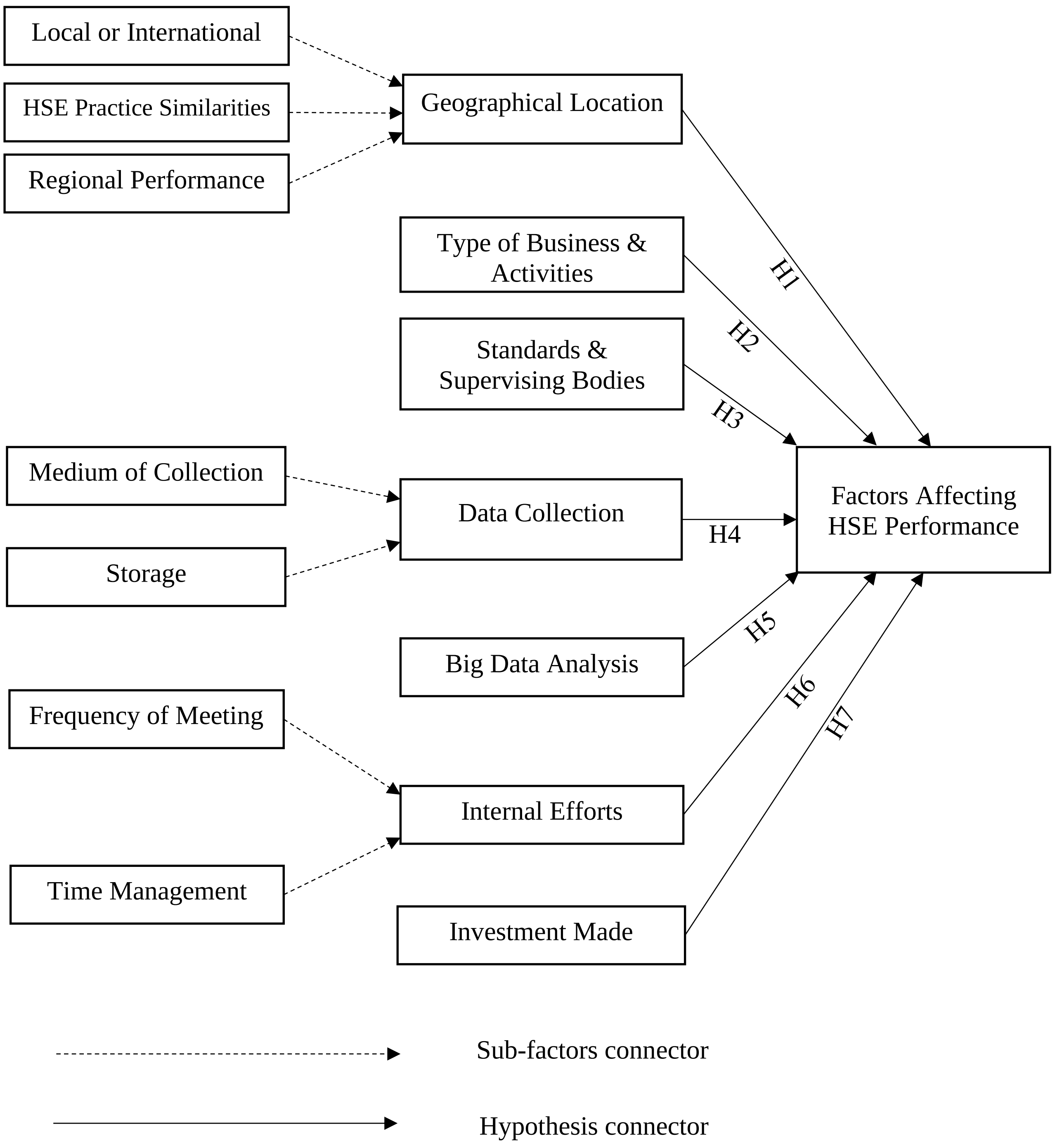
H5: Application of Big Data to analyze data positively impact HSE performance.

H6: Frequent meetings and proper time management positively impacts HSE performance.

H7: Investments made into HSE positivity impacts HSE performance.

5.10 Conceptual Model Diagram of Factors/Elements Affecting HSE Performance

Fig. 5.1. Conceptual Model of Factors Affecting HSE Performance



CHAPTER 6

6.0 RESULT ANALYSIS AND DISCUSSION

A questionnaire comprising of 32 questions was developed and administered to the targets group which were employees of oil and gas companies in Ghana, primarily the upstream sector. This chapter presents analysis and discusses their response.

6.1 Geographical Location of Organization vs HSE Performance

6.1.1 Local or International Company

In order to know whether the companies have offices outside Ghana, the respondents were asked to indicate if they operate only locally in Ghana or have branches outside Ghana (international). From table 6.1 below it can be seen that 23 of the 30 oil and gas companies sampled are international whilst 7 are local. This is a fair representation of what is on the ground in Ghana as most well-established oil and gas companies operates in other countries too.

Table 6.1: Local or International Company

Type	**Frequency**	**Percentage**
Local	7	23.3
International	23	76.7
Total	**30**	**100.0**

6.1.2 Similarities in HSE Practices Between Locations

Companies having international branches were asked to respond to whether they have different HSE practices in each country or region they operate in. Table 6.2 displayed below shows the response in this regard. Of the 23 international organizations, 12 (52.2%) mentioned that their operations are more or less the same, 7 (30.4%) specified they are the same and 4 (17.4%) quoted that they differ.

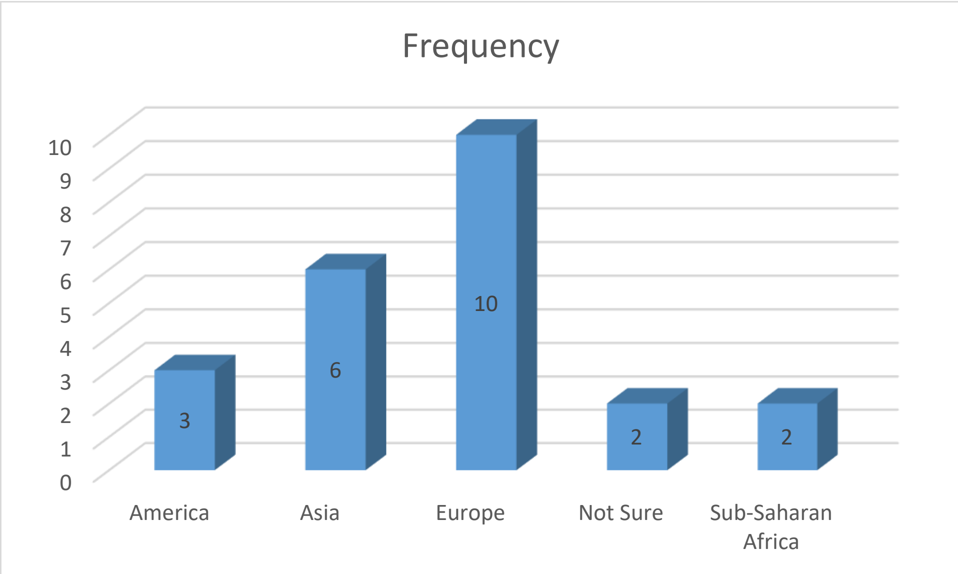
Table 6.2: Similarities in HSE Practices Between Locations

Similarities	**Frequency**	**Percentage**
Same	7	30.4
More or less the same	12	52.2
Differs	4	17.4
Total	**23**	**100.00**

6.1.3 Regional Performance of HSE Issues

The question was put forward for respondents to write down which region of the world has the best HSE performance. Of the 23 international companies; 10 said it is Europe which was highest frequency, this was followed by Asia with 6 choosing it; 3 people quoted it is America and 2 respondents each cited Sub-Saharan Africa or they are not sure of the region which has the best HSE performance. This is illustrated in figure 6.1 below.

Fig 6.1: Regional Performance of HSE Issues



6.1.4 Why are they the Best

Respondents were further asked to mention why they think the chosen region has the best HSE performance. Table 6.3 shows their responses. 15 percent specified they have better infrastructure, 5 said they are more technologically advanced and 3 quoted they have a more qualified work force.

Table 6.3 Why are they the Best

Why are they the Best	**Frequency**	**Percentage**
Better Infrastructure	15	65.2
Technologically more advanced	5	21.8
More qualified personnel	3	13.0
Total	**23**	**100.0**

6.2 Type of Business and Nature of Activities Performed

6.2.1 Type of Business

From table 6.4 it can be seen that, 25 of the companies operates upstream, 2 operates midstream and 5 operates downstream. This adds up to 32 instead of the 30 original companies because 2 companies operate both upstream and midstream. It can also be observed that most of the companies operates upstream. This was carefully chosen by the researcher because the nature of the study requires mainly upstream operators since they are more likely to be larger organizations and also have a fair representation of employees in many departments in order to assess the relatively risk associated with each.

Table 6.4: Type of Business

Type of company	Number	Percentage	Percent of Cases
Upstream	25	78.1	83.3
Midstream	2	6.3	6.7
Downstream	5	15.6	16.7
Total	**32**	**100.00**	**106.7**

6.2.2 Nature of Activities Performed

Respondents were given a list to select all the activities undertaken by their companies. The activities are; exploration, production, processing, distribution, marketing and other services. The highest number was for those into production which was 25 representing 83.3%. Exploration companies were 8 or 26.7%. Processing, distribution and marketing all had 3 or 10%. 1 company is into services. This sums up to 43 which overlaps the total number of companies by 13. This is so because some companies undertake more than a single activity.

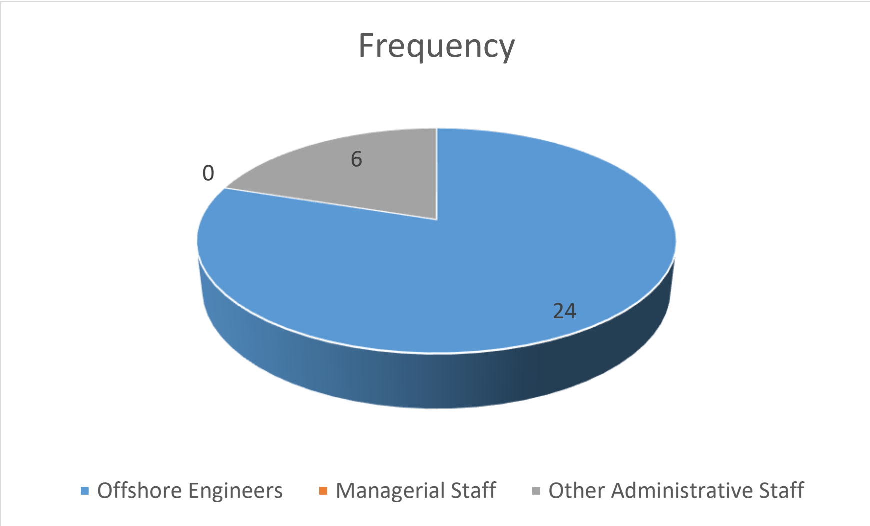
Table 6.5: Nature of Activities Performed

Activities	Number	Percentage	Percent of Cases
Exploration	8	18.6	26.7
Production	25	58.1	83.3
Processing	3	7.0	10.0
Distribution	3	7.0	10.0
Marketing	3	7.0	10.0
Other Services	1	2.3	3.3
Total	**43**	**100**	**143.3**

6.2.3 Team with the Most Frequent Incidents

Since there are usually several units in a typical oil and gas company and they have different risk levels, respondents were asked to choose among a list of categories of staffs who they think have the most frequent incidents. The result is displayed in Fig 6.2, which shows that, 24 said offshore engineers had the most frequent incidents, 6 said administrative staff. No one chose management staff.

Fig 6.2 Team with the most frequent Incidents



6.3 Supervising Bodies to Make Sure they Comply by Standards,

6.3.1 Having Standards as Guidance to Activities

In literature, numerous standards exist that guide the operations of oil and gas companies to ensure safety. Respondents were asked if the operations or activities of their company follows some standards. As displayed on table 6.6 below, all 30 companies have standards.

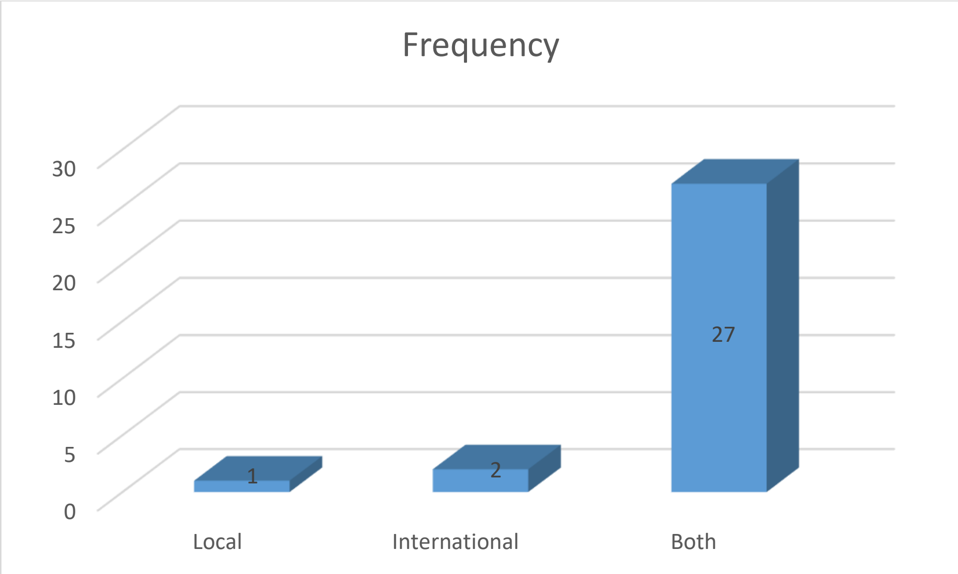
Table 6.6: Availability of Standards

Availability of Standards	Frequency	Percentage
Yes	30	100.0
No	0	0.0
Total	**30**	**100.0**

6.3.2 Visit by External Bodies Relations to HSE Performance

A follow up question to the one above was, does any external authorities come to supervise your HSE procedures and performance? All 30 respondents said yes. Of the 30, one company mentioned the supervising authority is solely local, while for two only international companies visit to supervise them. The remaining 27 quoted both local and foreign authorities visit to supervise their operations.

Fig 6.3: Visit by External Bodies Relations to HSE Performance



6.3.3 Frequency of Visit Relations to Incidents Per Week

Table 6.7 below is a cross tabulation of the frequency of the supervisory bodies visit and the number of incidents that occurs in the organization. Only 2 companies said they do have weekly visits and both said they have 0-5 cases of incidents per week. For those that said they are supervised monthly, 3 companies apiece said they have 0-5 and 6-10 incidents per week, bringing their total to 6 since no company have more than 10 cases. The highest frequency of visit was quarterly with half choosing it. 6 each said they have 0-5 and 6-10 cases per week and 3 said they do have 11-15 cases per week.

Table 6.7 Frequency of Visit Relations to Incidents Per Week

Frequency of Visit	**Incidents Per Week**			
	0-5	**6-10**	**11-15**	**Total**
Weekly	2	0	0	2
Monthly	3	3	0	6
Quarterly	6	6	3	15
Annually	3	1	3	7
Total	**14**	**10**	**6**	**30**

In order to find out if there is correlation within the variables, a regression analysis was conducted. Pearson's R and Spearman Correlation were 0.346 and 0.342 respectively. This indicates a moderately positive correlation between frequency of visit and incident level. The significant values of 0.000 for both methods means the correlation is significant since it is less than the significant level of 0.05.

Table 6.8 Symmetric Measures of Frequency of Visit Relations with Incidents Per Week

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance	Monte Carlo Significance		
						Significance	95% Confidence Interval	
							Lower Bound	Upper Bound
Interval by Interval	Pearson's R	.346	.192	1.948	.061[c]	.000[d]	.000	.095
Ordinal by Ordinal	Spearman Correlation	.342	.186	1.928	.064[c]	.000[d]	.000	.095
N of Valid Cases		30						

a. Not assuming the null hypothesis.

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

c. Based on normal approximation.

d. Based on 30 sampled tables with starting seed 402218460.

6.3.4 Frequency of Visit Relation to HSE Performance

The respondents were further asked to choose if the frequency of the visit or inspection have any effect on their HSE performance. No one said it has negative or somewhat negative impact, 1 person said it makes no impact, 10 said it has a high positive impact and the remaining 19 said it has very high positive impact. This can be seen in table 6.9.

Table 6.9 Frequency of Visit Relation to HSE Performance

Level of Impact	**Frequency**	**Percent**
Negative Impact	0	0.0
Somehow Negative Impact	0	0.0
No Impact	1	3.3
High Impact	10	33.3
Extremely High Impact	19	63.3
Total	**30**	**100.0**

6.4 How Data is Collected and Stored

6.4.1 Medium of Data Collection

Since the medium of data collection was one of the core parts of the research, respondents were asked to select the tool used in collecting data. The results revealed that, 10 companies use paper and pen exclusively. None of the companies uses only mobile app, and the remaining 20 companies uses both mediums; that is; pen with paper and mobile apps. This can be seen on table 6.10 below.

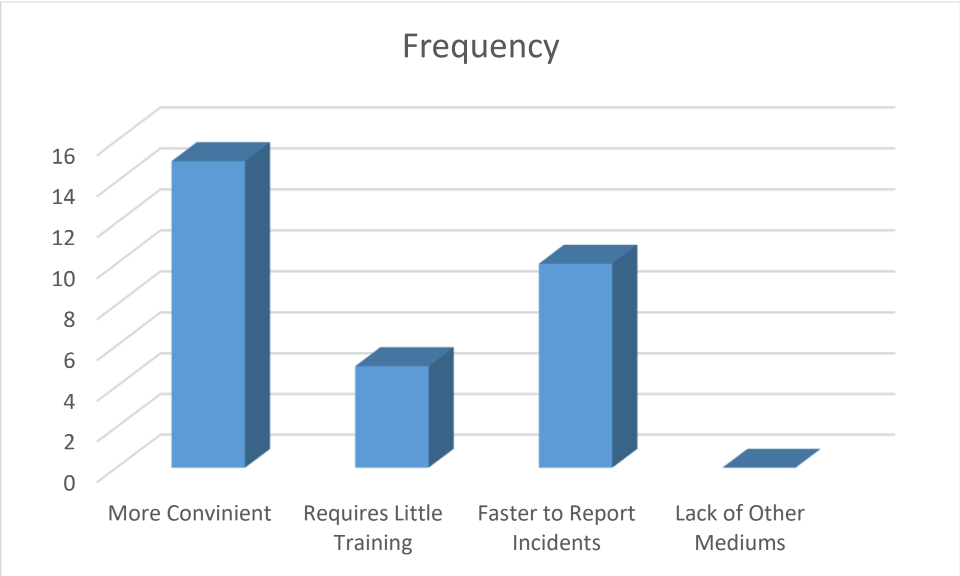
Table 6.10 Mode of Data Collection on HSE Issues

Medium	Frequency	Percent
Pen and Paper	10	33.3
Mobile App	0	0.0
Both	20	66.7
Total	**30**	**100.0**

6.4.2 Reasons for Using Pen and Paper

In order to know the reason behind the use of pen and paper as a tool for data collection, respondents were asked to select the main reasons for their continued usage of pen and paper despite the advent of mobile apps for decades. Half of them (15), said it is more convenient. 5 representing 16.7% mentioned it is because it requires little training and the remaining 10 or 33.3% said it was faster to report incidents. Those were their primary reason for their continued usage of pen and paper. No one chose lack of other mediums.

Fig 6.4: Main Reason for Using Pen and Paper



6.4.3 Storage of Data after Being Collected with Pen and Paper

Respondents using pen and paper as data collection tool were asked to select how data is stored after it is collected. Most of them that is; 27 (90%) of the 30 said it is immediately entered into the computer database, only 3 (10%) said they are immediately manually archived. This is displayed in table 6.11.

Table 6.11 Storage of Data after Being Collected with Pen and Paper

Storage Type	Frequency	Percentage
Immediately Entered into the computer database	27	90.0
Archived	3	10.0
Total	**30**	**100.0**

6.4.4 Main Reason for Using Mobile App

Those that use mobile apps for collecting data were asked to select their main reason for it. Of the 20 respondents that indicated they use mobile apps for collecting data, 14 representing 70% said it is more efficient, 20% that is 4 said it makes reporting of incidents faster and 2 or 10% said is it easier to store data with the mobile app. The responses are displayed in table 6.12 below.

Table 6.12: Main Reason for Using Mobile App

Main Reason	Frequency	Percentage
More Efficient	14	70.0
Faster to report Incident	4	20.0
Easy to Store Data	2	10.0
Total	**20**	**100.0**

6.4.5 Data Storage after Being Collected by Mobile App

Table 6.13 shows the response on how the various companies store data after it is collected via mobile app. 15 (75%) respondents said the data is automatically updated on the company's database and 5 respondents (25%) quoted they manually upload the data into the database.

Table 6.13: Data Storage after Being Collected by Mobile App

Storage Type	Frequency	Percent
Automatically updates on the company's database	15	75.0
Manually uploaded into the database	5	25.0
Total	**20**	**100.0**

6.4.6 Relations Between Medium of Data Collection and Incidents Per Week

Table 6.14 is a cross-tabulation of the types of data collection tool to the number of incidents per week. It was discovered that, of the 10 companies that uses only pen and paper, 9 has 0-5 incidents per week and 1 has 6-10 incidents per week. No company uses only mobile apps. When it comes to combination of the two mediums, 5 said they record 0-5 incidents in a week, 9 said they have 6-10 incidents and 6 said they have 11-15 incidents in a week.

Table 6.14 Relations Between Medium of Data Collection and Incidents Per week

Mode of Data Collection	Incidents Per Week			
	0-5	**6-10**	**11-15**	**Total**
Pen and Paper	9 (90.0)	1 (10.0)	0 (0.0)	10 (100.0)
Both (Pen & Paper/Mobile App)	5 (25.0)	9 (45.0)	6 (30.0)	20 (100.0)
Total	**14**	**10**	**6**	**30**

6.4.7 Usefulness of Data Collected in Decision Making

A Likert scale ranging from 1-5 with 5 being the highest was made for respondents to select their rating of the usefulness of the data collected with regards to its usefulness in decision making. Of this, 8 (26.7%) said it is very useful and 22 (73.3%) said it is extremely useful. The options for useless, somehow useless and no difference were left empty.

Table 6.15 Usefulness of Data Collected in Decision Making

Level of Usefulness	Frequency	Percent
Useless	0	0.0
Somehow Useless	0	0.0
No Difference	0	0.0
Very Useful	8	26.7
Extremely Useful	22	73.3
Total	**30**	**100.0**

6.4.8 Use of IoT to Collect Data

The use of IoT to collect data was extensively covered in literature. Respondent were therefore asked to select if they use it or not. It turned out that only 6 respondents do not use IoT and the remaining, 24 said yes to using IoT for data collection.

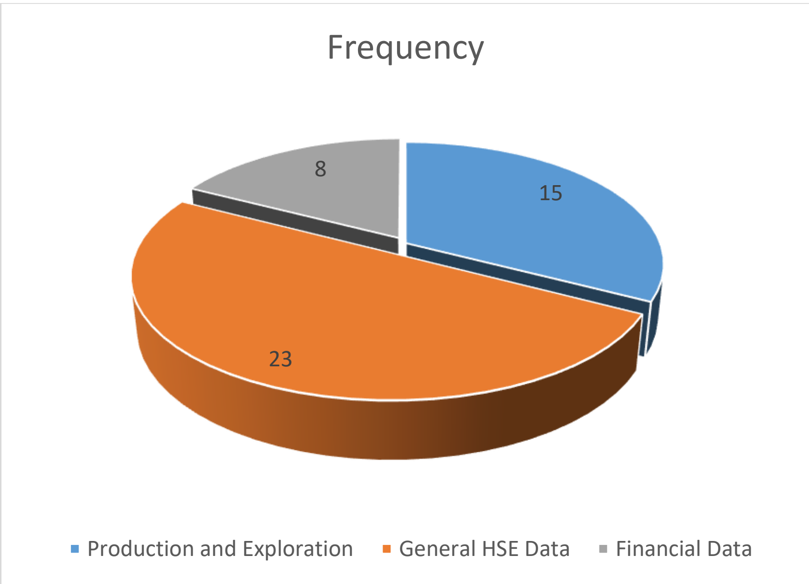
Table 6.16 Use of IoT to Collect Data

Using IoT to Collect Data	**Frequency**	**Percent**
Yes	24	80.0
No	6	20.0
Total	**30**	**100.0**

6.4.9 Type of Data Collected with IoT

As IoT can collect variety of data in real time, respondents were asked to choose all types of data they are used to collect in their organization. Figure 6.5, illustrates the breakdown of their selections. Of the 24 that said they use IoT, 15 chose production and exploration as a data it captures, 23 said it captures health and safety issues and 8 said it captures financial data. A column was provided for them to list 'other data' captured but it was empty. This question was to know if their answer to HSE issue with regard to IoT was reliable.

Fig 6.5: Type of Data Collected



6.4.10 IoT Relations with Incidents Per Week

Of the 30 companies sampled, 24 uses IoT to capture data and 10 of these specified they have 0-5 incidents a week which is 41.7%. Nine (9) which represents 37.5% had between 6-10 incidents per week and 5 have 11-15 incidents per week. O the six (6) companies that do not use IoT, 4 do record 0-5 incidents per week and 1 each for 6-10 and 11-15 incidents per week. Juxtaposing the relative percentage of those who use it to those who do not, it is difficult to draw conclusions as to which alternative is better. As such correlation and regression analysis will be performed to know the relation and causality of the variables.

Table 6.17 IoT Relations with Incidents Per Week

Use of IoT	**Incidents Per Week**			
	0-5	**6-10**	**11-15**	**Total**
Yes	10 (41.7%)	9 (37.5%)	5 (20.8%)	24 (100%)
No	4 (44.7%)	1 (16.7%)	1 (16.7%)	6 (100%)
Total	**14**	**10**	**6**	**30**

Pearson's R and Spearman correlation are 0.151 and 0.167 respectively, this numbers points to low correlation. Using 95% confident interval, the approximate significant values of 0.425 and 0.379 also tell us the relation is not significant. The same is true for the significant values (p-value) of 0.573 and 0.487. Even their lower bounds of 0.563 and 0.496 are greater than the significant value of 0.05. This is shown in table 5.18.

Table 6.18 symmetric measures of IoT relations to risk per week

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance	Monte Carlo Significance		
						Significance	95% Confidence Interval	
							Lower Bound	Upper Bound
Interval by Interval	Pearson's R	.151	.182	.809	.425[c]	.573[d]	.563	.583
Ordinal by Ordinal	Spearman Correlation	.167	.182	.894	.379[c]	.487[d]	.477	.496
N of Valid Cases		30						

a. Not assuming the null hypothesis.

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

c. Based on normal approximation.

d. Based on 10000 sampled tables with starting seed 92208573.

6.5 How Data is Analyzed

6.5.1 Use of Big Data to Analyze Data

Literature revealed the growing trend in the adoption Big Data Analysis to analyses data by oil and gas companies. Respondents were therefore asked to specify whether their company uses Big Data applications. The result is displayed in table 6.19. Of the 30 that responded to the question, 11 said no and 19 said yes.

Table 6.19 Use of Big Data to Analyze Data

Use of Big Data	Frequency	Percent
Yes	19	63.3
No	11	36.7
Total	**30**	**100.0**

6.5.2 Is the Use of Big Data New

Since Big Data was relatively newly adopted by the oil and gas industry, respondents were asked if it was newly introduced or it has been in usage for a long time. Of the 19 that said yes to using Big Data, 13 said it has always been part of their information system whilst 6 quoted it was introduced recently. Their response is seen in table 6.20.

Table 6.20 Is the Use of Big Data New

Is the Use of Big Data New	Frequency	Percent
Yes	6	31.6
No	13	68.4
Total	**19**	**100.0**

6.5.3 Has There Been HSE Improvement Upon the Use of Big Data

Respondents, mainly those who said Big Data was recently introduced, were asked to specify if they have noticed an improvement in their HSE performance upon the introduction of Big Data. Eleven (11) people responded to the question and all said yes there has been an improvement.

Table 6.21 Has There Been Improvement in the Use of Big Data

Big Data Improve HSE Issues	Frequency	Percent
Yes	11	100.0
No	0	0.0
Total	**11**	**100.0**

6.5.4 Big Data Relations with Incidents Per Week

The table below is a cross-tabulation between the companies using big data and those not using it in relation with incidents per week. It can be observed that, 12 of those using big data records 0-5 incidents per week, 5 have between 6-10 incidents and 2 companies have

11-15 incidents per week. For those not using big data, 2 companies have 0-5 incidence per week, 5 have 6-10 incidents per week and 4 have 11-15 incidents in a week.

Table 6.22 Big Data Relations with Incidents Per Week

Use of IoT	**Incidents Per Week**			
	0-5	**6-10**	**11-15**	**Total**
Yes	12 (63.16%)	5 (26.32%)	2 (10.52%)	19 (100%)
No	2 (18.18%)	5 (45.45%)	4 (36.36%)	11 (100%)
Total	**14**	**10**	**6**	**30**

The Pearson's R and Spearman Correlation for Big Data analysis usage in relation to incidents per week are 0.506 and 0.521 respectively. This shows a positive moderate correlation. A look at the significant column shows, 0.033 each. Since this is less than the significant level of 0.05, it means the correlation is significant.

Table 6.23 Symmetric Measure of Big Data Usage in Relations with Incidents Per Week

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance	Monte Carlo Significance		
						Significance	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Interval by Interval	Pearson's R	.506	.146	3.105	.004[c]	.033[d]	.000	.098
Ordinal by Ordinal	Spearman Correlation	.521	.143	3.227	.003[c]	.033[d]	.000	.098
N of Valid Cases		30						

a. Not assuming the null hypothesis.

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

c. Based on normal approximation.

d. Based on 30 sampled tables with starting seed 1291153757

6.6 Frequency of Meeting and Time Management

6.6.1 Frequency of Meeting vs Number of Incidents Per Week

As seen in table 6.24; 25 of respondents said they meet weekly to discuss HSE issues and 5 said they meet monthly. None chose either quarterly or annually as frequency of meeting. In order to know whether the frequency of discussing HSE issues impacts its occurrence, a cross-tabulation was made between the two variables. Of the 25 that said they do discuss it weekly, 14 have 0-5 cases in a week, 6 have 6-10 cases and 5 have 11-15 cases. For those who meet monthly, 4 said they have 6-10 cases a week and 1 person said they have 11-15 cases a week.

Table 6.24 Frequency of meeting vs Number of Incidents Per Week

Frequency of Meeting	Incidents Per Week			
	0-5	6-10	11-15	Total
Weekly	14	6	5	25
Monthly	0	4	1	5
Quarterly	0	0	0	0
Annually	0	0	0	0
Total	**14**	**10**	**6**	**30**

Table 5.25 below shows the regression analysis of meeting frequencies to incidents per week. The correlation values of 0.556 and 0.571 for Pearson's R and Spearman Correlation respectively indicates a moderately strong positive relation between the variables and the significant levels of 0.000 implies the relationship is significant.

Table 6.25 Symmetric Measures of Frequency of meeting in Relation to Incidents Per Week

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance	Monte Carlo Significance		
						Significance	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Interval by Interval	Pearson's R	.556	.130	3.535	.001[c]	.000[d]	.000	.095
Ordinal by Ordinal	Spearman Correlation	.571	.125	3.678	.001[c]	.000[d]	.000	.095
N of Valid Cases		30						

a. Not assuming the null hypothesis.

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

c. Based on normal approximation.

d. Based on 30 sampled tables with starting seed 139908985.

6.6.2 Importance of Time Management in Relations to HSE Performance

Table 6.26 displays the response given by the 30 respondents regarding the importance of time management in improving their HSE performance. The result indicates that, 10% said it has no impact in their HSE performance, 30% and 60% said it is very important and extremely important to their HSE performance respectively. No one chose negative impact or somewhat negative impact.

Table 6.26 Importance of Time Management in Relations to HSE Performance

Importance of Time Management	Frequency	Percentage
Negative Impact	0	0
Somewhat Negative Impact	0	0
No Impact	3	10

Very Important	9	30
Extremely Important	18	60
Total	**30**	**100**

6.7 Investment Made to Improve HSE Performance

6.7.1 Do you Invest in Improving HSE Performance

As shown in table 6.27, below, all 30 respondents mentioned their company do invest in improving their HSE performance.

Table 6.27 Do you Invest in Improving HSE Performance

Invest in HSE	**Frequency**	**Percent**
Yes	30	100.0
No	0	0.0
Total	**30**	**100.0**

6.7.2 Investment to Improve HSE Performance

This is a follow up question to the one above. Respondents were asked to write down or select the types of investment made by their company to improve HSE performance. 16 chose hiring of competent staffs, 29 chose frequent training of staff, 19 selected provision of specialized clothing and 3 chose increased awareness as the form of investment made by their company to improve HSE performance. An option for 'others' was provided but was left empty by respondents. Their response is shown in table 6.28.

Table 6.28 Investment to Improve HSE Performance

Type of Investment	**Frequency**	**Percent**	**Percent of Cases**
Hiring of Competent Staff	16	18.4	53.3
Frequent Training of Staff	29	33.3	96.7
Providing HSE Equipment	19	21.8	63.3
Creating Awareness	23	26.4	76.7
Total	**87**	**100.0**	**290.0**

6.7.3 Types of Investment Made Relation to Incidents Per Week

The output of the incident per week by the types of investment shows very little differences, especially when looking at their percentage numbers. The number of incidents per week between 0-5 for all four investment methods range from 31.3% - 43.5%. With the best (43.5%) being awareness creation. For incidents between 6-10 shows all four interventions were between 31.6%-39.1%. Here also awareness creation has the better outcome since 6-10 incident per week is not as bad as 11-15 incidents per week. Incidents between 11-15 has the most disparity, it ranges from 17.4% - 31.5% which is almost double the figure. It therefore seems awareness creation and provision of HSE equipment has the best impact on HSE performance. On the other hand, hiring of competent staff is the least effective method. It must however be noted that many companies do combine two or more investment strategies towards improving their HSE performance.

Table 6.29 Types of Investment Made Relation to Incidents Per Week

Type of Investment	**Incidents Per Week**			
	0-5	**6-10**	**11-15**	**Total**
Hiring of Competent Staff	5 (31.3%)	6 (37.5%)	5 (31.5%)	16
Frequent Training of Staff	13 (44.8%)	10 (34.5%)	6 (20.7%)	29
Providing HSE Equipment	9 (47.4%)	6 (31.6%)	4 (21.1%)	19
Creating Awareness	10 (43.5%)	9 (39.1%)	4 (17.4%)	23
Total	**14**	**10**	**6**	**30**

Table 5.30 displays the regression table for hiring of competent staff in relation to incidents per week. The correlation values of 0.369 and 0.367 for Pearman’s R and Spearman Correlation values respectively shows a positive moderate correlation. However, with significant values of 0.200 and 0.167, means it is not significant, thus giving evidence to the null hypothesis.

Table 6.30 Symmetric Table of Hiring of Competent Staff to Incidents Per Week

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance	Monte Carlo Significance: Significance	95% Confidence Interval: Lower Bound	95% Confidence Interval: Upper Bound
Interval by Interval	Pearson's R	.369	.158	2.103	.045[c]	.200[d]	.057	.343
Ordinal by Ordinal	Spearman Correlation	.367	.162	2.091	.046[c]	.167[d]	.033	.300
N of Valid Cases		30						

a. Not assuming the null hypothesis.

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

c. Based on normal approximation.

d. Based on 30 sampled tables with starting seed 792558341.

Table 6.31 displays the regression table for Frequent Training of Staff in relation to Incidents Per Week. The correlation values of 0.176 and 0.186 for Pearman's R and Spearman Correlation values respectively shows there is no correlation. The significant values of 0.667 gives a strong indication to the null hypothesis.

Table 6.32 Symmetric Table of Frequent Training of Staff to Incidents Per Week

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance	Monte Carlo Significance: Significance	95% Confidence Interval: Lower Bound	95% Confidence Interval: Upper Bound
Interval by Interval	Pearson's R	.176	.089	.949	.351[c]	.667[d]	.498	.835
Ordinal by Ordinal	Spearman Correlation	.186	.093	1.000	.326[c]	.667[d]	.498	.835
N of Valid Cases		30						

a. Not assuming the null hypothesis.

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

c. Based on normal approximation.

d. Based on 30 sampled tables with starting seed 792558341.

The table below is the regression table for Provision of Specialized Tools in relation to incidents per week. Pearson's R value is 0.006 and that of Spearman Correlation is 0.000, both showing no correlation. The significant values of 0.905 each also gives strong evidence to the null hypothesis.

Table 6.33 Symmetric Table for Provision of Specialized Tool in Relation to Incidents Per Week

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance	Monte Carlo Significance: Significance	95% Confidence Interval: Lower Bound	95% Confidence Interval: Upper Bound
Interval by Interval	Pearson's R	.006	.180	.032	.975[c]	1.000[d]	.905	1.000
Ordinal by Ordinal	Spearman Correlation	.000	.181	.000	1.000[c]	1.000[d]	.905	1.000
N of Valid Cases		30						

a. Not assuming the null hypothesis.

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

c. Based on normal approximation.

d. Based on 30 sampled tables with starting seed 792558341.

Table 6.34 is a display of the regression table for awareness creation in relation to incidents per week. For Pearson's R, the correlation is 0.206 and that of Spearman Correlation is 0.237, both numbers show weak moderate correlation. However, the significant values of 0.433 and 0.67 shows that the correlation is not significant given evidence to the null hypothesis. However, the lower bound for Spearman shows a significant of 0.000 which is lower that the level of 0.05.

Table 6.34 Symmetric Table for Creating Awareness in Relation to Incidents Per Week

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance	Monte Carlo Significance		
						Significance	95% Confidence Interval	
							Lower Bound	Upper Bound
Interval by Interval	Pearson's R	.206	.179	1.091	.285[c]	.433[d]	.256	.611
Ordinal by Ordinal	Spearman Correlation	.237	.175	1.270	.215[c]	.067[d]	.000	.156
N of Valid Cases		29						

a. Not assuming the null hypothesis.

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

c. Based on normal approximation.

d. Based on 30 sampled tables with starting seed 1559535668.

6.7.4 What is Being Done to Improve HSE Performance

Respondents were asked to provide a brief response to what management is doing or can do to improve the HSE performance. As seen in table 6.35, eight (8) said awareness creation, 5 said frequent training, 4 mentioned the incidents level should be published based on departments so each department will identify their fault and work on improving it. Two (2) respondents suggested that the best safety personnel should be rewarded. There was one response each for 'introducing simpler incidents reporting methods' and 'investigating causes of incidents to avoid its recurrence'. One respondent combined three factors which are training, awareness and reporting. Finally, 8 did not respond to the question.

Table 6.35 Interventions to Improve HSE Performance

Interventions to Improve HSE performance	Frequency	Percentage
Awareness Creation	8	26.7
Frequent Training	5	15.7
Published Incidents Level Per Department	4	13.3
Reward Best Safety Personnel	2	6.7
Introduce Simpler Ways of Reporting	1	3.3
Investigate and Control	1	3.3

Training, Awareness and Reporting	1	3.3
Total	**30**	**100**

6.8 Incidents

6.8.1 Recording of Incidents

Respondents were asked to respond to the question ‘do you record all incidents or only serious ones.’ Their response is displayed on table 5.36 below. 26 or 86.7% said they record all injuries be it serious or not and the remaining 4 (13.3%) said, they record only serious or complex injuries.

Table 6. 36 Recording of Incidents

Recording of Incidents	Frequency	Percent
Yes, all	26	86.7
Yes, only Serious ones	4	13.3
No	0	0.0
Total	**30**	**100.0**

6.8.2 Most Frequent Incidents

With regards to the frequencies of incidents, 29 of the respondents specified, first aid incidents are the most frequent and only 1 person quoted enclosed space is the most frequent incident. No one chose “exposure to electrical power” or others.

Table 6.37 Most Frequent Incidents

Types of Incidents	Frequency	Percent
First aid Incident	29	96.7
Enclosed Space (Lack of Oxygen)	1	3.0
Exposure to electric power	0	0
Others	0	0
Total	**30**	**100.0**

6.9 Discussion

The purpose of the research is to contribute to our knowledge of the effects that the types of data collection tools used by oil and gas companies have on their performance, particularly the HSE performance. The study was conducted in Ghana as a developing country. This is because most of the related works have been studied in the developed world and as such this will serve as a basis for comparison for both regions of the world. Several factors were directly or indirectly identified from existing literature that impacts the HSE performance of oil and gas companies; they are: (1) Geographical location of the company since they have different levels of technological development and also have different climatic conditions with its associated risk; (2) The nature of business, such as upstream, midstream or low stream since they are exposed to different types and levels of risk; (3) Supervising bodies to make sure that the oil and gas companies comply with standards; (4) The effectiveness of the tools used for data collection and how collected data is stored; (5) How the collected data is analyzed; (6) The frequency of meetings and proper time management and finally (7) Investments made to improve HSE performance.

These seven (7) factors formed the basis of the hypotheses.

6.9.1 Geographical Location of Organization vs HSE Performance

In order to find out if the geographical location of a company impacts its HSE performance, four main questions were asked. Firstly, respondents were to state if their company operates only in Ghana or has offices in other countries. Those operating internationally were then ask to tell if their HSE practices varies from region to region of the world or they are the same. Thirdly they were to state the region of the world that has the best HSE performance and finally to write down why those regions performed better than the rest.

Analysis of the response revealed that most (about 80%) of the companies operates internationally and a little over 80% of them said their HSE practices are either the same or similar. With regards to the best region with the best HSE performance, almost half chose Europe as the best region, this a followed by Asia as the second best. USA as an advanced country is noticeably low with only 3 out of the 30 saying they have the best HSE performance. The outcome of the analysis seems to support established literature such as that of Bouti and Allouch (2017) who after their study of HSE performance in the oil and gas industry across the globe said majority of incidents occurred in North America.

Interestingly, although the study was conducted in Sub-Saharan Africa only two respondents said Sub-Saharan Africa has the best performance. This outcome should not have been the case because the region has relatively less challenging weather condition. The main adverse weather condition happens during the harmattan period which is characterized by dusty atmosphere that affects visibility (Minka and Ayo, 2014). However, the poor performance of the sub region can be explained by respondents answer to the question of why they selected other regions as having the HSE performance. Their answers were, those regions have better infrastructure and are more technologically advanced. Deliotte, (2013); and Świerczyńska, (2015); also made the same assertion of the low infrastructural development of Sub-Saharan Africa which could impact their HSE performance.

If the lack of infrastructural development and other facilities are the main reasons for the poor performance of Sub-Saharan Africa, then it makes it more difficult to understand why USA is also relatively low compared to the other developed world. A clue may be taken from the words of Zolotukhin, (2019) that the arctic region of the world has several challenges which negatively affects HSE performance. Which in the case of USA, this happens mostly in the State of Alaska. However, the same can be said of part of Europe who also has many oil reserves in the arctic regions.

USA is probably low because of an important variable that was not tested. That is; respondents working in international companies should have been asked to indicate where their offices are located around the globe. Probably only few have branches in USA which is why only 3 said it is the best. If most of them have offices in USA it might also rank as high as Europe.

Answers provided to the question on whether their HSE practices differs from region to region also offered additional insight. Twelve (12) said they were more or less the same, 7 said they were the same and 4 said they are different. More or less the same in this case means little adjustments were made to suit the region they work in. It can therefore be said that many international oil and gas companies do their best to maintain their HSE practices in every region they are located in with only few developing something new to suit to the region.

If there are wide differences in both weather conditions and technological development, it would be better to make more drastic changes to HSE practices in each region. As such probably the current practices also adversely affect the differences in HSE performance around the globe.

With thus said, H1 is true. The geographical location of an organization does impact its HSE performance.

6.9.2 Type of Business and Nature of Activities Performed

To know which sector in the oil and gas industry have more incidents, respondents were asked three separate questions. The first was to indicate whether they operate upstream, midstream and or downstream. Secondly, they were asked to select the various operations conducted by their organization, that is; either exploration, production, manufacturing, refining, marketing or provision of services. This led to the main question, which is to select the unit which has the most frequent incident(s). The last question seems to be the most relevant but the two earlier ones helped in selecting and focusing more on companies in the upstream since they are more likely to have many departments which includes both engineers and none engineering staff.

Results suggested that offshore engineers were the most prone to incidents. This outcome is supported by research such as that of Schouwenaars (2008), whose decades of study of the major incidents in the oil and gas industry revealed that incidents mostly occur not in administrative centers but rather where engineers mostly work. Also, Alliance Insurance Agency (2018), listing of 5 high risk field in the oil and gas sector had 4 of them being places where engineers work. In the same vein Bouti and Allouch (2017) noted that one third of incidents occurred in turbine hall area and one-quarter in a High-Risk Activity (HRA). One may suggest that a follow up question should be asked to know why most said engineers, but it seems such a question is unnecessary because it is quite intuitive to expect engineers to be at most risk since most of the equipment and hazardous products in the oil and gas industry are used by them.

Another outcome of the study that is supported by literature is the nature of the most frequent incidents that occurs as seen in table 5.37. Bouti and Allouch (2017), said most of the injuries requires first aid treatment which the outcome of this study strongly supports. When serious ones occur that becomes fatal, it will most likely be quickly be announced by the national news media.

Following from this discussion it can be concluded that H2 is valid. Offshore engineers have a higher risk of incidents than other workers.

6.9.3 Supervisory Bodies to Make Sure they Comply by Standards

To know if supervisory bodies play an important role in improving HSE performance, five analysis and or questions were asked. They are; do you have standards as a guide to activities; are the standards local or international, relations between visit by external bodies and HSE performance; relation between frequency of visit to incidents per week and finally relation between frequency of visit to HSE performance.

For the first question all 30 companies said they have standards that they follow in the execution of activities and almost all combines both local and international standards. Concerning the frequency of the supervisory bodies visiting, 76.7% choose between weekly to quarterly which is quite high and that seems to explains why all the respondents thinks their visit plays a huge role in their HSE performance. Cross-tabulation of the frequency of their visit with the weekly records of incidents shows that to a large extend the more frequent the number of visit the less likely the occurrence of incidents.

The regression model also revealed that the correlation is significant hence there is no evidence in support of the null hypothesis. The null hypothesis is therefore rejected in favor of the alternative hypothesis. This is in line with the answer to a direct question that was asked respondents to know if the frequency of visit impacts their HSE performance. Almost 90% said it has a high positive impact or very high positive impact. This also seem to be the findings of González (2011) and Government.no (2018) that frequent supervision results in better HSE performance. Also, Basak Yanar, Lay and Smith (2018) affirmed that constant supervision leads to better HSE performance.

It could be explained that, when a company knows they are under constant scrutiny, they will put in enough measures to have a positive outcome so as to be in the good books of their supervising authorities and the opposite may occur to those with little scrutiny. Which is probably one of the purposes of the standards and their enforcing bodies.

Therefore, H3 is true. Higher frequent visit of supervisory bodies to enforce standards positively impacts HSE performance of the organization.

6.9.4 Effectiveness of the Tools Used for Data Collection and How Data Collected is Stored

To know the reasons behind the continual usage of pen and paper for data collection, a number of reasons were gathered from literature and listed for them to choose. The list also included lack of other medium to see if they would have preferred an alternative input medium. Since no one chose lack of other medium, it is fair to conclude that ‘convenience’; ‘faster to report incidents’ and ‘little training requirement’ were the main reasons why they still use pen and paper. One may argue that it is probably because they have not been exposed to other better medium that is why they are satisfied with pen and paper but this only applies to 7 of the 30 respondents who do not have electronic medium.

Also, the result on what happens to data collected via pen and paper is reasonably good because 27 of the 30 said they are immediately entered into the computer database which makes it easier to retrieve for decision making. Only 3 said they are manually archived. This outcome is however in contrast to Jha (2015); Biscardini, et al., (2018), findings that retaining of records on papers can be an issue and companies are at a dilemma as to what to do with them, that is; to either input it into the computer database or discard them.

Concerning the reasons for using mobile apps, majority chose its efficiency over any other reason. Also, most respondents said the collected data via mobile app is directly uploaded to the computer database which is a major point in Jha (2015); Biscardini, et al., (2018) work on why digital tools are preferred. All respondents agreed to the immense importance of data collection for decision making to the improvement of HSE issues. This means decisions are not made arbitrary but based on hard data.

The data on the medium of data collection and incidents per week, seems contrary to expected outcome. Most of the companies that use only pen and paper recorded lower rate of accidents than those that uses both mobile app and pen and paper. This trend was also replicated in the use of IoT to record or capture incidents. The low correlation and high p-value gives a strong evidence to the null hypothesis hence it cannot be rejected. It was rather expected that the use of improved tools to record data would result in better HSE performance. It must however be understood that, having the right tools does not necessarily translate into excellent outcome (Midttun, 2018; Merkazy, 2019) and probably those using pen and paper have mastered the act to make it work and with time the mobile app users might get its full benefit too. Pen and paper users could be under-reporting incidents or their incident reporting are not linked to the improvement of HSE performance.

It must be noted that since no company uses only mobile app it is impossible to make direct comparison with that of pen and paper. However, the opposing result cannot be ignored; a viable reason could be that IT tools are so efficient at recording and the number of incidents might be higher due to its accuracy, whereas paper recordings could easily be forgotten and not recorded especially if one is not at hand. Also, a variable that should have been tested is the number of employees in the company since that will make a huge difference. A company of 1000s of employees' number of risks would normally be higher than the one having 10s or 100s of employees. Testing all these absent variables discussed would give a better view as to why the result seem contrary to literature.

With thus said, H4 is not valid, there is little evidence to suggest that the use of digital tools positively impacts HSE performance.

6.9.5 How Data is Analyzed

A series of questions were asked and compiled regarding whether the use of Big Data for analysis improved HSE performance. Results show that all respondents that use big data to analyses data collected said they have seen an improvement in HSE performance than when they were not using it. Due to the unanimous agreement, it is difficult to contest this outcome and it also in agreement with established literature such as that of Cowles, (2015); Tan et al., (2016); Riddle (2017) and Hussain (2019) who wrote on how the use of Big Data to analyze data reveals many underlining HSE issues and provides suitable guidelines to mitigate them.

Also, a cross-tabulation showing the usage of Big Data in relation with incidents per week shows a positive out. The same was true for the regression table which showed that the positive correlation between the two variables is significant.

It can therefore be concluded that H5 is valid;

The use of Big Data for analysis positively impacts HSE performance.

6.9.6 Frequency of Meeting and Time Management Relations to HSE Performance

Frequency of meeting and proper time management was seen as a vital component to good HSE performance. Analysis of the data show the importance the companies place on both factors. All companies meet at least once a month and the more frequent the meeting, the better their HSE performance as seen in the cross-tabulation between frequency of meeting and incidents per week. There are a few outliers where companies meeting weekly recorded relatively higher numbers of incidents, but as a whole, there appears to be a positive relation between high frequency of meeting to low incidents. The regression model also shows it is significant giving a strong evidence against the null hypothesis. This outcome is not far from what was expected as the more they talk about HSE issues during meetings the more they try to improve it. It also supports the findings of Health and Safety Executive (2020) who made the same assertion what when employees meet regularly to voice out their concerns, management can address it quickly and avoid unnecessary mistakes or a repetition of it.

Also, time management plays an important role in controlling risk. Analyzed data reveal that most respondents have a positive view of time management importance to better HSE performance. In this case one can argue that, having a schedule as to when to come to work, time for break and time to close contributes to keeping people alert always. In the same vein, researchers such as (Amorin 2013; Hystad et al. 2014; Bouti and Allouch 2017; Horbah, Pathirage and Kulatunga, 2017) all attested to the fact that human errors are major reasons for the occurrence of incidents which are mostly due to fatigue.

From the argument above, H6 is true. Higher frequency of meeting and proper time management positively impacts HSE performance.

6.9.7 Investment Made to Improve HSE Performance

All the companies said they invest in HSE improvement. The most common investment is the frequent training of staff and virtually all companies are practicing it. The least practiced is hiring of competent staff but even with that, the number of companies doing that exceeds half the total number of respondents. It is therefore quite fair to say that it is reasonably practiced by the sector. The other two investments are; Provision of specialize protective clothing and creating awareness. These two are well practiced in the industry.

A cross tabulation was made to see which investment type yield the best result in terms of incidents per week. Comparing their relative percentages revealed a not so similar outcome. It appears that awareness creation and provision of HSE equipment has the best impact on HSE performance. On the other hand, hiring of competent staff is the least effective method. However, many companies do combine two or more investment strategies in improving their HSE performance. They will therefore get the best of each and minimized the negative effect of any intervention.

A t-test was conducted to determine the absoluteness of each strategy. It appeared that, all four strategies were not significant which therefore gives evidence to the null hypothesis. Therefore, one cannot affirm that a particular investment strategy yields better HSE performance. It must be indicated that a much-preferred test would have been between companies that invest in improving HSE performance to those that do not. This was the original intent of the question. However, since all the companies invest in HSE improvement, this comparison cannot be made.

In a separate question of what management should do or is doing to improve HSE performance, most respondents said, creating more awareness and frequent training. Both of which has already been asked and tested, however since employees think that will be helpful, it can be argued that management should do more of it. This is in line with Griffith, (2014), Morrish (2017); Morgan, 2017; and Rospa, 2020 mentioned the benefits of training in improving HSE performance. It must be specified that few respondents suggested ‘publishing of incidents level per department’ in order for them to focus on their specific incident(s) and address it to improve their HSE performance. Another person also suggested rewarding of best safety personnel.

From the discussion above and the regression analysis pointing to the null hypothesis, it can be concluded that H7 is not valid; Investments made into HSE does not positivity impacts HSE performance.

Correlation and regression analysis where applicable were employed to determine the validity of the hypotheses. However, in some instance such as H1 and H2, series of questions and their relative frequencies and percentages were used to validate it. Also, R^2 should have been computed to determine the extent to which the identified factors affect HSE performance.

6.10 Research Question

In answer to the research question, it can be said that various forms for mobile apps are being used by oil and gas industries in Ghana to collect and analyze data for HSE purposes. It however appears that mobile apps users have higher risk per week than those using traditional pen and paper. However, since the tool for reporting does not play direct role in causing incidents it can be argued that the efficiency of mobile app reporting is the reason for the higher rate since it collects virtually all data. Also, companies that use Big Data to analyze their collected HSE data said they have noticed improvement in their HSE performance.

CHAPTER 7

7.0 CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

To investigate the causes of HSE issues and how to mitigate them, several factors were identified from literature. They are; (1) Geographical location of the organization; (2) Type of business and nature of activities performed; (3) Supervisory bodies to make sure they comply by standards; (4) Effectiveness of tools used for data collection and how data collected is stored; (5) How data is analyzed; (6) Frequency of meeting and time management and (7) Investment made to improve HSE performance. These seven hypotheses were tested.

Not all the results obtained after analysis of these factors agreed with established literature. As literature suggested, the geographical location of the company does affect its HSE performance which is partly due to the different weather conditions and technological advancement. Also, the nature of business and activities performed plays a huge role in the number of incidents occurring with offshore engineers being the most likely to be injured as the literature noticed and also first aid injuries were the most common incidents which is also well documented in the literature. Companies using Big Data to analyze their data all observed it has improved their HSE performance which is also supported the regression data. When it comes to the tools for collecting data, the results differ from existing literature to an extent. For instance, companies using pen and paper for recording seems to have lower HSE issues than those using digital tools. An explanation could be because digital tools are more efficient and records all incidents sometimes immediately they occur. Whereas paper base records could easily be ignored and not recorded or even discarded after recording without putting it in the computer database.

Though not specifically stated in the literature, the frequency of visits by supervisory bodies to enforce the standards leads to improved HSE performance. In the same vein, frequency of meeting and proper time management leads to better HSE performance. There was little evidence in support of or against investments in HSE performance leading to positive outcome. In all, five of the seven hypotheses were validated and two were rejected.

7.2 Managerial Implications

The outcome of this study can be used by management to look more critically into their HSE performance to identify grey areas for improvement.

The following observations were made;

- Companies solely using pen and paper should be more critical of their incidents records as they might be ignoring certain incidents and as such will not work to resolve it. Having proper records will help in preventive measures to avoid an unforeseen danger in the future.
- Since the geographical location of a company impacts its HSE performance, much time should be given to access the specific risk in each region after which mitigation strategies could be developed to prevent them.
- Even though there was little evidence for investment in HSE performance leading to improve rates of incidents, employees generally have a positive view of investment made to improve HSE performance and doing so will be a motivating factor to them.
- Though a reasonable proportion of employees in the developed world do not really see the significant of meetings, the same is not the case in Sub-Saharan Africa. Overwhelming majority of employees sees meetings as a useful tool in combating HSE issues. Meetings could therefore be an effective mode of communication on HSE issues in the organization.
- They can also use this study to design a model which will make it easier to identify all the necessary factors that effects their HSE performance.

7.3 Theoretical Implications

The outcome of this work is in line with many established elements identified in the literature that improves HSE performance in oil and gas industry such as that of Bouti and Allouch (2017) who acknowledge that North America has poor HSE performance and that majority of the incidents are easily treated with first aid medications. In the same way the findings of the team at the highest risk agreed with that of both Schouwenaars (2008) and Bouti and Allouch (2017) that, offshore engineers are the most likely to be injured.

The works of Cowles, (2015) and Tan et al., (2016) was seconded by this study in that the use of Big Data to analyze HSE data improves HSE performance. This study also asserted that time management and frequent rate of meeting do have positive impact on HSE performance. It was also confirmed that frequent visits by standards enforcing organizations leads to improvement in HSE performance by organizations.

It was expected that the used of digital tools to collect data will result in improved HSE performance, however the mapping of the data showed otherwise. A reason might be due to the convenience of recording or even automatic recording when using IoT thereby leading to high records of HSE cases than when using pen and paper which might easily ignore some cases especially if they are resolved early. Also, four investment strategies were identified, that is; hiring of competent staff, frequent training of staff, Provision of specialize protective clothing and creating awareness. None were validated as improving HSE performance.

These 7 points forms a theoretical basis for determining the factors affecting HSE performance.

Based on the research study, the following suggestions are made which will help address the high rate of HSE issues in the sector.

- Since there are wide gaps in technological development across regions and also different severity in weather conditions, it will be more appropriate for oil and gas companies to make drastic changes to their HSE approaches in each region.
- Having insurance companies involved in the supervision process will help reduce the frequency of incidents.
- Companies using only paper-based method of recording data should make it a point to record all incidents and if possible, switch to a more modern forms of data collection.
- Proper time management helps in preventing most human errors.

7.4 Limitations and Future Research

Several factors that impact HSE performance were identified from literature and were used in the formulation of hypothesis. These hypotheses were meticulously tested to determine their validity and have a truly representative outcome. However, there are certain factors that might limit its generalizability to all developing countries.

Issues such as the number of employees, the age of the organization are important elements that should have been tested. Since they may affect the number of incidents. Also, respondents not using Big Data should have been asked what they use instead and then compare their risk performance to those using Big Data. These three factors might result in different outcome especially with the use of digital tools for data collection and Big Data. Also, the work was entirely conducted in Ghana which is just one of the many developing countries in the world.

With limited resource such as time and finance this work is a one of a kind and can be used as a basis to explore deeper elements in HSE performance of oil and gas companies.

To get an accurate answer of the region in the world with the best HSE practices, future research should enquire respondents to indicate the various regions their companies are located. This will eliminate bias in the analysis. Finally, future studies should look at least five developing countries spread across many continents towards generalization of the outcome towards HSE practices.

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Appendix

Questionnaire

I am Samuel Elorm Kofi Somone enrolled in M.Sc. Logistics final year of Molde University College – Specialized University in Logistics. In order to complete this program, it is required to submit a thesis on the topic "Implications of data tools in the oil and gas industry in Ghana". I have prepared a questionnaire to assist in collecting information towards analysis and insight in this regard. I would kindly request you to provide few minutes towards responses. The information gathered is anonymous and for academic purposes only. Your response will be immensely helpful in this study and are highly appreciated. It should not take more than 10 minutes to answer this questionnaire.

Thank you.

Organizational Data

1. Is your company local or international?
(a) Local (b) International

2. Which sector does your company operate? Please select all that apply
(a) Upstream (b) Midstream (c) Downstream

3. What are the main activities performed by your company? Please select all that apply
(a) Exploration (b) Production (c) Processing (d) Distribution
(e) Marketing (f) Others please specify ……………………………..

4. Do you have standards that you follow concerning health, safety and environment (HSE) issues?
(a) Yes (b) No

If you answered yes to question 4, please proceed to the next question otherwise please go to question 7.

5. Are the standards local to your country, international or both?
(a) Local (b) International (c) Combination

6. How many standards do you have related to HSE. (How this mere number will be helpful in extracting some information/knowledge)
(a) 1-5 (b) 6-10 (c) 11-15 (d) 16-20 (e) 20+

Data Collection Methods

7. How do you generally collect data on health, safety and environment issues.
(a) Pen and paper (b) Mobile apps (c) Both

8. Please select the main reason for using pen and paper
(a) More convenient (b) Requires little training (c) Faster to report incidents
(d) Lack of other medium (e) Other (s), please specify ………………………..

9. What happens after data is collected with pen and paper?
(a) Immediately entered into a computer database (b) Archived
(c) Other(s) please specify ………………………….

10. Please select the main reason for using mobile app
(a) More efficient (b) Faster to report incidents (c) Easy to store data

11. What happens after data is collected with a mobile app?
(a) Automatically updates on the company's database
(b) manually upload it into the database
(c) Other(s) please specify ………………………….

12. From a scale of 1-5, with 5 being the highest, indicate whether the data collected is helpful in decision making? Mainly towards health, safety and environmental decisions.

13. Does your company make use of Internet of Things (IoT) to capture data for EHS?
(a) Yes (b) No

14. If yes, please what kind of data does it capture, if yes choose all that apply.
(a) Production and exploration (b) Health, Safety and Environmental data
(c) Financial data (d) Other ……………………………….

Data Analysis

15. Do you use Big Data applications to analyze data?
a) Yes (b) No

16. If yes, has it always been part of the information system or it was introduced along the line.
(a) Always been (b) Introduced along the way (New)

HSE Improvement/ Investment/ Management

17. If new, has there been improvement in health, safety and environmental performance since its implementation.
(a) Yes (b) No rather worsen (c) Things are the same.

18. Do you invest in improving health and safety performance?
(a) Yes (b) No

19. If yes, what kind of investments are made? Select all that apply.
(a) Hiring of competent staff (b) Frequent training of staff on hazard issues
(c) Provision of Specialized tools and protective clothes
(d) Others ……………………………………………

20. How often do you meet to discuss HSE issues in the organization
(a) Weekly (b) Monthly (c) Quarterly (d) Annually

21. Does any authority visits to supervise your health, safety and environmental assessment performance?
(a) Yes (b) No

22. If yes, authority is
(a) Local (b) International (c) Both

23. How frequently do they visit?
(a) Weekly (b) Monthly (c) Quarterly (d) Annually

24. From a scale of 1-5 with 5 being the highest, indicate if the frequency of their inspection affects your HSE performance?

25. Do you keep records of injuries and other incidents at the work place?
(a) Yes, all (b) Yes only serious and complex ones (c) No

26. Which team records the most frequent incidents?
(a) Offshore engineers (b) Management staff (c) Other administrative staff

27. What are the most frequent incidents?
(a) First aid incident (b) Electrocution (c) Enclosed space (lack of oxygen)

28. On the average, how many incidents do you record in a week?
(a) 1-5 (b) 6-10 (c) 11-15 (d) 16-20 (e) 20+

29. What is being done to improve the statistics of data related to EHS? Please provide brief response…….…………………………...……………………………………………………
……………………………………………..……………………………………………

30. As an international organization do you think your company's health, safety and environmental practices differs from region to region over the world or these are the same?
(a) Differs (b) Same (c) More or less the same

31. Which region or part of the world performs better in health, safety and environmental issues and why?
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……………………………………………………………………………..………………

32. On a scale of 1-5 with 5 being the highest, indicate the role of time management in improving health, safety and environmental issues?
