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Oil and Gas Sector: A Systematic Literature Review of Digitalization, Cybersecurity, and Human Factors in the Post COVID World

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ABSTRACT

The human factor, digitization, and cybersecurity are interconnected to each other. Recently, cyber threats are becoming more complex and real due to the enormous growth and advancement in sophisticated technology. Consequently, cyber threat actors have gained access to the nation-states' critical infrastructure, particularly the oil and gas sector. This requires oil and gas producers to take concrete measures to safeguard themselves against these stealth enemies. In the light of rapidly changing digital and cybersecurity landscape, a deeper understanding of the interaction between digitization, cybersecurity and human component is needed. Oil and gas practitioners and academics have been working collaboratively and independently for decades to digitize the industry to make it more cost-efficient and resilient. However, different aspects of digitization, for example cybersecurity and human aspect were not able to keep up with the pace of digitization. Therefore, the purpose of this paper is to chronologically track the development of the smart factories, importance of human factor and cyber security practices employing various digitization strategies and identify the gaps in digitization, human factor and cybersecurity and their interrelationship. This is done by adopting a systematic and methodical approach to undertake a systematic literature review on digitization of petroleum industry. 61 papers were shortlisted after a careful and rigorous research in four major databases, that is, SCOPUS, AAPG ProQuest and Web of Science. This paper discusses the publication patterns, origin and purpose of digitization models, and its adoption in the petroleum sector domain, while recognizing the significance of human factor and cybersecurity. In the past, there was a trend of taking actions after the cyber-attack has occurred, human impact was relatively ignored, and the pace of digitization has been more than the advances in cybersecurity management. This knowledge gap poses a major challenge in the oil and gas sector, where billions of dollars are at stake. With the passage of time, as digitization programs have evolved, cyber security and employee training and awareness have become integral components, and cybersecurity has been incorporated as an essential component of digitization frameworks in the proposed models. However, these models need to be validated and updated further and to be explored at the project level.

Keywords: Cybersecurity, Digitization, Digital transformation, Human factor, Oil and gas sector

INTRODUCTION

The world is currently undergoing fourth industrial revolution, an era of rapid technological transformation and disruptive technologies. With the advent of the fourth Industrial Revolution, boundaries between the physical, digital, and biological realms have become blurred, bringing new challenges and opportunities. This has shaped all aspects of our life, including big data, cloud computing and artificial intelligence. Integration of physical assets, including machines, and digital systems can provide accurate insights, enable businesses to respond to challenges in real time, and makes them more efficient (Aramco, 2022). A real impact of digitalization, however, requires full integration across all aspects of an organization. Nevertheless, full digital transformation of the oil and gas industry will revolutionize the way energy is supplied to the world. It will further enhanced the operational efficiency and safety at workplace, while minimizing the environmental footprint of the company (Aramco, 2022). However, on the other hand it is increasing the complexities of cyberthreat landscape (Radler, 2011). Therefore, this study aims to conduct a systematic literature review (SLR) to chronologically trace the history of digital transformation, cybersecurity and the ever-present human factor in the oil and gas sector. It further elaborates the current state of digital advancements, cybersecurity and human involvement; and identifies the best practices that can be employed and explore the opportunities for future work.

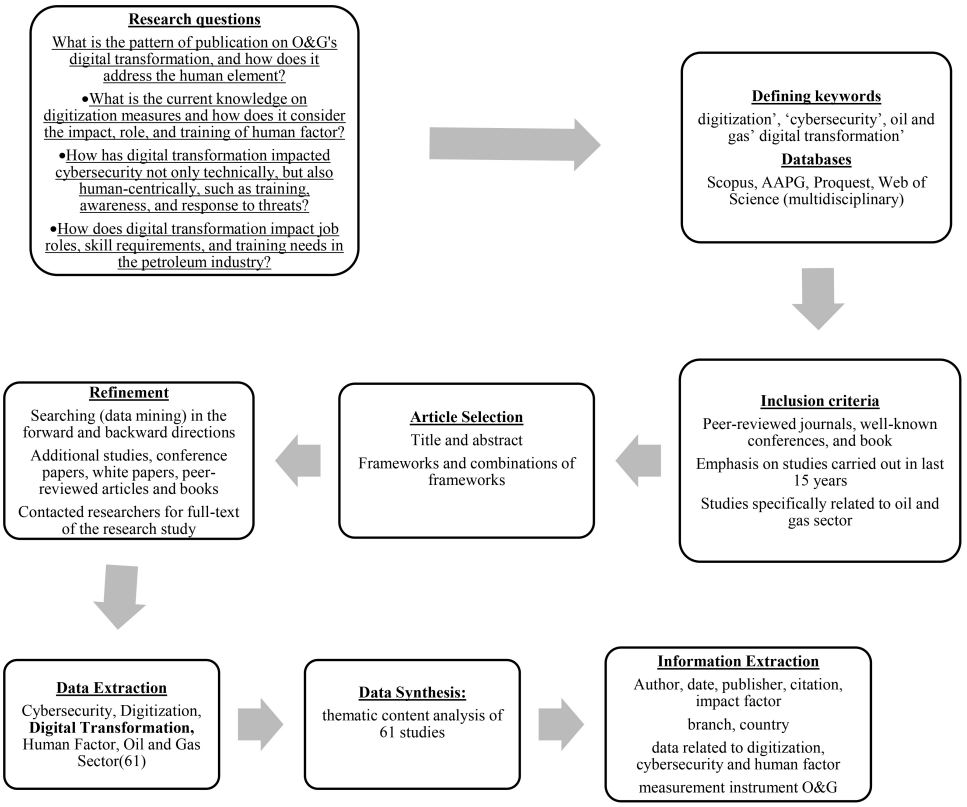


Figure 1: Systematic review process.

METHODOLOGY

This study aims to conduct a systematic literature review (SLR) guided by the research of various scholars (Webster and Watson, 2002); Brereton et al., (2006); Kitchenham (2004); White and Schmid (2005); (Petticrew and Roberts, 2006); Mullen and Ramirez (2006); Moher et al., (2008); Rousseau et al., (2008); Okoli and Schabram (2010); Pickering and Byrne (2013); Siddaway (2013); Frank and Hatak (2014); Boell and Cecez-Kecmanovic (2015); Okoli (2015); Cooper et al., (2018); Fink, 2019; Al-Tabbaa et al., 2019). The detailed process along with investigated research questions has been shown in Figure 1. The scope of the shortlisted studies is oil and gas sector. SLR methodology allowed to assess and map the literature in a systematic manner and helped in the synthesizing the findings qualitatively (Snyder, 2019). This study adopted the qualitative analysis (thematic literature analysis) (Cronin et al., 2008). Meta-analysis was extremely challenging due to the variety of methodological designs used in selected studies.

OIL AND GAS INDUSTRY DIGITAL TRANSFORMATION

As an industrial system, petrochemicals have become the largest industry of the modern age over the past several decades, and it has played a vital role in the economic development of the world, improving the lives of people. The size of the global economy has increased dramatically in recent years due to the growth of the petrochemical industry and the evolution of industrial pattern (Kadambur & Kotecha, 2015). Regions like North America, Asia Pacific and Middle East has played a significant role in this development. Almost every day, the structure of the product is reforming and there is production of more and more highly performed, and high-valued specific chemicals (Li et al., 2015). The technological revolution has accelerated the growth of petrochemical industries and it will benefit the industry in a rapid manner (Khosravi et al., 2015) (Ramteke & Srinivasan, 2011). The effects of combination of operation technology, information technology and manufacturing technology on production, operations, and distribution are profound and influences how petrochemical companies produce (Sa'idia et al., 2014).

The concept of Industry 4.0 was launched at the Hannover Messe in Germany in April 2013, following the steam engine era (Industry 1.0), the electrification era (Industry 2.0), and the information era (Industry 3.0) (Yin et al., 2018). The main goal of Industry 4.0 is to promote industrial change through information technology, also known as the intelligent era (Ahamed & Vignesh, 2022). Oil and gas industry is living in the dawn of a technological revolution, and the next decade promises to be a golden period for technology in the sector (Lahti et al., 2018). The technology in the petroleum sector has rapidly developed in the world, and every decade has experienced earth-shaking transformation (Yang et al., 2016).

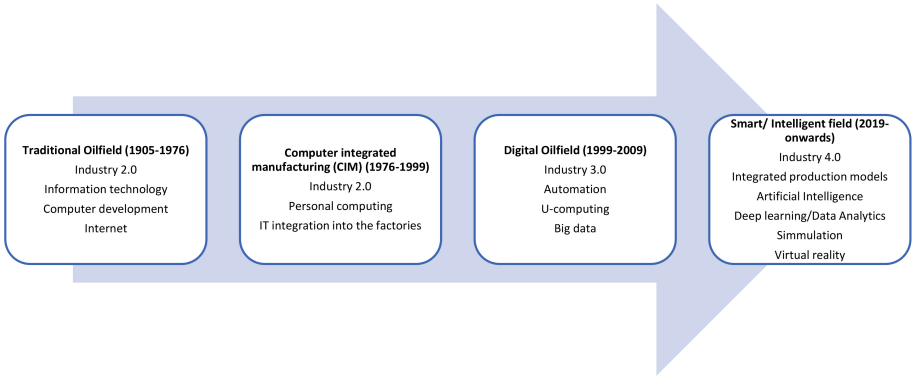
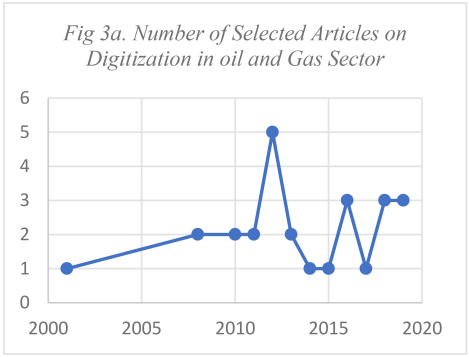


Figure 2: Development of smart oilfield model collated from (Korovin & Tkachenko, 2016) (Yin et al., 2018).

THE STATE OF 'DIGITIZATION' RESEARCH

To evaluate the current state of digitization research, metadata was extracted, that is, title, year, publication type, affiliation, journal's impact factor, and number of references and citations. The selected papers were categorized into three groups: concept paper, (theoretical and simulation-based articles); case study paper; and review paper (Fig. 3b).



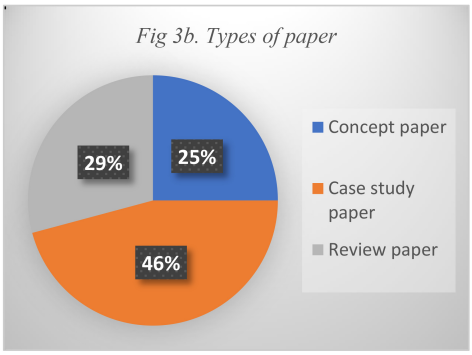


Figure 3: a) Number of selected articles on digitization in oil and gas sector, b) Types of paper.

This study identifies various theoretical frameworks chronologically, that were developed during the digital transformation of the petroleum industry. Figure 3a illustrates the publication pattern over the past years. The digital transformation publication started gaining prominence during 2000 experiencing peak in 2012. This is due to the fact that at that time various cyber risk management models were born.

DISCUSSION

With the emergence of information technology and computing, oil and gas sector started integrating these technologies in its production and supply chain process. Sophisticated technology is involved in the production and

distribution process at different levels, that is, upstream, midstream, and downstream. Upstream plays a vital role in the petroleum industry. The aim of all the strategies studied and implemented is to further enhance the production process. Most are designed at improving the drilling process (upstream). This section discusses the outcomes of the review and qualitative analysis of shortlisted that highlighted some interesting developments discussed below:

Oil and Gas Development Model

Due to the COVID-19 pandemic and rising volatility in the market, the O&G industry has seen a recent downturn. In addition, a long-term decline in demand and consumption for the industry is expected to be seen due to the push for carbon taxes, cleaner, greener, and more sustainable energy, globally (Fonseca & Azevedo, 2020) (Benayoune, 2021). In order to make the O&G industry more competitive, it is important to determine the challenges of integrating state of the art technology in the conventional O&G sector and researching more efficient ways to make the sector competitive (Benayoune, 2021).

The Industrial Revolution 4.0 is based on the integration of industrialization and information technology. Figure 1(a) shows the Industry 4.0 strategic framework (Hankel & Rexroth, 2015), which consists of four major themes, including, smart factories, smart production, smart services and smart logistics (Kagermann et al., 2013).

Prior to the development of the digital age, oil and gas exploration was carried out by manual labor, based on geological surveys, and primitive drilling methods. In the United States, for example, horizontal drilling and fracking technology have led to significant industry growth. Throughout the U.S., oil and gas exploration and development were primarily driven by human expertise and decision-making (Hsu et al., 2017). The brief history of the evolution of smart factory has been given below:

Early Digitization- Computer Integrated Manufacturing (1970s-1980s)

Petroleum sector was revolutionized by computerization during the 1970s and 1980s. The introduction of Computer Integrated Manufacturing (CIM) was the first wave of technological integration into factories that revolutionised operations humans (Wu et al., 2001). However, this technological shift was not seamless. On the one hand, it posed challenges for the workforce to adapt to technology through training and development. While on the other hand, it instilled the fear of job loss in the employees (Zuehlke, 2010).

Rise of Smart Technologies-Smart Wells (1990s-2000s)

In the 1990s and 2000s, smart technologies emerged, including Smart Wells and Integrated Operations. The decade witnessed the rise of the discussion revolving around "smart factory" both in academic and business spheres (Lucke et al., 2008; Radziwon et al., 2014). Different terminologies have been introduced to elaborate the notion of smart factory. For example, Ubiquitous Factory (U-factory) proposed by Yoon et al. (2011) and Factory of Things (FoT) by Zkule (2011) attempts to explain the same concept of smart

factories. Moreover, the Smart Process Manufacturing is also related to smart factory. (Li et al., 2015). In mid 2000s, intelligent digital oilfields (IDF) were introduced. The purpose of IDF was to create a platform where collaboratively informed decisions can be made using real time data integrated with the asset models. It uses AI (neural networks, data mining tool and proxy models) (Vanish et al., 2013).

As a result of these advances, the human operator has been transformed from an executor into a supervisor. It has become necessary to train and upskill continuously. This further resulted in human-centric challenges, such as resistance to change, distrust in automation, and concerns about job security (Ang & Utomo, 2017; Rob et al., 2016).

Era of Connectivity and Collaboration-Industry 4.0 (2010s)

The recent era has witnessed the rise of fourth generation of computing. A number of innovative technologies have affected the workforce in the 2010s, including Industry 4.0, and blockchain. This has blurred the lines between oil and gas operations and IT, making interdisciplinary collaboration increasingly important. Recently, the concept of "exponential organization" has come to light that elaborates the process of making and managing the smart organizations in the future (Ismail, 2019). Currently, humans play a central role in the interpretation of data, making decisions, and formulating strategies. However, this has led to the rise of new challenges such as cybersecurity awareness, psychological effects of remote operations, and the necessity of continuous training (J. Crandal, n.d.).

Digitization, Cybersecurity and Human Factor in the Oil and Gas Supply Chain

The digitization process has been mainly directed at upstream section of the oil and gas industry i.e., exploration and production. Though the first integration of technology, didn't turn out as expected and made the production process costlier and more cumbersome (Zuehlke, 2010). Upstream has been majorly studied in the literature as upstream is the most significant part of oil and gas life cycle, while least importance has been paid to midstream.

The analysis indicates that managerial processes had been initially ignored. The focus was on integration of sophisticated technology, while ignoring the security and managerial aspect of the assets and organization. Therefore, creating a gap between adoption of technology, cybersecurity measures and training and awareness of workers (Imran et al., 2022). Moreover, companies adopted defensive mechanism to cyberattacks rather than having preventive strategies to address the vulnerabilities leading to cybercrimes. Recently cybersecurity measures and human development has become integral part of the digitization programs, however, a lot needs to be done (Lu et al., 2019) (Imran et al., 2021).

The shift from technology happened with the introduction of lean production which focused more on organization rather than technology. It emphasized the need for network, dynamicity, self -collaborating teams, and personal responsibilities rather than hierarchies and monotonous assembly

lines (Womack et al., 2010). Later in the decade, security started gaining prominence beside digitization and human development with the advent of Factory-of-Things (FoT) (Zuehlke, 2010). FoT focused on four dimensions: technology, framework, security and human-integrating all four important aspects of digitization process. DOF, another important development intended to optimize the production by developing advanced analytic collaborative model, through which experts onshore can collaborate with offshore personnel using real time data (Reddick et al., 2008).

Throughout the oil and gas value chain, the production and operation personnel need to monitor various measurements for temperature, pressure, flowrates, vibration, power, etc. The Digital Oil Fields (DOF) enables the implementation of highly sophisticated technology to the sensors, data analytics, communication, collaboration and decision making, making the process more human centric (BP, 2019; Dashti et al., 2012; Carvajal et al., 2018b). Later, blockchain technologies directly focused on cybersecurity along with improving the production process (Cann, 2017).

This represents an important trend that most of the organizational models used to manage the changing technology and issues related to it have become redundant and there is a need to adopt and study the new management models created considering the human centric and cybersecurity challenges of integration of new technology in the production and management system (Imran et al., 2021). During the past decades, Industrie 4.0, block chain technology and agile management has tried to bridge this gap in the academia and industry. They emphasize on collaboration, teamwork, decision making and increased user involvement in each stage of production (Priyanka, 2016; Lu et al., 2019).

It was further found that the pace of digitization is more than the cybersecurity development. It is believed that in the future, due to exponential advancement in technology, cybersecurity would also incorporate artificial intelligence and machine learning to identify and analyze threats. The smart CS would be able to take counter measures to resolve the issues and recover the systems (Kim et al., 2018). On the other hand, these innovative technologies would also lead to development of cyber-attacks that could affect or disable the functioning of CS countermeasures. These malicious codes would have the ability to detect cyberspace environment, identify the vulnerabilities itself and conduct a cyber-attack (Kim et al., 2018).

Oil and gas organizations are a vulnerable target for hackers due to their enterprise structure, such as, the complex production process and operating systems, little overlap between information technology (IT) and operation technology (OT), firewall causing real time system delays, inconsistent network standards between departments, vendors' security systems that are not updated on time and historical legacy problems (Mittal et al., 2017). The intelligent sensors are considered to be the most vulnerable segment of the enterprise network. They can provide the real time information about the offshore oil field operations (Carvajal et al., 2018a). Blockchain technology can be potentially helpful in combating these cyberattacks. (Cann, 2017) (Koeppen et al., 2017). It can play an important role in revolutionizing four important aspects of petroleum sector, that is, supervision, trading, decision

making and management, and cybersecurity. It is an important technology especially with respect to big data (Kadir, 2017). Blockchain technology can be used to secure data, increase transaction transparency, and provide tracking services for goods or equipment in the petroleum sector (Kadir, 2017). Despite the many advantages of blockchain technology, the current operating system is yet to reach its full potential, and there are many risks associated with it (Surujnath, 2017) (Walch, 2015).

CONCLUSION

This paper is a systematic review of digitization, cybersecurity and human factor in the oil and gas sector in a chronological manner and aims to integrate the development of cybersecurity, management practices and industrialization centrally placing humans in the process. It is evident from the review that the petroleum sector started to integrate new technologies into its supply chain and production system with the emergence of industrialization. The focus was mostly on the introduction of sophisticated technology in the production system (that is, the upstream section), in order to reduce cost and increase productivity.

Initially the cyber-security and human aspects of oil and gas organization were relatively ignored. The primary emphasis was on introduction of latest technology and later the improvement in management systems, human factor and cybersecurity were emphasized. Consequently, the pace of digitization has been more than the advances in other aspects of digitization process creating a knowledge gap that needs to be studied further.

In the oil and gas sector due to transformation from manual to digital operations, the human factor has become increasingly important. In spite of the technological revolution, the role of humans (from laborers to decision-makers) remain central to the digitization and cybersecurity process. As the petroleum industry continues to advance and grow, in addition to addressing digitization and cybersecurity, human challenges remains crucial.

Different studies have been conducted in the past on individual aspects of digitization, cybersecurity and human involvement, however, they failed to study their interrelationship in the oil and gas projects. Cybersecurity has recently been incorporated as an essential component of digitization in the proposed models. Still, it is required to explore it further at project level (Imran et al., 2022).

In summary, the gaps in literature were identified and it was established that blockchain has excellent potential to be used in cybersecurity and management practices, however, it has its own challenges, opportunities, and risks. Blockchain technology is still in its experimental stage, and many people in the sector do not have enough understanding. Blockchain technology can help in reducing costs and enhanced accountability, however, the technical and regulatory issues surrounding the technology need to be addressed. Moreover, as the sector continues to evolve, it will be imperative to strike a balance between technological advancements and the human factor, so the human factor will not be lost in the relentless march of progress.

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