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An Investigative Study Of Big Data Technology Application And Its Impact In The Upstream Operations Of An Oil And Gas Industry In Nigeria

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Abstract: ***Oil and gas industries operate in a highly controlled atmosphere and competitive market. Its upstream sector is technically challenging and economically risky with its operational complexity and a data-driven business with data sizes growing exponentially. However, a high percentage of this data is of poor quality and needs to be integrated. They need to adopt technologies that semantically integrate and analyze these dissimilar datasets around the upstream operations. Under these conditions, the traditional analysis tools would fail but with the appropriate infrastructure and tools like Big Data technology, oil and gas companies can get measurable value from these data. The research was carried out using a mixed method approach; the primary data in this study includes interview and observation while literature review sources and examination of archival sources which are secondary data form the basis of interview and give background knowledge for this research as well as case study. Data collected were analysed using qualitative case study analysis. From the research findings as relates to big data sources, usage and its impacts; large volume of seismic and sensors data that are collected by the firm are found to play significant role in reduction of time and cost to first oil, enhanced drilling operations, increased productivity, performance monitoring and contribute in no small measure to improved overall upstream activities. Findings further showed that the firm had incurred huge investment in analytics software to get more value out of big data. This study concludes that Companies are increasingly aware of the value of data and we can expect contention about data ownership, trust, sharing and privacy which in anyway affect amount of data we were able to collect for this research. Indeed, some oil giants are becoming leaders in big data like this case company Chevron, and the rest should embrace big data in order to remain competitive.***

Keywords: Big data technology, upstream operations, seismic, data-driven business, digital economy.

I. INTRODUCTION

Oil and gas industries operate in a highly controlled atmosphere and competitive market. The firms' top priorities are to increase production efficiency, optimise costs, and mitigate the impact of environmental threats (Baaziz & Quoniam, 2013). Its upstream sector is technically challenging and economically risky with its operational complexity and a data-driven business with data sizes growing exponentially (Feblowitz, 2012). Oil and gas companies conduct advanced geophysics modeling and simulations to support operations where seismic generate significant volume of data during

exploration phases. They closely monitor the performance of their operational assets. To do this, they use tens of thousands of data-collecting sensors in subsurface wells and surface facilities to provide continuous and real-time monitoring of assets and environmental conditions. This information comes in various and increasingly complex forms, making it a challenge to collect, interpret, and leverage the disparate data (Fan & Bifet, 2013). However, a high percentage of this data is of poor quality and needs to be integrated. They need to adopt technologies that semantically integrate and analyse these dissimilar datasets around the upstream operations (Perrons and Jensen, 2015). Under these conditions, the traditional analysis tools would fail but with the appropriate infrastructure and tools like Big Data technology, oil and gas companies can get measurable value from these data (Chakraborty and Gonnade, 2014).

A handful of oil and gas companies that adopted Big Data have benefitted immensely in the area of reduction of time to first oil and gas, lowering operating costs and improvement of the productivity of assets across the life cycle. Thus with Big data, firms advance decision making, obtain new insights, and formulate new business models with increased market presence and income by linking and evaluating data types in different ways (Chakraborty and Gonnade, 2014). Understanding and leveraging data in the upstream segment enables firms to remain competitive throughout planning, exploration and field development.

In the digital economy, Big Data is the oil. Indeed, it is like crude; valuable, but if not mined or refined it cannot be used to provide insights for decision making with potential to spur innovation and socioeconomic development in many sectors (Baaziz & Quoniam, 2013). So it's not surprising that energy companies, which rely on complex equipment for drilling and oil well maintenance, are in pole position to benefit from automation fuelled by advances in big data and machine learning. Specifically, analytics of large pools of data can provide relevant and timely insights to support decision-making processes. While big data has the potential to impact on every sector of the upstream, the problems they face and the uptake of big data and its impact are not the same across domains (Chakraborty and Gonnade, 2014)

There have been a lot of researches focusing on Big Data impacts, drivers and barriers for adoption in several industries, implementation challenges and benefits to oil and gas in particular, and even in the upstream processes. In our bid to study the uptake and usage of big data in the Nigeria oil and gas industry, no research has been found in literature to have examined this innovative technology uptake and usage across the main activities of the upstream oil and gas in developing economy like Nigeria. Therefore, this study presents the findings of a comprehensive case study in the upstream operations of an Oil and Gas industry in Nigeria (Chevron Oil). The rest of the article is structured as follows. Section 2 presents the literature review of relevant studies while Section 3 presents the case study and the methodology used to amass relevant data for analysis. The results of the empirical study are presented in section 4, while Section 5 centers on the analysis of results from the viewpoint of usage. The last section concludes the paper.

II. LITERATURE REVIEW AND CONCEPTUAL UNDERPINNINGS

A. BIG DATA

Big Data is a term with many definitions. It is conceived as huge amounts of data with an increasing trend every day. It is also seen as a phenomenon that enforces opportunities and challenges (Fan & Bifet, 2013)). Big data has not been a result of a particular factor; rather, it is a result of various interrelated developments in technology (Perrons and Jensen, 2015). Big data is also defined by describing their characteristics as being big in five dimension called (5V); Volume, Velocity, Variety, Veracity and Value. Big Data technologies describe a new group of technologies and architectures, designed to economically mine value from very large volumes of a wide variety of data, by supporting high velocity capture, finding and analysis, while safeguarding their veracity by an automatic quality control in order to obtain a big value (Oracle 2015, Baaziz and Quoniam, 2013).

B. UPSTREAM DATA

Upstream is no alien to Big Data. Oil and gas companies employ thousands of sensors installed in subsurface wells and surface facilities to offer continuous data-collecting, real-time monitoring of assets and environmental situations (Brulé, 2013, Baaziz and Quoniam, 2013). The concept of digital oilfield solutions through which the industry attains competitive advantage by utilising digital oilfield technologies to make better decisions began its journey with data management technologies (Perrons and Jensen, 2015). Improvement of exploration and production technologies in the upstream business are surrounded by the huge number of data streams that have assisted the digitisation and automation of many areas of upstream oil and gas industry (Martinotti et al, 2014). Combination of data from multiple sources to deduce events or patterns that show a current or pending danger, making faster decisions, supported by faster delivery of decision support system which detect possible attack and also foresee or avert cyber-terror actions.

Identical to generic Big Data, the upstream Data is also described by the 5V: *Volume:* seismic data acquisition and seismic processing; *Variety:* Structured: standard and data models, etc., Unstructured: images, log curves, well log, maps, audio, video, etc. Semi-structured: processed data such analysis, interpretations, daily drilling reports; *Velocity:* Real-time streaming data from well-heads, drilling equipment and sensors **;** *Veracity:*– Improve data quality, Run integrated asset models, combination of seismic, drilling and production data ,drive innovation with unconventional resources while *Value:* Increase speed to first oil , enhancing production ,reduce costs, reduce risks, especially in the areas of health, safety and environment (Oracle, 2015; Nicholson, 2012; Baaziz and Quoniam, 2013,, Feblowitz, 2012).

C. BIG DATA AND VISUALIZATION` IN THE OIL AND GAS UPSTREAM

It is evident that the industry has succeeded in collecting data about almost everything. Some oil firms have employed big data mining technologies to gain more insight out of such data (Martinotti et al, 2014). Big data has many applications in the upstream oil and gas companies. A recent survey by Accenture and Microsoft of oil companies and those involved in the support industries found that 86% to 90% of respondents said that increasing their analytical, mobile and Internet of Things capabilities would increase the value of their business (Marr, 2015). The search for new hydrocarbon deposits demands a huge amount of materials, manpower and logistics. With drilling a deep water oil well often costing over $100 million, no one wants to be looking in the wrong place. According to a report by Credence Research, the Global Big Data Services Market for the Oil and Gas Industry is expected to reach US$33.5bn by 2023. A typical modern offshore oilfield has more than 10,000 sensors pumping petabytes of data, forming deeply intertwined cyber-physical systems that rely increasingly on algorithms and robotics. As sensor technology becomes cheaper and wireless, there is a premium on the ability to extract and manage large volumes of data in real time (Oil review Africa, 2018).

Some of the applications of Big Data in the upstream sector of Oil and Gas companies include the following:

a. EXPLORATION AND DEVELOPMENT

That kind of insights enabled the industry to attain several innovative discoveries that were not possible with traditional technologies. By combination of Big Data and advanced analytics in exploration and development activities, managers and experts can perform strategic and operational decision-making (Feblowitz, 2012; Nicholson, 2012). Indeed, we are aware that non-renewable oil and gas under the earth could get dry one-day sooner than we consider. However new methods are being advanced to use the data that is being collected from probing and drilling these sites to help identify other sites where deposits could be (Tavallali et al, 2016).

b. DRILLING AND COMPLETION

Infrastructure such as drilling platforms and pipelines are becoming smarter; as they predict easily failure or downtime and intelligently act to prevent them from occurring and thus increase productivity (Seshadri, 2013). In this smart environment, Big Data is used to detect conditions or variances that would affect drilling operations so as to save human lives and equipment. Concurrent information returned from supervisory control and data acquisition (SCADA) systems on well-heads can be used to hold opportunities that maximise asset performance and optimise production (Tavallali & Karimi, 2016).

c. PRODUCTION

Most of the upstream oil and gas companies have concerns in sustaining production efficiency and improvements during the production phase (Martinotti et al., 2014). So, Big Data has proved fruitful in different areas around the oil and gas production efficiency. This few areas include: performance monitoring, production optimisation, safety improvement, and risk prevention (Baaziz and Quoniam, 2013). While there are many possible prospects and paybacks in utilising big data solutions in the upstream oil and gas industry, the principal value return seems to be in the production operation phase (Martinotti et al., 2014).

d. EQUIPMENT MAINTENANCE AND SAFETY

Several Big Data applications have been confirmed to be successful in oil and gas asset management. Cheung et al. (2015) described how data mining of sensors streaming huge volume data was used to perceive equipment failures and predict the incidence in advance of their happenings. Big data applications have been key enablers to these decisions at different levels of production facilities spanning from facility managers down to technician level

e. GAPS IN KNOWLEDGE

Thus far, the researchers have summarized Big Data definitions, concepts, applications, frameworks and enabling technologies as regards oil and gas upstream. However, no study is found to have focused on studying its adoption and potentials in Nigeria oil and gas firms in general and upstream in particular. Therefore, with recent developments in research, an empirical study of Big Data applications in upstream activities is necessary. This present study, therefore, tries to address this gap by providing a generic framework that can be used to explore novel opportunities that Big Data creates for enhancing the exploration, drilling and production processes of the chosen industry.

III. DATA COLLECTION METHODS AND PARTICIPANTS OF THE CASE STUDY

The research was carried out using a mixed method approach; the primary data in this study includes interview and observation while literature review sources and examination of archival sources which are secondary data form the basis of interview and give background knowledge for this research as well as case study. The primary method of data collection in this study was interview. Interviews were thus arranged with Data Analysts and IT and Technical Engineers from the organization as depicted in Table 1. In all cases some background information were sent beforehand to the interviewees and a brief introduction of the research at the beginning of the interviews was given.

We adopted a semi-structured interview approach to the interviewees speak and elicit their views and opinions, while we aimed to cover all the topics in the agenda and to request further explanations. After each interview we prepared the transcript, had an internal revision and then shared the report with the interviewee (normally within a week), receiving some minor amendments in two cases. The profiles of the

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interviewees are as shown in Table 1 below, categorized as per guidelines of Curry et al (2014).

We aimed to gather evidence about big data uptake and the societal impacts of big data in the oil & gas industry. The research agenda included big data uptake and usage. Multiple sources of evidence were employed in order to augment the validity of our findings, as recommended by Yin (2014). Single interviews of 80 minutes approximately were held with interviewee at Chevron Oil.

We interviewed participants four times and on two occasions. Overall, eleven interviews were conducted for this case study from December 2017 to April 2018.A qualitative case study analysis of the result was done. Next, we read over all the transcripts and started the coding of the data – this is the process of forming the material into pieces of text before bringing meaning to information. Finally, we identified the themes for analysis based on the coding scheme and obtained the findings of the case study.

Upstream Sector	Designation	Awareness of Big Data	Interest in Big Data	Big Data Usage Status
Operations	Senior IT Manager	Very High	Very High	Operational
Drilling and Reservoir Engineering	Data Analyst	Very High	Very High	Strategic
Exploration and Development	Senior Technical Manager (Geophysical Modeling)	Very High	Very High	Strategic
Production	Data Manager	Very High	Very High	Operational
Operations	Senior Data Analyst	Very High	Very High	Operational

Table1: Profile of Interviewees at the Case Study- Chevron Oil

IV. RESULTS

The first result will identify the main sources of big data in the upstream on Exploration, Drilling and Production activities as gathered from the interview. With such massive data assets collected in the oil and gas industry, there are a number of uses of data at the upstream as obtained from the interviews which are equally highlighted.

A. INTERVIEW

In an oral interview with *Senior Technical Manager (Geophysical Modeling),* she remarked that seismic data is a great source that geoscientist and petrol-physicist used to discover oil deposits during exploration. According to her, the company uses seismic vessel that send sound waves into the subsurface to detect reflected waves. This process generates exponential data typically in hundreds of gigabytes. This seismic data is very valuable and as such, the company secures it and the company as well has invested so greatly in high-speed parallel computing and storage infrastructures to generate 3D geology models out of seismic data. She further remarked that this data that are transferred into geological models to find deposits of hydrocarbons, this perhaps the greatest scientific breakthrough of the oil and gas firm. Geoscientists and petro-physicists evaluate these models to find possible deposits of hydrocarbons. She however stressed that converting seismic data into 3D models is computing-intensive and results in further amounts of data, in the 1 TB per one processed dataset. Indeed, she opined Chevron Oil stores around 6 PB of seismic data (raw and processed).

Another source of data is production data; which is quite important and get a lot of consideration, according to the *Senior Data Analyst (Operations),* he remarked that production data is very important for oil companies and receives a lot of consideration and that it is commercial-sensitive asset; the oil operators do the accounting of production data by themselves. Oil production is measured at every stage of the flow, while the aggregated figures are reported to the partners in the joint venture.

*The Data Manager (Production***)** opined in his interview that in the last decade, their industry has gone into a process of installing sensors in every piece of equipment in sub surface wells and surface facilities and then transferred onshore to a surveillance centre where operations are monitored. Some fields are heavily instrumented, for example, the Agbami field has approximately 100,000 data tags and the Abiteye field has around 80,000 data tags. Sensors are very diverse and generate a lot of data. Moreover, velocity, the rate at which data is streaming a greater challenge; e. g. a subsea factory produces that for instance 100 s of high-speed signals (10 Kbps) and can thus easily generate 1 Tetrabyte of data per day.

With reference to the comments of *Data Analyst (Drilling and Reservoir Engineering);* he said drilling platforms and pipelines similarly generates high-volume and high-velocity data. This data is analyzed in real time for security reasons and to monitor the drilling operations, that is, to detect if the reservoir is hit. Nonetheless, integrating the data and share it in an adequate way to human operators is actually challenging. The Data Analyst explained that there are some variances on how the data is captured: sometimes the operator has direct access to sensor data, while in other cases, for example, drilling, the vendor gets the raw data and sends it to the operator.

He further informed that the company also contract services such as vibration monitoring, providing access to sensor data in these cases. Since sensor data is not mainly sensitive, there are more data exchanges among operators and vendors, e. g. for condition-based maintenance of equipment. Drilling operations are normally contracted to specialized firms and the company get the data from drilling contractor and then select the target for drilling and decide whether to continue or not, by sometimes trusting on simulators. These decisions are based on the analysis of drilling data, as the main aim is to reduce the non-productive of very expensive drilling equipment and crews, opined the Data Analyst (Drilling and Reservoir Engineering).

Senior Data Analyst Operations in his interview said that this phase is possibly the most interesting area of upstream activities in terms of big data; as it consists of structured data that is very varied, ranging from 3D models to sensor data. Rate of data generation i.e. velocity is also a concern due to the large number of sensors involved creating data in real time. He explained that the main reason for applying big data

here is the reduction of well downtime, improving the lifespan of equipment and reducing the number of offshore workers. According Senior IT Manager (Operations), he affirmed that among the several uses of data in operations, condition-based maintenance is perhaps the one that is receiving more consideration. Since equipment is programmed to gather data, analytics are then applied for early recognition of potential failures before they occur.

B. DOCUMENTS AND ARCHIVES

'Chevron is currently using up to eight global "mission control" centers as part of its digital program with each focused on a using real-time data to make collaborative decisions in drilling operations, or managing wells and imaging reservoirs for higher production yields. The purpose is to improve performance at more than 40 of its biggest energy developments and that ultimately the company estimates that these centres will help it save $1 billion a year (Datanami, 2012)

According to Paul Siegle, President of Energy Technnology at Chevron speaking to Oil Review Africa in 2017 remarked that Oil companies are using distributed sensors, high-speed communications, and data-mining techniques to monitor and fine-tune remote drilling operations. The aim is to use real-time data to make better decisions and predict glitches. He equally added that the companies began to engage such technologies more than a decade ago, partly to help its aging staff multitask remotely. But the technologies have increased speed along with the underlying trends: cheaper computing and communications technology, and an explosion of data sensors and analytical software. He further remarked that the industry term is the "digital oil field," though the biggest companies have trademarked their own versions. At Chevron, it's the "i-field." The phases that are most successful at operating remotely and using data wisely will claim big rewards.

Chevron according to a report in white paper by World Economic Forum in 2017 by '*industry wide estimates suggesting 8 percent higher production rates and 6 percent higher overall recovery from a "fully optimized" digital oil field'* (Word Economic Forum 2018).

Chevron Oil, Nigeria reported on its website that at as part of investment in emerging technology that engineers only visit the wells only when there is a need for repair as sensor are now used to remotely monitor facilities unlike in the past when workers drives around daily to inspect thousands of well.

Chevron is under fire in Brazil, where the company took responsibility for a 3,000-barrel offshore oil spill in November caused by an unanticipated pressure spike in a well. Chevron's i-field program will help prevent accidents and improve safety (MIT Technoloy Review, 2012)

V. ANALYSIS AND DISCUSSION OF FINDINGS

This section gives the analysis and discussion of the results from the result section which include findings from the interview and archival sources, in relation to a few major themes identified for Big Data for oil and gas in the upstream. Table 2 **s**hows the identified themes. The research themes earlier highlighted for ease of analysis and discussion will be briefly discussed under the headings of operational areas. In the next section, detail analysis of the themes will be done based on the results were earlier presented in the last section.

A. EXPLORATION AND SCOUTING

It is observed from the result that seismic processing for the discovery of petroleum is the typical big data problem of the oil and gas industry. The case company has made large investments in high-speed parallel computing and storage infrastructures to generate 3D geology models out of seismic data. The resolution of the images obtained with seismic data is low and complex and for this reason petroleum experts (geophysicists and petrophysicists) try to use additional data sources such as rock types in nearby wells and images from other analogue areas. Nonetheless, the intricacy of exploration data makes the access of data to petroleum experts especially challenging, requiring ad hoc querying capabilities. Seismic data is challenging to analyze; complex geo-models are employed. New techniques, methods, analytics and tools can be applied to find new discoveries sometimes through the identification of big data sources and effective utilization of it. By combination of Big Data and advanced analytics in exploration and development activities, managers and experts can perform strategic and operational decision-making.

Operational Area	Usage of Big Data
Exploration and Scouting	Seismic Acquisition and Processing
Drilling and Wells	Drilling Operations
	Well Integrity Monitoring
Production	Reservoir Monitoring
	Oil Exploration
	Accounting of Production Data
Operations and Equipment Maintenance	Equipment Improvement
	Condition-based Maintenance
	Data- Driven New Products
	Data-enabled services
	Integrated monitoring center
	Integrated operations

Table 2: Research Themes from the Empirical Result

B. DRILLING AND WELLS

As obtained from the interaction with the interviewees, drilling operations are normally contracted to specialized firms. Oil operators get the raw data from drilling service provider and then choose where to drill. Decisions are based on the analysis of drilling data, cost and time of drilling operations as evidenced from data collected from the servicing company. Given the complexity of wells, and their reliability is monitored during their whole lifetime. It is found out also that well integrity monitoring is also outsourced to other companies, as they employ geological models and use core samples from the well taking into account the type of rock in the well. In addition, seismic data from producing fields can be employed to discover oil. Facilities such as drilling

platforms predicts easily failure or downtime and smartly act to prevent them from occurring and thus increase productivity

C. PRODUCTION

In addition, seismic data from producing fields can be used to discover oil pockets that can result in more wells for drilling and thus elongate the lifetime of afield. Finally, production data is carefully accounted through all stages of the petroleum workflow. Although production data is not exclusively challenging in terms of big data, it can be combined with other sources to gain further insight, for instance linking alarms with production data. Real-time security backups are also crucial as production becomes more complex. A thorough understanding of the reservoir performance e.g. water flowing can aid in taking smarter decisions and in reactions to situation. Seismic data is also employed in production for reservoir monitoring, creating 3D models of the reservoir in subsurface. Simulations are then carried out to evaluate how much oil should be produced in a well. So, Big Data has proved fruitful in different areas around the oil and gas production efficiency performance monitoring, production optimisation, safety improvement, and risk prevention.

D. OPERATIONS AND EQUIPMENT MAINTENANCE

The analysis of operational and other data has also led to new data-driven products or systems. Potentials in operations include data-enabled services such as failure detection or vibration monitoring as well as application in other area that aims to associate data from various sources such as operations and production data, and then utilise analytics to leverage decision-taking processes. Indeed, this seems to be possibly the most fascinating area in oil and gas in terms of big data. Among the numerous uses of data in operations, condition-based maintenance is possibly the one that is getting more consideration. Equipment is designed to collect data in continuous and real time and analytics are then applied for early detection of potential failures before the incident happens.

Indeed, it shows operational assets are becoming intelligent and predictive. Condition-based maintenance is thus much more efficient than conventional reactive or time-based approaches. Both operators and providers are concerned about cost reduction and improvement of equipment life span; as a result, there are a number of ongoing collaborations to support condition-based maintenance. Velocity and volume is also a concern due to the huge number of sensors involved producing data in real time.

VI. CONLUSIONS

In our study, by our brief interaction with big data managers and other experts; we gather a number of declarations, impressions and views about the uptake and usage of big data in the case company. Indeed, the oil and gas upstream is a data-driven business. While upstream is no stranger to big data, the industry is beginning to recognize its potential and there are many ongoing initiatives, especially in operations. In this case study a number of big data sources and its usages were identified. While this industry is quite familiar with large volumes of data, exponential advances can be expected in the near future, as innovative devices to track equipment and personnel performance are deployed ubiquitously and amassing more data than ever.

From the research findings as relates to big data sources and its usage; large volume of seismic and sensors data that are collected by the firm are found to play significant role in reduction of time and cost to first oil, enhanced drilling operations, increased productivity, performance monitoring and contribute in no small measure to improved overall upstream activities.

Findings further showed that the firm had incurred huge investment in analytics software to get more value out of big data. Nevertheless, volume has been found not only to be the only challenge of big data that the oil and gas upstream is facing; variety and velocity, veracity and value are becoming increasingly important as more data signals are combined and analyzed in continuous and real-time. Companies are increasingly aware of the value of data and we can expect contention about data ownership, trust, sharing and privacy which in anyway affect amount of data we were able to collect for this research. Indeed, some oil giants are becoming leaders in big data like this case company Chevron, and the rest should embrace big data in order to remain competitive.

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