Operational Excellence Dimensions in the Oil and Gas Sector: A Literature Review

[1] Muazu Hassan Muazu, [2] Salisu Bashir Gwangwazo
[1] Department of Business Admin and Entrepreneurship, Bayero University Kano
muazumuazu@gmail.com [1]
[2] Academic Programes Department, National Commission for Colleges of Education (NCCE)
salisugwangwazo@gmail.com [2]

Abstract

Operational excellence in the oil and gas sector has unique dimensions. This paper aim to review literature to elaborate on the dimensions and served as the continuation of the previous review that distinguished between manufacturing, services and oil and gas sectors dimensions of operational excellence. Journal articles, reports, professional papers, term papers and dissertations were reviewed. The paper found that operational efficiency, health and safety, assets and process reliability, and environmental performance are the dimensions of operational excellence in the oil and gas sector. Certain factors that could influence the dimensions were suggested. The paper contributed to literature and measurement of the constructs and consolidated on earlier review of the difference of the concept of operational excellence among different sectors. However, the paper's limitation lies in its inability to develop a framework showing the identified factors and how they relate to operational excellence in the oil and gas sector.

Keywords: Operational Excellence, Operational Efficiency, Health and Safety, Environment, Reliability.

1 Introduction

The global oil and gas industry had witnessed the transformation and related challenges due to the dynamism of the current economic environment. Operational excellence (OpEx) had been a widely accepted strategy in the oil and gas industry for its effect on firms' performance improvement (Shaw & Donovan, 2019). The contribution of OpEx in the transformation of oil and gas operation is enormous. Firms have registered drop in the cost of production, drop in emissions and waste, reduction in safety incidents and a number of a casualty had diminished (Ernst & Young, 2015).

OpEx has been well-thought-out as a cohesive management system that drives business productivity by maintaining proven practices and procedures of organisational activities. OpEx is the perspective of administrative management that underscores on the use of a variety of principles and systems, which is focussed towards the sustainable improvement of key performance metrics (Dahlgaard-Park, Reyes & Chen, 2018). Substantially, this basis was based on earlier development in the continuous improvement philosophies, such as Lean Manufacturing and Scientific Management. Antony, Escamilla and Caine (2003) postulated that the impetus of OpEx goes beyond the typical activity-based model of operational improvement; instead, it is of a complex model that also deals with risks.

Several scholars maintained that assessment of excellence is the process of determining organisational performance concerning a chosen model for continuous improvement for measuring expected outcome, achievement of result and what require improvement (Hillman, 1994). Excellence, as put by the European Foundation for Quality Management EFQM

(1999), is that outstanding practice displayed by firms in managing the organisation and achieving results concerning certain notions. Practices, such as management by the process, result orientation, people development and involvement, customer focus, continuous learning, leadership and stability of purpose, innovation, partnership development, improvement, and public responsibility are what excellence is all about (EFQM, 1999).

Again OpEx is regarded as a sensation that has gone beyond quality improvement and cost reduction alone, to efficient resource management, including assets, people and their safety (Ernst & Young, 2015; Van Assen, 2012; Duggan, 2009). OpEx is viewed as a systematic management of safety, environment, health, reliability, and efficiency (SEHRE) while accomplishing a standard that is world-class in nature (Parker, 1999). Continuous improvement philosophy, employees' empowerment and ownership are critical for achieving OpEx (Fok-Yew and Ahmad, 2014a; Duggan, 2009). Thus, OpEx is a wide-ranging a roach for boosting everyday operations in organisations. According to Ciptono, Ibrahim and Sulaiman (2010), in oil and gas industries there should be critical consideration of employees' safety, security, health and environmental protection, which requires business continuity strategies and operational integrity.

Although OpEx may be viewed as a strategy in its entirety, there are variations as to what it stands for in different industries. What it may portray and targeted at achieving in a particular sector, say manufacturing, retail, education, tourism, services or oil and gas might not necessarily be the same. Literature had shown clearly some of the divergent views and dimensions of OpEx, as presented in an earlier article published by the current authors titled "operational excellence in the manufacturing, services and the oil and gas: the sectorial definitional constructs and risk management implication" in 2017. The focused of the paper was on manufacturing, services and the oil and gas sector, where a table was developed that summarised the divergence and convergence of what OpEx dimensions are among the industries as shown in Table 1 below.

Considering the development in the concerns for clarifying the dimensions of OpEx in different sectors, this paper is aimed at consolidating the work of Muazu and Tasmin (2017) and elaborating the dimensions of OpEx in the oil and gas sector. It was done with a view to strengthening literature on OpEx for research purposes that shows clearly how the concept was measured and what constructs are essential for the measurement.

2.0 Literature review

2.1 Dimensions of Operational Excellence in the Oil and Gas

A dimension is a basis to which a concept or variable is defined and measured. It is the direction of how a concept is looked upon and operationalised in a study. In view of the above definitions based on industry, the dimensions of operational excellence are increased in productivity, cost reduction, flexibility, lead time optimisation and efficiency (Soliman, 2017; Fok-Yew & Ahmad, 2014; Kandasamy, 2016; McCreery *et al.*, 2013). However, due to the peculiarity of the oil and gas operations, OpEx in the sector emphasises on safety and health, reliability, efficiency, downtime minimization, risk management and the concern for the environment (Parker, 1999; Wilson, 2012; McCreery *et al.*, 2013; Feblowitz, 2015; Mitchell, 2015; Chevron, 2010; Nolan & Anderson; Ernst & Young, 2015; Heath *et al*., 2017; Edgame, 2014; Deloitte, 2015; Bellm, 2015; QEHS, 2017). In a similar notion, Elsevier (2016) maintained that achieving OpEx in the downstream sector has gone beyond skyrocketing profit margins to operational efficiency, reliability, safety and health, and environmental performance. This paper, therefore, elaborated the few dimensions of OpEx in the oil and gas sector with an emphasis on safety and health, reliability, operational efficiency and the environ-

ment. This paper is rather an extension of the current authors' previous work on OpEx dimensions in the oil and gas sector.

The previous review on the dimensions of OpEx among industries- manufacturing, service and oil and gas was conducted in 2017. It was found that there were similarities as well as differences in what OpEx stood for and the dimensions among the three industries. In Table 1, as developed by Muazu and Tasmin (2017), which showed the divergence and convergence of OpEx among manufacturing, service, and oil and gas industries.

Table 1: Convergence and Divergence of OpEx Dimensions among Industries
Muazu and Tasmin (2017)

Convergence	**Divergence**		
	Manufacturing	**Service**	**Oil and Gas**
Continuous improvement Cost reduction Quality of product/service Time utilisation Output optimization Employee engagement Integration of all work processes	Waste reduction (Lean) Flexibility Asset yield	Customer satisfaction Delivery period	Health and Safety Environment Reliability Operational efficiency

As an extension of previous review on OpEx in the oil and gas sector, the dimensions are further elaborated in the subsequent sections of this article. The dimensions as indicated in Table 1 shows that in the oil and gas sector, operational excellence has four dimensions that includes safety and health, operational efficiency, reliability of assets and process and environmental performance. Few researchers like Moktadir et al. (2020) conducted his study on the key performance indicators (KPI) of OpEx, which included management, operations, quality, economic, social and environmental. In the study they maintained that for a firm to attain excellence in operations they must have sound management, low cost(efficiency), care for the staff (safety and welfare) and a sound environmental management that prioritise safety of the environment at all times. An elaborate review on these dimension was done to further substantiate some of the meanings, factors, elements and fundamentally the measurement constructs that the literature assessment presents.

2.2 Safety and Health in the Oil and Gas

Most businesses, in almost every industry, operate in a relatively risky environment. These risks must be reduced to a reasonable point for an organisation to be successful. Oil and gas sector is one risky industry as regards health and safety (Osabutey *et al*., 2013). Health and safety in the occupation are referred to as the science of expectation, recognition, assessment and control of hazards emanating from the work process that impair the health and well-being of employees (Alli, 2008). Safety is the absence of adverse event that involves an unscheduled and intolerable loss often experienced by organisations, either on their staff, asset or process (Alkhaldi *et al.*, 2017). It is about staff wellbeing in the work place, the security of their lives and assurance of a healthy environment.

Health and safety represent major risks exposure firm's staffs are in the oil and gas sector, hence the need for effective management like for any other segment of the business risks (Fuller and Vassie, 2001; Mitchell, 2015). As a discipline, occupational health and safety promote the maintenance of high intensity of mental, physical and social wellbeing of employees in places of work and process (Ratna & Kaur 2016; Bennet & Foster, 2007). General-

ly speaking, health and safety policies are essential for organisations because it contributes to all facets of business performance as a vein of commitment to firms continuous improvement ideologies (McCracken, 2008; Mitchell, 2015). The policies assure people, the environment, regulators and every other stakeholder's expectations are fulfilled. Safety is the best starting point for improving business results leading to operational excellence (Wilson, 2012). It is the provision of a mechanism to enhance the working environment that provides staff and community with the assurance of safety and lesser harm to their body and their environment.

Safety and health are concerns that require strategic management attention because they can directly affect firm operational performance. According to British Petroleum BP (2016), functional safety leads to reliable operations of their assets, better efficiency and eventually, higher financial performance. As companies are working towards achieving and sustaining internal effectiveness, they also consider health and safety as a compliance issue that must be attended to for smooth operations in the oil and gas sector (Kolios & Luengo, 2016). It is a compliance risk for firms in the industry who fail to manage safety and health in their operations. However, Fuller and Vassie (2001) have it that fewer or no cases of staff accidents and fatality do not automatically indicate that safety and health are effectively managed in an organisation. There are situations where incidents frequencies will rise in an organisation despite their effective health and safety management. Generic cases like a natural disaster, terror attacks or pipeline oil spillage as a result of the explosion cannot be sto ed. For example the case of BP deepwater horizon in the Gulf of Mexico started as a small operational problem in the oil field that was not contained, which later turned out to be a serious incident where the spill led to the release of gas that kindles serious explosions that led to fire, injuries to people and eventual death (Nolan & Anderson, 2015). The problem led to a severe environmental disaster that cost the company millions of dollars.

Oil and Gas exploration, refining, transportation requires safety and health program to achieve operational performance excellence. According to National Institute for Occupational Safety and Health (NIOSH) (2010), oil and gas health and safety program is aimed at identifying potential risk exposures to chemicals, preventing bodily injuries and health to the workforce in the field. Because of these issues, ILO (2016) has been promoting a three-way collective effort of government, companies and workers commitment to continue building and implementing a preventive safety and health culture in the oil and gas industry. The interactive viewpoint on health and safety concerns were for ensuring regulations and checks among all parties involved. However, at some quotas, the blame for accident events are put on human error as the primary cause of avoidable events (ILO, 2016). And since human factor is played out, work process performance would be affected, and by implication, performance variation is increased. Nonetheless, studies indicated that the management of safety and health is effective when staff participation and sound leadership are in place (Bornstein & Hart, 2010). An active firm and unit leadership are essential as well as worker participation in safety and health management.

In a study conducted by Bornstein and Hart (2010) indicated that the management respondents harmer on individual employee involvement in safety and health management. On the other hand, employee respondents capitalised on management commitment as a significant ingredient to a safe and healthy work environment. It is now evident that management commitment/leadership brings about employee engagement in the organisation's safety and health management, which in turn improve operational performance and by extension operational excellence. Similarly, the findings from the study by Bornstein and Hart (2010) further buttresses the need for strong leadership in hazard identification and prompt response to events, and improved workers are training that can change their risk perception.

The American Petroleum Institute (API) (2004) revealed in a review report on safety incidents in oil firms operations between 1959 -1978. They investigated 88 incidents, out of which above 50% of the incident were predominantly caused by fire and explosion. The find-

ings indicated that major sources of safety issues were equipment failure (28%), human error (28%), faulty designs and construction (30%), insufficient processes (11%) and poor facilities inspection (5%). Other causes were procedural upsets (2%) and education (5%). They are considered as the causes of incidents that needed to be addressed. However, these causes are not always the case for all risk events; they do vary on the scenario and depending on the industry. Alkhaldi *et al.* (2017) posited that earlier studies indicated and proven that about 70% of the accidents in the oil and gas industry were as a result of staff error, negligence and sheer violation of operating rules. According to Penkey and Siddiqui (2015), regulatory framework and firm policies could not possibly address all the risk, the need for risk assessment a roaches and safety management is eminent for handling individual case potentials and also when they occur. All the arguments are emphasising on human factor (inadequate inspection, designs, negligence and unsafe acts) as the dominant cause of industrial accidents, as such workers are often blamed for it. Well, the blame on people will continue in their capacities are not built to be conscious of potential causes and effect of certain incidents and how to identify, report and or take precautionary actions or reaction.

Information technology is becoming an essential ingredient in the operation of most establishments. According to Ratna and Kaur (2016) the introduction of IT, information about outbreak of airborne and communicable diseases could be controlled, engineering safety can be achieved, incidents that can lead to bodily injuries can be minimized and all concerns on issues of heat stress, falls, explosion and machinery operations can as well be under severe watch. IT programs are helpful in this regard, as they help virtualise incidents before they occur and send an immediate signal as they occurred. David *et al*. (2003) posited that IT reduces errors by preventing adverse events by facilitating rapid response after an adverse event and helps in tracking and providing feedback about the undesired incident.

Some firms use IT as a tool for activity tracking that enables data downloads to smartphones, which are further put to use for developing organisational risk profile (Harrison and Dawson, 2016). The monitoring helps in recording incidents such as near-miss, falls, and exposures to gas and other health-related issues, and by extension, reduce insurance premium chargeable to firms. Similarly, Felemban and Sheikh (2013) opined that IT, specifically Radio Frequency Identification (RFID) is helping oil and gas companies in many ways. Areas such as search and rescue in the oil rig for cases of falls into the sea or missing person using RFID badges and other sensors (GPS and water presence). The device is used to track victims; mandatory checklist equipment helps detects and verify whether personnel wears the compulsory safety gadgets; worker tracking installed across all facilities to record and track every movement of staff that help report unauthorized movements, incidents of stair falls, health-related conditions, personnel headcounts and incidence audit. The contributions of IT to health and safety management in the oil and gas sector are enormous. Although it is capital intensive, it is better to invest in the prevention than to pay for the health or life of the staff and the cost of disruption in operation due to the incidence.

Strategizing ways to manage health and safety in the oil and gas using any form of IT to su ort in mitigating incidents requires data processing and measurement (Tan, Ortiz-Gallardo & Perrons, 2016). This data, looking at the functions of RFID elaborated above, is enormous that a Big data solutions could measure and analyse it in details. Big Data helps companies track and spot potential incidents before they occur (Campbell, Polo & Bouly, 2012; DeVol, 2004; Akoum & Mahjoub, 2013), it, however, has its lapses in oil and gas HSE characterized by already text coded, customized, and inaccessible data, also known as dark data.

In spite of increased understanding and awareness of workplace hazards, the poor performance of safety and health is prevalent in organisations which increase costs of managing incidences when they occur. Policies are made by government agencies or regulatory bodies to ensure the implementation of health and safety programs across companies (Alkhaldi *et al*., 2017). The global oil and gas regulatory guidelines provide that hazards and risks on

health and safety established after project assessment of site – host community, the assimilative capacity of the environment are to be adhered to by companies (International Finance Corporation (IFC) and World Bank Group (WBG), 2007). The guidelines cover areas of information on seismic exploration, drilling, development and production activities, transportation, pump stations and even decommissioning.

According to IFC and WBG (2007), the guideline justifies the protection of safety and health of people and the environment throughout the processes. Regulations vary among countries; it's either on their legal regime, method, institutional engagements and or management capacities. However, they are all aiming at reducing the number of incidents among oil project employees to a zero rate, particularly accidents that could lead to loss of work hours, disabilities, infections or even fatalities (IFC & WBG, 2007). Risk management matrix development for safety and health is dependent on regulatory requirements, local legislative content, firm's standard guidance (IPIECA & OGP, 2011) and regulatory regimes (ILO, 2016). Without regulations, more companies will not a reciate the health and safety of their employees.

A regulatory regime is a context to which a country controls how oil companies operate in their territories. According to ILO (2016), oil-rich countries govern health and safety undertakings of oil and gas firms based on their regulatory regimes – Prescriptive or performance-based methods. The prescriptive regime gives the regulatory body the power to define quantifiable goals and ensures operators compliance to meet the set requirements, whereas the performance-based a roach allows the operators to attain the set goals using their means (ILO, 2016). The difference between the two regulatory regimes is further explained in Table 2 In their view, Elsevier (2016) regulatory landscape regarding HSE is among the serious challenges facing oil companies because the rules and standards will continue to evolve.

Table 2: Description of the two major regulatory regimes in the oil and gas industry ILO (2016)

Prescriptive regime	**Performance-based regime**
Gives the competent authorities the possibility to specify exact requirements	Depends on dialogue and trust between the competent authorities and the industry
Requires comprehensive and detailed inspection	The companies need to aim for good safety culture
Reduces operators' responsibility to evaluate and manage risk	Tripartite cooperation and tripartite involvement
Depends on the industry's willingness to give access to and share information	Transparency and openness about reporting of failures and non-compliance
Can lag behind technological and social development	Requires a high degree of knowledge and competence

2.2.1 Health and Safety Management System (HSMS)

Management of organisations is responsible for the health and safety of all its employees at all levels. They must reduce incidents of accidents resulting into injuries to staff and health-related issues in the organisation and the entire community (Alli, 2008). According to Alli, HSMS needs to be a strategic goal of any firm as setting targets, and customer service is to the organisation. It involves people who are the primary resources for organisational success; they manipulate other resources like machines, raw materials and money to produce goods or services. Therefore, this means people safety and their health guarantees performance in an organisation. Thus, the management of health and safety must be integrated into the firm's business culture and procedures (Alli, 2008; Bennet & Foster, 2007). According to ILO (2009) and Alli (2008), an organisation as a whole need to prioritise health and safety as its primary objectives, then build a structure for HSMS undertakings with a clear definition of risk-prone areas, causes and consequences should they occur. Develop action plans and activ-

ities to contend the impact (reduce or prevent it) of diseases that cause ill health and bodily injuries, as shown in Figure 1 below.

The action plan would have to be evolving as situations and incidents may vary from time to time. Some incidents, fatalities, injuries recorded and lost time injury frequency has been used in recent time to measure safety and health performance in the oil and gas industry (Tang *et al*., 2017). Some of the core drivers of HSMS in the organisation include resources and commitment from the management, employee's participation, and training.

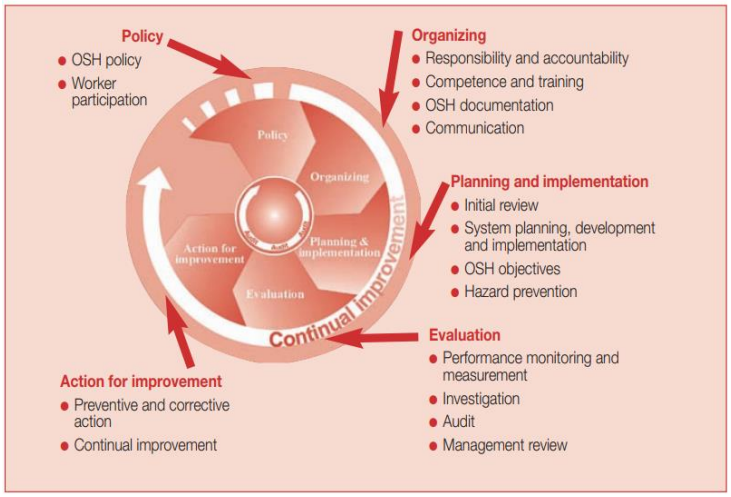

Figure 1: Health and Safety Management System
Alli (2008)

In a study, conducted on Chinese shi ing industry by Xue, Walters and Tang (2015), it revealed the existence of an imbalance between Shipmaster and crew participation in HSM, in that the latter lack of commitment to health and safety caused an indirect effect on crew's safety, health and wellbeing. The result from the shi ing industry shows how inefficiency on the part of management that led to forcing the shipmaster to sail to a port in a prolonged sailing condition that affected the general performance of the crew members. For this kind of situations, a functional unit needs to be created to see the implementation of HSMS that coordinates and delegates authority alongside funding to unit managers (ILO, 2009). This responsibility should further be delegated to supervisors because they are always with workers in the field. For this reason, they should be offering technical information and su ort, health and safety administration and provide training to subordinates. These actions promotes OpEx successful implementation, as workers becomes motivated by the provision of health facilities and continuous surveillance organisational performance improves.

The combination of management commitment and employee participation in health and safety program is incomplete when the staffs have no relevant skills. Employee training on health and safety is vital in HSMS integration for continuous improvement in the work process (Alli, 2008; Bennet & Foster, 2007). Apart from staff training on health and safety, management needs to build a culture in that regard to make it a norm in the organisation. According to Alkhaldi *et al*. (2017), safety, risk perception and beliefs, trigger of events and safety culture are requisites for managing safety and health risks and developing preventive strategies in an organisation.

Safety and health culture is regarded as the experiences and practices built over a long period by an organisation (Fuller & Vassie, 2001). Similarly, Adeogun and Okafor (2013) viewed safety and health culture as the priority organisations attached to employees' safety. On the contrary Back and Woolfson (1999) argued that companies use the employees' psychology to control their behaviours and actions in the guise of safety and health culture. Their argument was, there is no such need for health and safety culture. However, this argument is

their view, in the real sense; safety and health culture are needed in organisations because the consequence of an event affects both company's operations as well as the wellbeing of the employees. On this ground, health and safety, culture needs to be entrenched in the operations of oil and gas companies to help achieve excellence in operations.

Organisational culture is one of the most critical characteristics of firms that influence operational excellence, specifically quality improvement (Carvalho *et al.*, 2017). However, some researchers are of the view that organisational culture is aligned with subcomponents like preoccupation with failure, reluctance to simplify, sensitivity to operations, and commitment to resilience and deference to expertise (Zanko & Dawson, 2012). These are the ingredients required for a sustainable safety culture in an organisation. They argued that the major problem has to do with safety culture is lack of agreed definition that is acceptable to all organisations.

The new paradigm of focusing on workplace hazards and risk related to health has emerged. Which has to do with provision of medical services for sicknesses and rehabilitation of victims (Harrison & Dawson, 2016). In a review study by Schneider *et al.* (2013) on six major oil companies' health, safety and the environmental policy statements, it indicated that the companies shared common objectives and dedication to maintaining a safer and healthier working environment for employees by managing and communicating risks to their stakeholders. The companies covered in the study were ExxonMobil, British Petroleum, Weatherford, Sonatrach, Maraton oil and Shell. The review further shows that ExxonMobil was committed to managing safety by managing operational risks and response to emergencies. However, these are mere mission statements and not facts about HSE implementation in the companies, as the issues are still prevalent in the industry.

Safety and health as detailed in the above discussion, it shows that certain factors could influence the performance of health and safety as one of the dimensions of OpEx in the oil and gas sector. These factors are comprised of leadership, staff capacity, information technology, firm ownership structure and regulations supervising oil and gas industry operations. Perhaps if the elements are a lied as study variables could explain a significant effect on OpEx as a whole in the oil and gas sector.

2.3 Asset and Process Reliability, and Integrity

Reliability is another essential dimension that explains operational excellence in the oil and gas sector after health and safety. A machine, a aratus or system can maintain consistency in performance as regards intended function without failure (Business Dictionary, 2017). In the oil and gas business, capital assets are integral in the operations of the sector, particularly in drilling rigs, offshore operations, upstream oil wells, pipelines, LNG terminals and refineries (midstream and downstream) activities (Ossai, 2012). According to Nolan and Anderson (2015), reliability is the assurance enjoyed by companies on their assets, and personnel performance in production and product or service availability. Reliability is the ability of firms to identify potential asset failures for elimination, tracks and investigates such failures for improvement while considering assets lifespan from design to decommissioning (Ernst & Young, 2015).

The pinnacle of operations in the oil and gas is the ability of companies to meet and sustain production expectations reliably. According to Ernst and Young (2015), all capital projects must be converted into production assets, improve daily asset uptime, prevent an unnecessary shutdown and reduce the impacts of planned outages on the performance of the firm. For the reliability to be achieved, therefore, regular and plan maintenance is needed to align with critical risks identified in operation. According to Nolan and Anderson (2015), reliability is resolving issues related to facilities, business process and people that cause challenges blocking performance in an organisation. The resolution of the problems about assets

functionality, maintenance, service/product delivery and specification are aided by an IT tool called RFID (Felemban & Sheikh, 2013).

The RFID, according to Felemban and Sheikh (2013), provides solutions to asset management that are comprised of equipment identification of unreachable pipelines (underwater or buried), flanges and all other equipment deployed in a hostile environment that exposes them to corrosion, rust, abrasion and other wearing factors. Other uses of RFID on assets, according to Felemban and Sheikh (2013), are for monitoring and maintenance of equipment undersea and at drilling, exploration and transportation. Such that when the assets are due for maintenance an alert is received, this is so because the day the assets were acquired, their lifespan and periods of servicing are imputed into the database. RFID help also monitors workflow from start to the last stage of production and report any near miss and can as well allow workers to read instruction even when there is no internet connectivity because it is cloud-enabled. According to BP (2016), when recent technology is employed in operations for effective safety management and reliability of assets, thereby reducing technical risks that block efficiency of performance. BP (2016) maintain that with new digital solutions, potential issues with facilities that could lead to unexpected shutdown, causing loss of revenue and the rise of maintenance cost can be detected earlier. The early detection helps the firm save money by managing the issues at the micro level than when it goes major because of the multiplier effects on the revenue, environment and market positioning. Robust maintenance and inspection of assets, new or old may lead to higher reliability in their performance (Khan & Haddara, 2004).

Age is critical to the optimal performance of assets because of wear and tear or depreciation. According to Ossai (2012), the continuous exploitation of assets and ageing led to failures in the oil and gas plants. He maintained that research has shown that in the period between 1980 – 2006 major hazard incidents in Europe, half of them were caused by ageing facilities. And since plant safety is somehow dependent on assets reliability, the ageing should be considered as necessary as any other operational element. According to Khan and Haddara (2004), to achieve safe and efficient asset performance, it is pertinent to uphold reliability by reducing and eliminating unscheduled breakdowns.

The nature of capital investment in the oil and gas and the cost of downtime due to unscheduled breakdown are worrisome to the industry because it affects the availability of products and reliability of assets. Hence the need for condition-based maintenance, as opined by Veldman, Klingenberg and Wortman (2011), it is a program that recommends maintenance by processing information from condition monitoring sources and the remaining productive life of an asset or its components. The program helps in predicting maintenance need in good time before it gets worse-off in oil firms. However, the condition-based maintenance is achievable when staff are knowledgeable, the existence of a technical system and a sound managerial system as postulated by Veldman *et al.* (2011). It is a clear indication that staff capacity needs to be built for condition-based maintenance to attain reliability and by extension, operational excellence. It is so because of the complexities of plants and equipment and sophistication of a lications or programs; operators need the knowledge to make the diagnosis.

It is also critical in the oil and gas sector, unlike in service or manufacturing, to manage asset integrity and reliability to minimise downtime because it is costly for the industry. According to DiMatteo (2014), there are two primary a roaches (risk-based inspection and reliability-centred maintenance) for managing asset integrity and reliability. Risk-based inspection (RBI) is used to minimise risk through strategic inspection plans and analysis that aligns nature and level of asset's potential threat to determine the frequency of inspection. This technique is easy and cost-effective because the focus of inspection would be more on assets with higher risk tendencies. Thus, it ultimately reduces safety and environmental incidences (DiMatteo, 2014). The risk-based method, however, might expose other assets that are presumed

to have a less potential risk to a more severe one; it is so because the frequency of inspection on them drops according to the method. In the process, the assets would develop a gradual problem that ought to be handled before it becomes big within the inspection interval period.

The other method, as put by DiMatteo (2014), is the reliability-based maintenance. This a roach uses the result of assets condition analysis and performance to determine maintenance for more complex machinery whose failure or breakdown consequences are more severe. In this method, the assets performance priority and impact are considered first to avoid waste of time and resources on time-based or usage-based maintenance and breakdown repairs. To this end, a small and marginal improvement in the maintenance process brings about the rise in productivity, cycle times and profitability (DiMatteo, 2014). So to achieve the reliability of assets, maintenance is essential.

The oil and gas industry involves large capital expenditures as well as operational costs. The profitability of firms in the sector is highly dependent upon the reliability, availability and maintainability of the systems and assets employed in the production and operational process (Ostebo *et al*., 2018). Hence, for the control of production loss in the oil and gas sector facilities and downtime in operations, a consistent, cohesive reliability procedure is required. This requirement could be made during the technology development stage, in project implementation or operations by considering global best practices (Ostebo *et al*., 2018).

The diagram in Figure 2 shows the basis of reliability in the oil and gas operation. It covers the design, maintenance, availability of system, production and delivery of final products. These functions are broken into time-bound and volume bound. So, to achieve reliability and efficiency targets, oil and gas companies must develop data strategies that address several concerns (Bradley, 2013). These considerations, according to him, are holding the data within the firm, corporate structure and building an infrastructure to store and retrieve when needed.

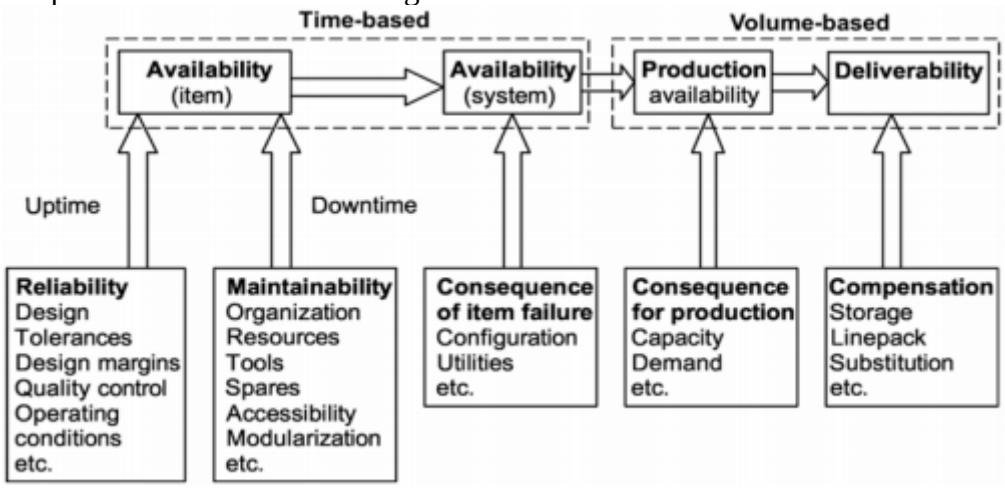

Figure 2: Time and Volume base production assurance terms
Ostebo et al. (2018)

From the above discussion, there is every clue that certain factors could be crucial for improving assets and process reliability in the oil sector as a dimension of OpEx. These factors include dedicated leadership, information technology tools, staff training, firm size and regulations guiding the operations of the oil and gas industry. Perhaps if the elements are a lied as study variables could explain a significant effect on OpEx as a whole in the oil and gas sector.

2.4 Operational Efficiency

Efficiency is the optimal level of the desired performance that maximises every resource for better output. According to Business Dictionary (2017) efficiency is the comparison between job performed with what ought to be achieved using similar resources. Efficiency in operation is considered as the relationship between business input and the output

generated from business operation, where output increases with little or no change in input (Nolan & Anderson, 2015). As the case may be, these inputs are the resources put (cost, people, time) and the outputs are the revenue, customers, o ortunities and productivity. The common scenarios in an improved efficiency are the same output for less input, more output for the same input and much more output for more input (Nolan & Anderson, 2015). This efficiency is fast-tracked with advancement in digital technology that offers innovative tools and systems that leverages on information to modernise operations for higher oil production output (Ernst &Young, 2015). The IT helps in compressing or merging repetitive processes to reduce the cost of production, thereby achieving efficiency in an organisation. This, of course, would be a problem as heads will roll, as employees and their unions will reject staff rationalisation by all means. However, Ernst and Young (2015) argued that companies' concerns are strategic on the hidden inefficiency and correctional work costs and not the cost of salaries and wages, and notwithstanding oil prices or projected profit.

Operational efficiency in the oil and gas is very vital as its effects cuts across so many functions of the sector because of the complexity of operating in the industry. Murshid (1988) considered efficiency as the outcome from the a lication of a suitable administrative principle that guides the internal performance of a firm. According to Oke and Kareem (2013), operational efficiency is an equilibrium position reached by an oil firm. This equilibrium means that the ability of a firm to create a surplus or excess revenue or output with optimum use of resources/inputs. Farrell (1957) postulated that operational efficiency is comprised of two elements, technical and allocative efficiency. These, according to Farrell, are expressed in terms of maximising output with little inputs and the utilisation of such inputs in proportion to their respective values.

Conversely, Oke and Kareem (2013) are of the view that companies could be technically and allocative efficient, but their operations might not be optimal. It means that efficiency does not guaranty a firm's profitability because of industry size, which might be efficient in one firm might turn out to be inefficient in another that is relatively bigger. On the other hand, Mitchell (2015) argued that operational efficiency is that ability to deliver a product or service with the least waste, operating, and energy costs by a firm. It means that efficiency is about how cost of operation is minimised at the same time output is optimised.

In striving to achieve operational excellence by maintaining operational efficiency, companies are employing the use of big data as an IT tool. According to Tan, Ortiz-Gallardo and Perrons (2016), companies used big data to increase operational efficiency, effective customer service delivery, explore new market o ortunities and develop new products. In a more elaborate view of the role of IT, Barry (2012) posited that real-life processes combine with sustained, committed leadership and IT best practice extends beyond safety and assurances benefits to delivering efficiency gains to the firm. It means that when IT is embedded in the entire work process, it can guaranty interactions between units and also between people and machines at reduced time lag. Elsevier (2016) further emphasised the need for information data to improve agility in operational efficiency. Agility in operations means having an extraordinary capability to balance cost, quality and time to produce and exceeds changing markets requirements profitably (Carvalho *et al.,* 2017). The ability of a firm to optimise the use of resources to achieve and sustain organisational goals is about efficiency.

Efficiency is an essential factor in the path of success in the oil and gas sector. According to Bai and Liyanage (2012), enhancing process efficiency and effectiveness in the cost of oil and gas production is critically needed. In their report BP (2016) shows that their efficiency had improved because the books of the company indicated a foreseeable loss due to drop in gas realisation and unfavourable foreign exchange experience; however their lower costs and efficiency offset that potential loss scenario. The drop in cost was associated with exploration write-offs, depreciation, depletion, lower rig cancellation charges and an increase in production. In the same strive for cost reduction; companies consider human resources activi-

ties that involve the recruitment of suitable staff and training of personnel for enhancing their capacity to improve efficiency (Namu *et al*., 2014). It is clear that when staffs have capacity can help reduce waste in the production process. Namu *et al*. (2014) further maintained that another strategy for cost reduction in operations is to exploit IT in the work process, with a click of a mouse, customers' orders are processed, inventories are checked and confirmed price of the spare part. As it is, cost reduction increases operational efficiency and firm performance at large.

Efficiency in the oil and gas sector, either operational or revenue-based, is affected by the ownership structure of the firm. According to Hartley and Medlock (2012), the significant difference between NOCs and shareholder-owned oil firms regarding efficiency cannot be underestimated. Hartley and Medlock (2008) further argued that a NOC management faces political pressure to employ staff they do not require and also granting resource rents to domestic companies and workers at a discounted value that affects NOC operations as well as revenue. However, other factors affect the operational efficiency of NOCs, issue such as corruption of officials. As in the case of Nigeria, all the refineries are not working; this is costing the Nigerian NOC (NNPC) more money to lift the crude for refining abroad then import the refined product at international market rate. The practice had created windows for corruption, as government pays subsidies for the imported refined petroleum products.

From the review presented above, there is a hint that some factors could be critical on how the operational efficiency of the oil sector could be enhanced as an OpEx dimension. These recognised factors include committed leadership, staff capacity, information technology tools, and firm ownership. Conceivably, if the factors are utilised as research variables could play a significant role in OpEx successful implementation as a whole in the oil and gas sector.

2.5 Environmental Performance

The environment is another critical dimension of OE in the oil and gas industry. Awareness of the importance of environmental challenges has turned out to be the central concern of the oil sector as well as regulators some decades ago (Oil industry international Exploration and Production (EandP) Forum and United Nations Environment Programme Industry and Environment Centre (UNEP), 1997). The environment is comprised of the host communities where oil production activities are taking place, the animals, vegetation and the climate. These activities had further exposed the global environment to greater danger because of climate change. According to the EandP Forum and UNEP (1997) report, oil and gas activities is affecting the environment with oil spills, accidents and fires, land damage, air and water pollution.

According to U.S. EPA (2008), the release of wastes due to oil and gas exploration activities like fluid leakages from drilling, air emissions and storage wastes made it difficult for the industry to eliminate the effects on the environment. The efforts of the oil firms to reduce such adverse effects are seen in their environmental performances. These efforts and practices to minimise the impact on the environment can be executed at the internal level or the broader su ly chain level operations of a firm (Graham & McAdam, 2016). Environmental practices at the internal operations have been researched by Hart and Dowell (2011) that sought to measure linkage with firm performance. Hart and Dowel (2011) maintained that the disclosure by a firm of its environmental practices affects its market performance. When the experience is not right, investors become scared of a repeat of similar experience in the future, thus leading to adverse reactions.

The oil and gas industry, unlike other sectors of the economy, is faced with quite numerous issues that pose operational bottlenecks in achieving environmental performance. Performance in this sense that, the environment is eliminated of pollutions of all kinds. These constraints are associated with the continuous need for exploration of oil and natural gas for

government revenue generation. According to U.S. EPA (2008) wastes are generated from drilling activities, and extraction of natural resources, which are mostly not reusable in any form and they must be disposed of to prevent the environment and the people. Despite efforts by the oil firms to curb the challenges, the problems are still evolving. Hence there is the need to do more on some environmental concerns to attain excellence (U.S. EPA, 2008). Impliedly, the environment may not be free from pollution as long as oil and gas production cannot be stored. However, it can be reduced and or controlled by internal operations.

As suggested by U.S. EPA (2008) to remedy these worries, all stakeholders such as government and the industry must get to the drawing board to redirect and improve existing policies, regulations and technologies, with commitment and innovation. Earlier studies like that of Ramanathan *et al*. (2017) have proven that regulation indeed influences the environmental performance of the firm. The pressure to control the impact of oil production on the environment doesn't just stop with the government regulations, even NGOs, congressional oversight functions, and communities continue to scrutinize the probable risks associated with expanding production on land or high sea (U.S. EPA, 2008). In a study conducted by Kassinis and Vafeas (2006) on the effect of pressure from stakeholders (government and community) on environmental performance, the result shows that community pressure significantly improved such performance of oil and gas firms. By implication, community interaction with oil and gas firms would help reduce some of the environmental challenges. Also, a powerful pollution prevention strategy reduces potential and actual adverse impacts on the environment created during production activities (Schoenherr, 2012).

There is every indication from the review that certain factors could influence how environment performance of the oil sector could be improved as a dimension of OpEx. These identified factors include committed leadership, staff capacity, information technology tools, firm ownership and size and regulations guiding the operations of the oil and gas industry. Perhaps if the factors are a lied as study variables could explain the significant effect on OpEx as a whole in the oil and gas sector.

3 Methodology

In this review article, earlier work on OpEx across industries (manufacturing, service and the oil and gas) was reviewed and some elements and tables were recapped to show a continuation or a consolidation to works already done. Several journal articles and professional reports were reviewed and reported. Some texts and conference papers were also used as material for sourcing information for the current article. Practical company reports and real life experience were also gathered and synthesized to give deeper understanding on the various dimensions of OpEx in the oil and gas sector. Tables and charts were adapted and adopted to explain certain scenarios of OpEx individual dimensions in the oil and gas sector. Several search engines were explored for accessing the materials used in the current review, such as Google, research gate, Scopus, and Wiley online. Some of the keywords used for the search included operational excellence, operational efficiency, reliability, health and safety, environmental performance, oil and gas, dimensions, and constructs. Others were evolution, challenges, risk management, assets and machinery maintenance, su ly chain management and lean strategy.

A small sample was drawn from some oil firms in Nigeria randomly and data was collected from 50 management staff across engineering and maintenance, health and safety, productions and operations departments.

An exploratory factor analysis was conducted on the measurement constructs of the OpEx dimensions in the oil and gas sector. Several iterations were conducted to stream out irrelevant measurement constructs regarded as free standing, cross-loading as well as those items with less than 0.50 coefficients of the rotated matrix.

4 Results/Findings

4.1 Measurement of Opex Dimensions

The review shows that there four dimensions of OpEx in the oil and gas sector, which health and safety, operational efficiency, reliability and environmental efficiency. It further revealed the operationalization of the dimensions of OpEx. According to Hox (1997) operationalization of variables is the interpretation of a theoretical construct into observable phenomena by identifying empirical indicators for the concepts and their sub-domains. The dimensions are particular to oil and gas operations as put by (Ernst & Young, 2015; Chevron, 2010; Wilson, 2012; McCreery *et al*., 2013; Feblowitz, 2015; Edgeman, 2014; Delloitte, 2015; Elsevier, 2016; Asat *et al.,* 2015; Soliman, 2017; Kandasamy, 2016; Parker, 1999; Mitchell, 2015; Nolan & Anderson; Heath *et al*., 2017; Deloitte, 2015; QEHS, 2017). The measurement items were driven from the works of the scholars as cited earlier

An exploratory factor analysis (EFA) was conducted on the adapted items, cross loadings, free standing and those constructs with coefficients below 0.5 were deleted after series of iterations. The measurement constructs or items that were tested are presented in Table 4. The rotated matrixes were within the accepted threshold of 0.5 as argued by Yong and Pearce (2013).

Table 4: Measurement Items of Operational excellence Dimension

Items	**Operational Excellence**	
	Safety and Health	**Rotated Matrix**
1	Facilities and machines designs have improved to prevent injuries to people and fatalities	0.795
2	A comprehensive safety program related to safe-work-practices is in place for each location	0.758
3	Safety and health risk management process is periodically reviewed to assess risks related to health, facility operations and modifications	0.712
4	There is a drop in staff injuries, fatality and process incidents	0.695
5	Lost workdays hours per employee (due to injury or health) are continuously dropping	0.656
6	Our staff now have work confidence and health assurances because of available medical services	0.639
7	All aspects of operations essential to safety and integrity are properly designed and constructed, tested, inspected before the commencement of operation	0.557
8	Emergency response teams are always on red alert to handle incidents	0.541
	Assets and process Reliability	
1	Pre-startup reviews on new or idle facilities are conducted prior to operation and after shutdown to ascertain compliance	0.785
2	Failure analysis is conducted to determine causes and develop steps to mitigate its effects	0.729
3	Unplanned plant shutdown is minimal now due to proactive maintenance and condition monitoring of the mechanical integrity of our assets	0.685
4	Ageing assets are continuously maintained and often replaced before decommissioning	0.654
	Operational Efficiency	
1	Costs related to production, maintenance, litigations, and risk incidences are reduced	0.787
2	Some processes in operations have been integrated for speedy and efficient production	0.707
3	Operational process is optimised, and profitability is improved through the efficient use of people, time and assets	0.654

4	Quality has improved through interacted assurance processes across design, marketing and production units	0.516
	Environmental Performance	
1	We identify, assess, mitigate and manage potentially significant risks and impacts to the environment (including living organisms)	0.756
2	We take inventories of all emissions, releases, wastes and potential contamination caused by our operations	0.698
3	We periodically evaluate contractors and sub-contractors on environmental performance for contract renewals and awards	0.612

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