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DIGITAL TRANSFORMATION IN OIL AND GAS PRODUCTION SYSTEMS: OPPORTUNITIES, CHALLENGES, AND ADOPTION WITH BIG DATA ANALYTICS, ARTIFICIAL INTELLIGENCE, MACHINE LEARNING, AND INTELLIGENT FIELD TECHNOLOGIES

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ABSTRACT

Digital Transformation in Oil and Gas drives optimization of oil and gas operation to operate efficiently, lower cost of operations and maximize production and safe operations. The oil and Gas industry is embracing Digital Transformation with the advancement in digital technologies such as big data analytics, and artificial intelligence, machine learning and intelligent field technologies. The digital solutions help them to understand the reservoir better, optimize drilling and production operations, faster decisions, and more importantly safe operations. It is not an easy switch for companies to transform their traditional business operations to digital business operations due to various factors such as people, process, technology, data. In this paper, the authors discuss various challenges faced by the Oil and Gas companies and reviews Work System Framework elements while introducing new elements such as Design Thinking and Digital Factory that shall assist companies to successfully transform and operate digitally.

Keywords: Digital Transformation, Optimization, Design Thinking, Work Systems, big data analytics, artificial intelligence, machine learning, intelligent field technologies

1. INTRODUCTION

Oil and Gas industry is facing intense pressure to enhance operational efficiencies to meet evolving challenges such as low oil prices, maturing oil fields and environmental requirements. The focus is to maximize production with less carbon footprint. (1). Most of the production globally comes from giant fields. Production is continuously in decline, which requires optimization essential. Oil depletion depend on three key factors such as market prices, demand, and technology advancement. Operating companies focus to extend the producing life of the field using cost-effective technologies (Schlumberger, 2016). Globally 70% of the total oilfield resources in production today are mature fields. (International Energy Agency, 2017).

As there is decline in the new hydrocarbon discoveries, operators focus to produce more from the existing fields by maximizing recovery from mature fields while extending the operating envelope of aging. Mature fields significantly contribute to future reserves by effective recovery optimization. Upstream companies face challenges to maximize the return from brownfield. (Georgina, 2014). Companies focus to sustain production by applying various methods such as Stimulation, completing additional zones, deploying artificial lift equipment before making any decision to drill new wells while ensuring better reservoir management and production optimization strategy, and deploying production technologies.

Production Optimization ensures maximizing returns from the developed reserves. Production Optimization comprise to the various activities such as measuring, monitoring, analyzing, modelling, and implementing actions to enhance productivity of field.

Upstream Operators are increasingly moving towards digital technologies to augment their business process to better understand the reservoir, optimize drilling and production operations and faster decisions while ensuring safe operations. Operating companies estimate additional 125 billion barrels of oil is expected to be unlocked by shifting to digital oilfields (Tim Haidar, 2012). Reservoir and production optimization workflows and processes are increasingly being digitalized by integrating data, business process leveraging digital technologies such as AI/ML, analytics.

2. Digital Transformation in Oil and Gas

Digital transformation marks a fundamental shift from traditional business operations about the way an organization uses technology, people, and processes to enhance business performance. Digital Transformation drives the way an organization uses technology to establish new revenue streams or operations models to enable competitive advantage, business value and performance. With the evolving energy and field challenges, operators are moving their priorities from capital projects to focus on maximizing the value from the existing oil and gas assets (Mark Cullen, 2016). Digital technology is expected to add USD 1 trillion in value to energy companies in the next decade. (The World Economic Forum,2018). The need for operational efficiency together with advanced technologies represent drives disruption in the way energy companies are operating. The emergence of advanced technology trends such as analytics, robotics, intelligent control systems provide companies the opportunity to accelerate digitalization in a persistent manner. (PWC, 2016)

Digitalization in oil and gas industry is about creating value from data to drive business and financial performance. For the upstream industry, an improvement of 1% in production can drive huge financial results (Judy Feder, 2020)

Digital Oil Field promises improved field operations, reservoir recovery, increased production rates and safe operations. The technologies include intelligent sensors and devices, instrumentations & controls, monitoring equipment, smart software solutions, immersive visualization environment, and advance communication systems. Digital Oil Field (DOF) looks exciting but it’s a very complex environment to enable digital workflows involving data, people, process, technology, and organization. Digital projects if not managed properly is bound to fail without generating value despite spending millions of dollars. Each company either IOC or NOC has their own business objectives and there is no single digital solution that fits all with varied digital maturity. In the past DOF project implementations were implemented in a siloed manner targeting specific use case but it’s not emerging to be strategic in nature to operate in an integrated manner.

3. The Prize of Production Optimization

Shell estimates that implementation of digital oil field can increase the total amount of oil recovered from a field by 10% and gas by 5%, while boosting the rate of production. (Gaurav Dixit, 2018). Despite advancement in technology, only around 35% of the oil is recovered and only about 3% of data is used for operations. There is enormous scope for technology to transform the oil and gas industry, reduce capital expense, lowering operating costs, enhance production and recovery factors. By 2050, BP estimates that technology has the potential to reduce average lifecycle costs by around 30% per barrel across different oil and gas resources. (BP Technology Outlook, 2018)

By Optimizing production, a 100-well project, a major operator could generate an additional 1.4 million barrels per year, that has added more than $20 million to their annual cash flow. (Ian Jones, 2019). Barclays estimates that greater efficiencies will save oil producers $150 Billion annually by implementing digital solutions. (Stevens, 2020). ExxonMobil revealed that by partnering with Microsoft they could potentially add 50,000 oil-equivalent barrels of production per day in the Permian by 2025, generating “billions of dollars in value over the next decade.” (Staale Gjervik, 2019). According to McKinsey, Digital technologies not only has the potential to transform and create more business value from existing business operations but could reduce CAPEX by 20% and OPEX by 3-5% (McKinsey Report, 2018)

ConocoPhillips reported that they have increased their production by 30 percent in fields where they have deployed production optimization solutions. In a period of three years, and assuming the then net price of $40 per barrel, the additional barrels shall yield an additional $1 billion in their revenue. (McKinsey, 2016)

4. Digital Adoption Challenges

1. DOF project implementations are more tactical and siloed in nature rather than strategic.
2. Lack of collaboration among different business groups – Reservoir Engineers, Drilling, Production, Operations engineering
3. The oil and gas business is data-intensive, with the shift towards digital acceleration, companies must effectively deal with petabytes of data coming from the digitalized field.
4. Transforming traditional workforce to adopt new technology, solution to work smartly and efficiently.
5. Technology proliferates as more siloed project are implemented with in business units, and there is no collective technology portfolio management at organization level to ensure maximize the value generation of digital investments.
6. Technological, operational, and organizational constraints
7. Products and solutions from multiple vendors, ad hoc and point to point integration.
8. Aging workforce & knowledge management

It is observed that many digital transformations initiatives lag or fails to achieve the goal due to several reasons, such as lack of holistic digital strategy, poor leadership, lack of collaboration between IT and the business, lack of proper employee engagement and substandard operations, as per the analysis by Capgemini and MIT Sloan School of Management. The key reasons of a derailed digital transformation are obsession with big bang change, focus more on cost reduction as a business driver, and failure to engage the business. (Tyagarajan, 2018)

A survey of nearly 100 senior executives across the global Oil and Gas industry by Hexagon observed that internal transformation readiness issues relating to people, processes, data, and technology are by far the single largest barrier to digital transformation. (Graces, 2019)

Traditional operations and legacy technology infrastructure is a key risk to companies that can't transform themselves quickly when comparing to the companies that were "born digital," according to research conducted by North Carolina State University Initiative and management consulting firm Protiviti Inc (Mengqi, 2019).

5. Production Operations as a System

To effectively monitor, control and optimize the well and reservoir productivity its essential to understand the principle of fluid flow through production system. Typically, Oil and Gas production system is the system that delivers hydrocarbon fluids from the reservoir to the surface and the processing and treatment of the fluids, storage, and transfer to a purchaser. (PetroWiki, 2015 Society of Petroleum Engineers)

The key components of the production system include Reservoir, Wellbore, well completion, wellhead, flowlines, and surface processing units and artificial lift systems. A digital solution comprising of various components of the production system and the integration of those components generally leads to improved well productivity through analysis of the entire system. The Production system experiences a continuous pressure drop when the fluid flows from the reservoir into and through the production system, (Mach, J, 1979). A complete production systems approach from the sub-surface, wells to the process and pipeline network is vital to address the production optimization in an integrated manner. (Mark Cullen, 2016)

The operative control is implemented with the mentioned equipment and described as the "fast loop" in the diagram in Fig. 1 illustrating the smart field control. Reservoir Management along with the Production forms the heart of a company's field development and production deliverability strategy (Rossi, 2000)

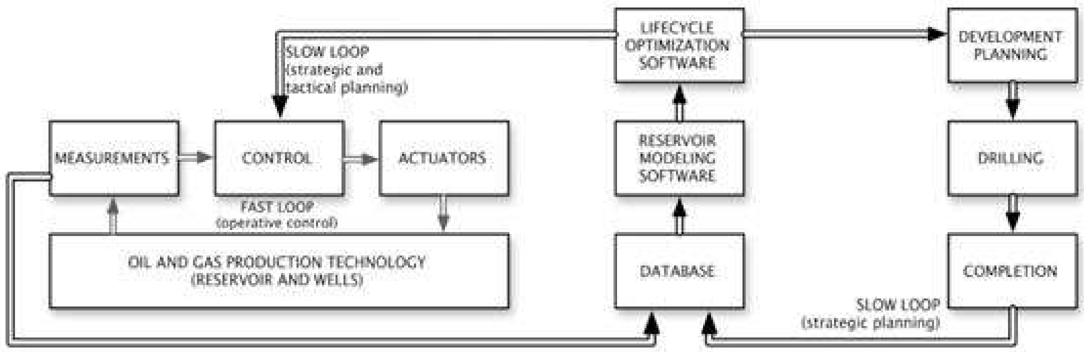

Figure 1 : Fast loop and slow loop of a smart solution, based on the ideas of Rossi et al.

Intelligent solutions are becoming prevalent in manufacturing and process industries, while it gradually getting adopted in the Energy and other industries. Modern philosophy of science explains the role of intelligence progresses with the evolution of the rationality concept. The rationality of the evolution model encompasses three steps: classical, nonclassical and post-nonclassical rationality (Stepin VS, 2015). The traditional concept refers to 16th–19th century science when research mainly focuses on the observations and experiments. The later emergence of nonclassical paradigm (late 19th century – mid-20th century) incorporates the idea of control and addresses the self-regulating objects and processes. The present post-nonclassical rationality (mid-20th century – present) focuses on formation of self-organizing systems that can select the required self-regulating modes, and through that accomplishing set goals. These self-organizing systems carries certain organizational hierarchies, i.e., the components are positioned into sub-systems which organize their activities to perform according to the existing system priorities and its life-long philosophy. Human contribution is essential in the overall systems organization, and integrated information systems are employed for interfacing human and machines together to operate the system to achieve sustainability. To maximize the value from existing producing assets, Chevron and Marathon follows a complete system approach to achieve their production optimization goals leveraging digital technologies. (Mark Cullen, 2016).

A system that comprises of network configuration and associate flow in a production value chain can be fundamentally associated to computer driven decision making. The term “cyber-physical systems” is frequently used in the perspective of production processes, especially in the assembly lines in manufacturing industry. The terminology covers the solution for computation and communication and its integration into the physical processes, aiding to the range of the process capabilities (Lee EA, 2008). Furthermore, the terminology “Industry 4.0” and “Industrial Internet of Things” are used to describe intelligent solutions that can smartly operate with minimal human interaction or autonomously (Porter ME, 2014), integrated into production processes.

6. Framework for Systems Optimization

For the literature search, the author has searched most representative key word search, search criteria and classification schemes on studies related to digital transformation and systems framework. The author did not restrict to the study within Oil and Gas domain, which is typically a slow adopter of digital technologies, but investigated evolving digital transformation from other industries shall contribute to effectively define the digital transformation framework for Oil and Gas. Work System Framework provides a holistic framework and elements for system development and implementations. The authors reviewed the current challenges and evolving digital capabilities and opportunities and proposes additional new elements to enhance the Work System Framework as the reference for Oil and Gas digital transformation.

6.1 Work System Framework

Alter in 2003 originally proposed the work system theory to study the impact of Information systems implementation in organizations. Typically, during those periods, the effort was to transform the business process from manual to computerization. The current and future business driver for companies is to move towards digitalization of the whole system. Work system theory proposes three key steps to effectively implement and operate systems (1) Define work system (2) Propose a framework of potential variables that shall influence the transformation (3) Work Cycle.

A key component of work system theory during implementation is the existence of "Feedback loops" for continuous assessment and improvement in achieving the objectives. The feedback is taken continuously to ensure the initiation, system implementation and functionalities are as per the business needs considering any change due to internal or external factors. If the project milestones are not realistic with the ever-changing environment, the project plan is revised to achieve realistic milestone. The work system framework forms a key framework for years to come to help business professionals to effectively implement IT solutions, realize business value and its sustenance.

The work system framework identifies nine key elements as depicted in figure-2. They are strategies, processes and activities, participants, information, and technologies, products and services, customers, environment and infrastructure. Work theory consists of three components: the definition of work system, the work system framework (WSF) and the work system life cycle model (WSLC).

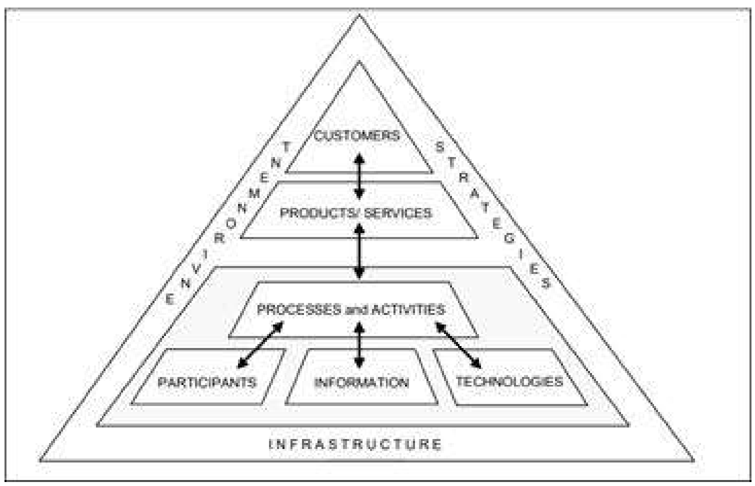

Figure 2: Work System Framework (Alter, 2013)

Gaps in work system framework

- The enablers affecting stages of digital transformation not mentioned.
- Integrated approach to multiple work system not mentioned.
- The process of prototyping new technology and screening not mentioned.

7. Proposed Digital Transformation Framework Components

The proposed digital transformation framework enhances the Work System Theory by considering the evolving technology and business requirements to incorporate other elements that is essential for digital transformation. Below are key elements that need to be fully incorporated for the effectiveness of the framework.

Business Digital Strategies focuses on using technology to improve production business performance, whether that means creating new workflows and solutions, transform current processes. It specifies the direction an organization will take to create new competitive advantages with technology, as well as the tactics it will use to achieve these changes.

Processes and Activities

Information Management focuses on the how an organization manages and controls the information it produces in the oil field. It deals with how information is organized, integrated, accessed, and presented for executing production operations process efficiently. Full data transparency is becoming a reality, while ensuring information is delivered to the relevant business process and people.

Digital Infrastructure

Digital infrastructure is the foundation to deploy advanced digital technologies that brings together interconnect physical and virtual technologies. The next generation digital infrastructure comprises of cloud environment, high performance computing, network, storage, and associated applications and services. Oil and Gas product companies are moving their solutions to the cloud environment that bring more processing power, advance analytics, and run AI/ML models. Hence, organizations need to review their current infrastructure and establish a futuristic digital infrastructure depending on their business vision. Below are additional elements proposed.

Next Generation Technologies

Fourth Industrial Revolution (IR 4.0) drives the digitization of various business segments, driven by disruptive technologies including the rise of data and connectivity, analytics, AI/ML, human-machine interaction, and improvements in smart devices. IR 4.0 accelerates companies to adopt digital technologies and transform their operations to be digital to enhance their operations and efficiency. In the oil industry, IR 4.0 enables capabilities such as AI-assisted sub-surface interpretation, advanced drilling operations, integrated asset optimization, autonomous well control, inspection of pipelines, enhance HSE.

Integrated Planning

An integrated digital strategy is one of the essential pillars for successful digital transformation of an organization. Digital Strategy encompasses a holistic approach in implementing and rolling out various digital initiatives across the organization. This helps to identify right technologies to support different initiatives in an integrated manner as well as streamline the budget and bring economy of scale.

Performance Measurement

Performance Measurement focus on measuring key indicators that positively ensure the digitalization is being carried out in most effective manner and is being executed in a right direction towards its success. This includes the way data is managed, how the digital program is executed as per the project timelines and deliverables. The framework should have component to measure the performance of digital transformation.

Partners

Partner ecosystem is one of the key components of digital transformation. Successful digital transformation is enabled by high level of collaboration with partners who are providing digital products, services and consultancy in the production and operation domain. Production operations domain compose of multivendor environment. This could be digital equipment such as edge devices, telemetry, intelligent instrumentations, AI tools and products etc. No single partner shall be providing all these capabilities. Strategic partners shall work together to identify solutions to challenging problems.

Open Architecture

Open Architecture is a technology infrastructure with specifications made public by the designers. This enables multiple parties to seamlessly integrate and deliver solutions in a standardized manner. It provides the owners a competitive advantage and options to leverage solutions from a wide variety of providers and assures future scalability and flexibility.

Design Thinking and Agile Methodology

Design Theory emphasis on the importance of Design and case studies to drive innovation and deliver innovative solutions within an organization. This also enables effect role out of solution in an agile manner where a Minimal Viable Product (MVP) is designed and developed with full involvement of the business and rolled out in a fast pace to realize business advantage. This is transformational from the old practice of water fall model where the product is made available to the end users after a long period between requirements gathering and product delivery.

Digital Factory

Digital Factory (DF) as a concept represents a virtual model of a real production line. Digital Factory environment is integrated by data, digital technologies and people, in which the real-world conditions is represented by digital computer models. Such digital solutions enable to effectively monitor, control and verify all conflict situations before actual implementation of factories and to design optimized solutions (Furmann, R., 2007). In the manufacturing domain, Digital Factory is applicable mainly as a support the planning, simulation, and optimization of batch manufacturing of highly sophisticated products. Mostly Digital Factory concept is applied in automobile industry, mechanical engineering industry, aerospace, ship building industry as well as electronics and consumer goods industries (Bohusova, B., 2009). Digital Factory enables the virtual environment for manufacturing processes lifecycle design and manufacturing systems using simulation and virtual reality technologies to optimize performance and productivity while reducing cost and time(Gregor, M. & Medvecky, S., 2010).

Benefit Realization

The ultimate success of digital transformation is what value it has brought to the business in terms of cost, performance, efficiency, and people development. This could be the measure of how much extra barrels of oil and gas produced by implementing digital solutions or by measuring the reduction in cycle time of executing production workflows which enables companies in producing more and avoiding downtime or HSE issues.

8. CONCLUSION

Work System Framework provides a holistic framework and elements for system development and implementations. The authors reviewed the current challenges and evolving digital capabilities and opportunities and proposes additional new elements to enhance the Work System Framework as the reference for Oil and Gas digital transformation covering open architecture, design thinking, digital factory model and other key elements discussed in this paper.

9. GAPS AND LIMITATION OF THE CURRENT RESEARCH

The current research present focus on the holistic framework of the digital operations in the production optimization specific to upstream oil and gas. The purpose of the study it to provide a reference framework to assist implementation of digital production optimization strategy. The study does not go deeper understanding of each of the framework component and the method of implementation of each of the framework components, which would provide a reference for effective adoption of the proposed framework.

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