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Proposing a conceptual model for cloud computing adoption in upstream oil & gas sector

M.M. Lawan[a], C.F. Oduoza[b], K. Buckley[a,b,*]

Faculty of Science & Engineering, University of Wolverhampton, Wolverhampton WV1 1LY, United Kingdom

* Corresponding author. Tel.: +447459103061. *E-mail address:* m.lawan@wlv.ac.uk

Abstract

Cloud computing is a paradigm which offers IT services such as storage, network and processing power via the internet. The technology has gained popularity in recent years with adoption in different sectors due to the numerous benefits it offers such as scalability, flexibility and cost reduction. Although some are quick adopters, others are considered cautious adaptors. The upstream oil and gas industry fall under the latter category due to some challenges with regards to adoption decision. Migrating to a cloud platform depends on a number of factors. A clear understanding of these factors is necessary to enable decision makers in the industry to be more proactive and appropriately guided in their plan towards adoption. Therefore, this study aims to identify the factors that may influence cloud adoption in the industry. A literature review was conducted in order to propose an integrated model, which is a combination of the Technology environment organisation (TOE) framework, institutional theory, and diffusion of innovation. The model groups the factors into three fundamental categories. In addition, the study reports benefits of the cloud technology in the upstream oil and gas sector, challenges hindering adoption, as well as approaches by earlier researchers to support cloud migration in the industry.

Keywords: Cloud computing; Adoption; Upstream oil and gas industry

1. Introduction

Cloud computing represents a paradigm shift in the way computing services are outsourced. Computational resources are delivered as a service rather than a product. Even before the advent of cloud technology, IT technologies such as web 2.0 and virtualisation have existed individually [1]. The cloud simply combines part of their capabilities to form the cloud environment [2]. Several computing paradigms existed in different forms since the start of computing technology in support of public service. However, none has succeeded due to lack of internet for public access and the need for high speed processing capacities.

The cloud offers numerous benefits for organizations, deployment flexibility, cost reduction and scalability are some of the significant reasons for migrating towards the technology [3]. The upstream oil and gas industry, which identifies and produces oil and natural gas benefits immensely from the cloud technology due to the fragmented pattern of activities. The cloud helps the industry with effective and efficient flow of information and remote data management [4]. According to [5], cloud computing can transform upstream operations, thus making the industry more agile and productive.

Despite the enormous benefits offered by cloud technology, the upstream oil and gas industry has been cautious in moving towards the technology. There are still several concerns about adoption, most notably data security [6]. According to Accenture's 2017 upstream digital technology survey, only 45% of mainstream upstream oil and gas companies are using cloud technology for upstream operations [7]. From literature, it is clear that some studies are available on cloud migration in the upstream oil and gas industry. These studies aim at supporting the migration process in the industry with a focus on cloud application, cost, challenges and benefits [4, 8, 9, and 10].

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However, the studies did not cover the factors that influence adoption in the upstream oil and gas sector.

It is evident in prior studies that cloud migration can be affected by some factors [11, 12, 13, 14, 15 and 16]. To better understand the adoption of this technology in the upstream oil and gas sector, it is imperative to study all the factors that influence adoption. With a clear understanding of these factors, decision makers in the industry would be more proactive and appropriately guided in their plan towards cloud adoption. Therefore, this paper proposes an integrated model consisting of factors that might encourage or discourage adoption in the upstream oil and gas industry.

1.1. Application of cloud computing

Generally, cloud computing resources are accessible via the internet. This process allows customers and organisations to easily access and utilise the resources according to demands. The importance of easy access to information from remote locations makes the cloud compatible with several fields. Recently, the technology has widely been applied in various sectors especially manufacturing healthcare, education, library, and agriculture among others.

1.1.1. Manufacturing

In cloud manufacturing, resources and capabilities are shared on a cloud platform which enables better decision making for sustainable manufacturing [17]. Managers and engineers can have access to real time production data. The concept accelerates growth in productivity, saves costs and improves operational efficiency. For example, IBM has developed a cloud platform called 'IBM Watson IOT' which balances data in the manufacturing process to improve their business [18]. Similarly, Siemens has the Mindsphere cloud platform, which connects digital data with production facilities and physical products to enable faster and efficient finished products [19]. This is illustrated in (Fig1).

Fig. 1. Mindsphere cloud platform.

1.2. Oil and gas industry

The oil and gas industry is extensive. The value chain involve series of activities to acquire oil and gas to consumers. This large industry can be categorised in to three chronological sectors: The upstream, midstream and downstream. The value chain is illustrated in (Fig2).

1.2.1. Upstream

This sector is also known as the exploration and production sector. Activities include searching for potential onshore or offshore oil and gas fields, drilling of exploratory wells, and subsequently recovering the crude oil and/or natural gas to the surface. The upstream consist of three segments which are exploration, drilling, and production.

1.2.2. Midstream

This segment involves activities that connect the upstream and downstream sectors. Operations covered include transportation, processing, storage and distribution, the main aim is to deliver crude oil and natural gas to refineries. Transportation options can differ depending on content and distance, varying from pipeline to huge cargo vessels. Natural gas needs to be compressed or liquefied, while oil can be transported in its normal state.

1.2.3. Downstream

This sector includes operations such as refining and processing of crude oil and natural gas into usable products such as gasoline, diesel, jet fuel, asphalt etc. It also covers marketing of finished products from the refineries to end users or retailers.

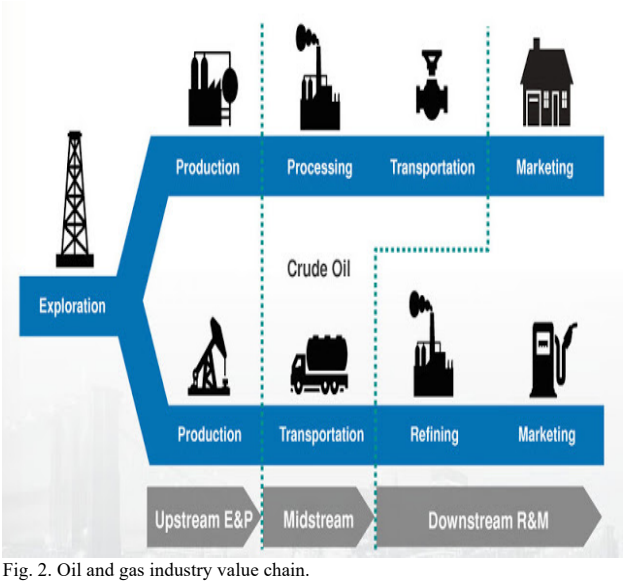

Fig. 2. Oil and gas industry value chain.

1.3. Literature on cloud in upstream sector

The study of Ma et al. [4] discusses the implementation of cloud computing in oil and gas exploration. Data gathered through questionnaire was used for evaluation of cloud implementation. In addition, the work also compared results to understand the method applied by different petroleum companies. The study is significant as it makes recommendation for oil and gas companies to exploit cloud computing. However, their work does not take into account factors that affect cloud adoption in the industry.

The study of Khan et al. [8] focuses on exploring the various ways cloud computing could be applied in upstream oil and gas operations. The study elaborates cloud application and the potential benefits the technology could offer the upstream oil and gas industry. The authors also stated future avenues for cloud application to enhance hydrocarbon in remote oil and gas operation. The study only discussed cloud application and did not touch adoption.

The study of Perrons and Hems [9] analyses the suitability of the three cloud deployment models. The authors highlighted the challenges facing the upstream oil and gas industry and how those challenges were overcome by other industries in their journey towards the cloud. The deployment models discussed include public, private and hybrid cloud. The authors argue that the move in the form of private and hybrid cloud is just a steppingstone. While the study unravels cloud deployment models and their suitability, it did not investigate factors that influence adoption.

The study of Kukreja and Karnawat [10] discusses the migration strategy and challenges hindering the move towards cloud computing within exploration. The study highlighted cost, organisational change and network access bandwidth as some of the challenges. However, there may be other challenges that affect adoption.

1.4. Challenges

Despite the enormous benefits offered by the cloud, the technology has not yet fully penetrated the upstream oil and gas industry due to some challenges [6]. According to Yuan et al. [20] the sector is highly data intensive where data security and compliance is a major concern when considering cloud computing. There is reluctance in having sensitive exploration data stored in an unknown location. Another challenge is the large amount of seismic data which needs to be shared across the network without latency [21]. Furthermore, the upstream oil and gas industry is known for its investment legacy in IT applications and infrastructure [9]. Looking at the significant amount invested to acquire existing IT infrastructure, upstream oil and gas organisations are reluctant to make the move.

However, all these challenges are present in other sectors. For example, the health sector much like the upstream oil and gas sector is also highly data intensive with medical records transferred between personnel [22]. But the issue of data security is tackled by encrypting the data before being placed on the cloud. In terms of huge computational data, open source software frameworks such as Hadoop help in achieving huge computing power by splitting the task into sub-divisions and also coordinating servers as they work on them [23]. This process has been applied by Wisconsin medical college to move highly sophisticated computational tasks and large amount of data to the cloud.

The upstream oil and gas sector obviously has been very cautious in moving towards cloud technology due to some challenges most notably data security, investment legacy in IT infrastructure, and huge computational data. This gives an opportunity for further research. Also, the study of Tan et al. [24] urges on the need for the research community to address the fear preventing oil and gas companies in adopting the cloud technology.

1.5. Benefits

There are numerous benefits which cloud technology offers the upstream oil and gas industry. Significant reasons for migration include deployment flexibility, cost reduction and scalability [3]. Other benefits include

- Storage of large results of seismic survey [6].
- Timely interpretation of seismic data to maintain quality of hydrocarbons [25].
- Real-time collaboration across reservoir modelers for faster and better decision making.
- Remote access to data and services through common devices [26].
- Real-time information on dangerous rocks for safety [27].

2. Technology adoption theories

These are theories and models developed by different researchers to analyse the adoption of a new technology. The most widely used models/theories by researchers to analyse the adoption of IT technology are Technology Organisation Environment (TOE) framework, Diffusion of Innovation (DOI) theory and Institutional theory.

2.1. Technology organisation environment (TOE) framework

The TOE framework was proposed by Tornatzky and Fleisher [28] to understand how the adoption of a new technology happens in an organisation. It investigates the impacts of three elements, namely the technology, organisation and the environment. The technological context explains the internal and external characteristics of an innovation and the changes it brings to an organisation. The organisational context refers to the internal characteristics of an organisation that can influence the innovation process. This includes organisation size, structure and the availability of adequate resources. Finally, the environmental context refers to factors within the environment of the organisation that might influence the innovation process. This includes competitors and regulatory environment.

2.2. Diffusion of innovation (DOI) theory

Developed by Rogers [29], the DOI theory is commonly used by IT researchers to analyse the adoption of new technologies

and ideas at an individual and organisational level. It focuses on analysing the attributes of a technology which the TOE framework did not focus on. The DOI puts forward five technological attributes that have a direct impact on adoption rate. These are relative advantage, complexity, compatibility, observability and trialability.

2.3. Institutional theory

This is a commonly used theory to examine the adoption of an information technology. It adds new and vital factors to the environmental context of the TOE framework. Factors such as competitive pressure and trading partner pressure, which might influence adoption process.

3. Proposed model

An integrated model has been proposed consisting of factors derived from literature on cloud computing adoption models and technology adoption theories. It also includes other factors such as accessibility, existing IT applications and infrastructure, and data integrity that have not been investigated in prior studies. This model is an integration of Technology organisation environment (TOE) framework, institutional theory, and diffusion of innovation. The factors are grouped into three fundamental categories. (Fig3) illustrates the proposed model.

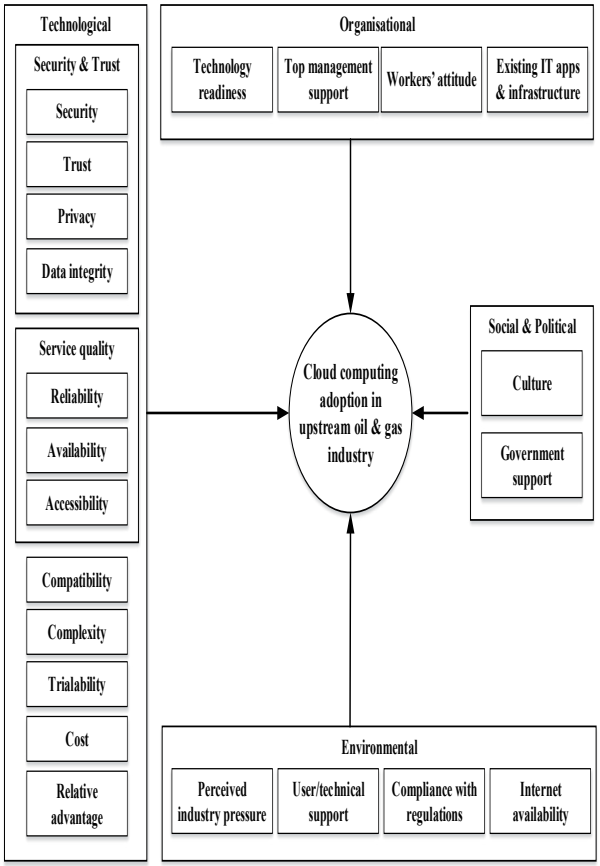

Fig. 3. Proposed model for cloud computing adoption in upstream oil & gas industry.

3.1. Technology context

The technological context describes the technological characteristics of cloud computing and the factors that affect adoption decision.

3.1.1. Security

Cloud computing security refers to the level of standards and procedures in place to secure an organisation's information and the system from unauthorised access. This is a major concern for organisations as they have doubts over data confidentiality [22]. The risk of data security and compliance is a major concern for the upstream oil and gas industry considering cloud computing [20]. With sensitive information like exploration data in upstream oil and gas operations, secured applications and networks are important for data integration and sharing. Therefore, this factor may influence adoption intentions.

3.1.2. Trust

Trust is an important variable for organisations to consider when deciding to adopt cloud computing [30]. It involves the level of confidentiality, integrity and authenticity offered by service providers with regards to data storage and other services. Cloud computing is a technology that offers virtualization of servers in remote locations. The upstream oil and gas industry deals with huge sensitive data which must be protected and backed up for future need. Adopting cloud computing would mean placing trust in a third party to provide them with a sufficient service and protect their data without knowing the location of the data.

3.1.3. Privacy

Another factor that could influence adoption is privacy. It refers to the confidentiality of data. Organisations considering adopting cloud computing must know that they are surrendering their data to a third party as it will be stored on cloud-based servers, this creates fear of unauthorised access [31]. The upstream oil and gas sector is a highly data sensitive industry that places data privacy above everything and intrusion may lead to disaster. These data include the results of exploration and Trade secrets such as location of well logs [9].

3.1.4. Data integrity

This means the safety of data during transfer without any manipulations. Cloud technology involves transferring data online, which would be considered essential for the upstream sector operation. However, using the cloud would mean uploading data for dispersed personnel to have access to it, which definitely involves data transfer. Therefore, the fear of data being manipulated during transfer may influence adoption.

3.1.5. Reliability

Refers to the ability of a system to fulfil its intended function in a proper manner as expected. It involves ensuring a high quality of service to end users, with a high transmission rate, minimum rate of errors, and fast recovery. Organisations fear

that outage from service providers may lead to setbacks [12]. In the case of the upstream oil and gas sector, geological data from exploration must undergo processing before any decision can be made. In addition, data storage and integration are also crucial. A reliable process which is fast and error free is required to avoid setbacks.

3.1.6. Availability

Availability is a significant variable to be considered by organisations when adopting cloud computing. Cloud technology is a service offered online and must be available at all times. The upstream oil and gas industry operate on the bases of information sharing and decision making. It requires a stable service with highly redundant infrastructure to avoid failure at any time.

3.1.7. Accessibility

This is the ability of organisations to have access to the technology wherever they are located. Service may be available but accessing it another thing. The upstream oil and gas industry deals with drilling and exploration in some of the most remote locations around the world (both onshore and offshore).

3.1.8. Compatibility

Compatibility is the degree to which an organisation's way of practice is adaptable with the new technology [29]. Wang et al. [32] states that this factor is crucial in deciding the adoption of a new technology. Organisations are more likely to consider adopting cloud computing if their existing work application systems are compatible with the technology. It is necessary for the cloud technology to be compatible with the organisation's current infrastructures and values [33]. The upstream oil and gas sector have a fragmented pattern of practice in which collaboration among personnel is paramount for faster and better decisions. Big data storage and analysis is also a significant part of the industry's operation, data must be readily accessible so that experts can collaborate, analyse and make fast decisions. An effective cloud technology must be compatible with this process.

3.1.9. Complexity

Rogers [29] defined complexity as the degree of difficulty involved in understanding and using an innovation. Complexity of adopting cloud computing technology is measured by the efficiency of data transfer, speed of execution, interface design, system functionality, the integration between applications and cloud infrastructures, etc. It is essential for organisations to consider this element when deciding on adopting cloud computing [11]. Generally, in the upstream oil and gas industry, cloud technology is not too common, and its adoption is at a slow rate.

3.1.10. Trialability

Trialability is an element of DOI; it refers to the degree to which a technology may be experimented on a limited basis [29]. This factor enables an organisation to use cloud computing for a while before deciding on whether to adopt it or not [34]. Establishing a cloud platform for the upstream oil and gas sector needs an investment and most of the industries might want to try the technology before making a final decision.

3.1.11. Cost

This refers to the upfront cost needed to establish a cloud platform, which includes system integration, software and hardware facilities. Some organisations have enough facilities at their disposal while others don't. This factor can be influential in adoption decision because if the cost of infrastructure is very high, organisations' managers might be reluctant to adopt cloud technology [35]. Upstream oil and gas industries without established infrastructures will need to spend on an infrastructure which supports the cloud platform depending on the type of service. The cost is relatively lower compared to traditional IT; however, it is necessary.

3.1.12. Relative advantage

An element of DOI, relative advantage is the degree to which the technology is perceived to offer more benefits to organisations [29]. To and Ngai found that it is paramount for organisations to consider the advantages in adopting an innovation [36]. Cloud computing technology presents companies with many solutions which boost their productivity and performance, enabling them to gain relative advantage among their competitors [34]. The cloud offers the upstream oil and gas companies a great level of scalability and reduces the cost of implementation and maintenance (technical support and all upgrades). Furthermore, it eliminates the dependence on IT consultants and their potential disappointments, thus enabling the industries to respond quickly to third party requests and operational developments.

3.2. Organisational context

The organisational context describes the characteristics of an organisation which can either encourage or discourage the adoption of cloud computing technology.

3.2.1. Technology readiness

This refers to the level of human resources and technological infrastructure available to support cloud computing usage and management [32]. Karim and Rampersad found that technology readiness is a critical factor that influences the adoption decision [37]. If an upstream oil and gas industry has the adequate human resource and infrastructure to support cloud computing platform, then adoption will be met in a positive manner.

3.2.2. Top management support

It refers to the level of support dedicated by the top management towards the adoption of a new technology. Lian et al. found that this factor is paramount because the top management have the authority to approve the provision of adequate resources, make adjustments and impose the acceptance and use of cloud computing [22]. Adoption of cloud computing is a huge project for the upstream oil and gas

industry, which requires sufficient budget and support from top management.

3.2.3. Workers' attitude

This refers to the attitude of workers towards cloud technology. It includes attractiveness as well as cloud benefits in terms of user performance and ease of work.

3.2.4. Existing IT applications and infrastructure

This includes the existing traditional IT system already in use and the amounts spent to acquire them. The upstream oil and gas industry is known for its investment legacy in IT applications and infrastructure [11].

3.3. Environmental context

The environmental context describes the environmental factors of where the upstream oil and gas industries operate which might affect adoption decision.

3.3.1. Industry pressure

This refers to the degree of competition an organisation faces of its competitors within the industry. This factor is an important determinant of a technology adoption [38]. In the case of cloud computing, this factor forces organisations to adopt the technology in order to gain better operational efficiency and greater benefits [33]. The upstream oil and gas industry is a sector with intense competition on who acquires the licence to get to the oil first. This competition may drive an industry to adopt a technology which gives it an advantage over its competitors.

3.3.2. User/technical support

This refers to adequate user/technical support from cloud service provider. Pre and after adoption support from service provider can influence and encourage adoption of cloud technology [34].

3.3.3. Compliance with regulation

These are government laws and regulations in place which may encourage or discourage the adoption of cloud computing [12]. This factor is influential, because the lack of regulations on data hosting location and security breach might hinder adoption decisions [35]. The upstream oil and gas industry is data sensitive which requires laws and regulations that govern data protection.

3.3.4. Internet availability

Availability of internet connection has been proven to be influential in cloud adoption. Organisations fear that the lack of internet connection would prevent them from accessing cloud computing services [14]. The upstream oil and gas industry operate in the most remote locations around the world.

3.4. Social and political context

This context describes social and political factors that may encourage or discourage adoption.

3.4.1. Culture

This refers to the social behaviour of a certain set of people or society. There has been a strong correlation between the organisational practices of industries and the perception of people in various national cultures. Alhammadi et al. found that programmed cultural beliefs influence the adoption of cloud [39].

3.4.2. Government support

This refers to government industrial strategy to support technology adoption. It includes a plan of how industries should operate, as well as government financial support towards achieving the plan. Some countries set strategies to ensure a greener environment and this is relevant to cloud computing technology. Therefore, this may factor influence adoption.

4. Conclusion

The upstream oil and gas industry benefits immensely from cloud computing. However, adopting the technology depends on a number of factors that may influence adoption decision. In an attempt to support adoption, this study has proposed a model consisting of factors that may affect adoption in the industry. The factors include technological characteristics of cloud computing, the industry organisation, environmental constraints, as well as social and political influence. As this is an ongoing research, the model shall be modified and validated in future research.

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