Chapter 07

Advanced Materials, Artificial Intelligence, and Sustainable Technologies for Energy and Environmental Engineering
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Technological Integration in Oil and Gas Industry Supply Chain Management

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ABSTRACT

The oil and gas industry exists at 3 main sectors (upstream, midstream, downstream), each of which includes a set of different processes. The management of these processes is related to different areas. One of these areas is supply chain management, namely transportation. Supply chain management assumes the responsibility of managing many complex processes, from the acquisition of oil and gas products as raw materials to their delivery to consumers. However, the management of these processes gives rise to some issues, the solutions of which require the integration of modern technologies. Some of these technologies are IoT, Blockchain, Big Data Analytics, Artificial Intelligence, which are also mentioned in the article. The article examines Supply Chain Management issues in the Oil and Gas industry, the integration of the listed technologies for improving this sector, and their benefits.

Keyword: Oil and Gas; Supply Chain; Management; Logistics.

INTRODUCTION

Oil and gas, as a raw material, unites many industries around itself. One of them is the supply chain and, accordingly, logistics. These two industries are responsible for many processes, from the acquisition of oil and gas as a raw material to its delivery to the end user. Supply chain and logistics are concepts that are often used together, but they are not the same. However, it is possible to consider logistics as part of the supply chain.

Yildiz(1) gave the following definitions regarding supply chain and logistics in his article: “The definition of logistics is the planning, implementation and control of the efficient flow of goods, services and related information from the point of origin to the point of consumption in order to meet the needs of customers. Supply Chain covers the entire supply chain from raw materials to finished products. Its management is a control process and involves the integration of activities between different organizations to maximize the flow of goods, information and services from suppliers to customers. It includes tasks such as supply ordering, production planning, inventory tracking, distribution channel management, etc.”

Supply chain models are divided into different purposes. In general, the most well-known supply chain models are as follows:

- Continuous flow model: a traditional model that has the property of stability.

- Agile model: the adaptation of the supply chain to changing market demands in the shortest possible time. Which is further accelerated by adaptive artificial intelligence models in the modern era.
- Fast supply chain model: one of the modern models applied by enterprises with products with short life cycles.
- Efficient Supply Chain Model: a model that has the property of maximizing efficiency.
- Custom-configured model: a model designed for a personalized approach.

Professionals should base their choices on the nature of the industry, customer requirements, and overall business goals.[2]

PAL[3] outlined the main parts of this model as follows: the most basic model of supply chain management is the ITO model, which includes input-transformation-output components. The simple structure of the ITO model[4] is as follows:

INPUTS (things, people) TRANSFORMATION (manufacturing, service) OUTPUTS (goods, services)

Additionally, it also includes resources, which include employees, equipment, facilities, systems, suppliers, etc. Another supply chain management model is the SCOR model.

The Supply Chain Operations Reference (SCOR) model is a powerful tool for assessing and comparing supply chain operations and performance. SCOR provides a unique framework that integrates business processes, metrics, best practices, and technology into a single structure to support communication among supply chain partners and improve the effectiveness of supply chain management and related supply chain improvement activities.[5]

The main processes of the SCOR model are: Planning, Source, Make, Deliver and Return. These were the 5 main processes of the previous versions, and in the new versions a new process has been added. The Enable process.

This process is a supporting tool, reflecting the increasing importance of activities that ensure the effective functioning of the main processes such as quality management, sales operations planning and supply chain risk management.[6]

The GSCF (Global Supply Chain Forum) model, like SCOR, focuses on the processes that connect the supply chain and the description of the physical flow of goods between supply chain members.[7] It is implemented through three main elements, the supply chain network structure, supply chain business processes, and management components.[8] There are eight relevant processes in the GSCF model: Customer Service Management, Demand Management, Order Fulfillment, Production Flow Management, Supplier Relationship Management, Product Development Management, and Returns Management. Logistics also plays an important role in the supply chain processes in the GSCF model.[9]

The concept of incorporating environmental sustainability procedures into a conventional production network is called “green supply chain management (GSCM).”[10] The process of Green Supply Chain Management ensures the integration of environmentally sustainable procedures into all stages, from the acquisition of raw materials to their delivery to the end user.

One of the key elements of GSCM is a circular supply chain that minimizes waste by creating closed systems where products and materials are reused, recycled, or remanufactured.[11,12]

Modern supply chain management is forcing businesses to change their models and strategies in this direction by integrating factors such as reducing costs and increasing customer satisfaction.

Logistics involves the coordination and transportation of goods from the production area to the delivery point, including the warehouse area. Its main goal is to optimize costs, space, and time to ensure the efficient distribution of goods and services.[13]

Supply chain management also includes logistics and is applied in various fields. One of these is the oil and gas industry.

Logistics and Supply Chain Management in the Oil and Gas Industry

The oil and gas industry is of great importance in the global context. It plays an important role in the world market, being used in small and large industries such as transportation, heat and electricity generation. The oil and gas industry is usually divided into three main sectors: upstream, midstream and downstream.[14,15]

- Upstream sector: this sector involves the search for potential underground or underwater crude oil and natural gas deposits, the drilling of exploratory wells, and the drilling and operation of wells that subsequently produce and bring the crude oil or crude natural gas to the surface. The upstream industry is sometimes known as the exploration and production (E&P) sector.
- Midstream sector: it processes, stores, markets, and transports commodities such as crude oil, natural gas, natural gas liquids, and sulfur. The midstream provides a vital link between remote oil production areas and population centers where most consumers are located.
- Downstream sector: this includes refineries, petrochemical plants, petroleum product distributors, retail outlets, and natural gas distribution companies.

The supply chain is interconnected with all three sector. Blueoceanacademy[16] on its website states the role of supply chain in the oil and gas industry as follows: “Each stage of the oil and gas chain is interconnected with the next. This means that there are several chain links that need to be analyzed and properly understood. These may include transportation, sales, materials management, technology, processing and other processes. In addition, there are supply chain management systems and tools that are used. Supply chain management in the oil and gas sector must be strictly adhered to from the planning stage to the execution stage. Companies should have a dedicated staff to act as consultants for the entire supply chain management in the oil and gas sector. These consultants should liaise with refinery managers and supervisors and operating engineers. These consultants aim to understand the entire operation of oil refineries and pipelines, propose and implement new technology to improve efficiency, and develop new strategies to increase production capacity.”

Thus, as mentioned, the sequence of processes consisting of several chain blocks maintains the competitiveness of the oil and gas industry even in the era of increasing renewable energy. Although the transition to renewable energy is currently being more widely accepted by various countries, the demand for the oil industry continues and will continue in the near future. In fact, the Global Oil and Gas Industry Market is predicted to reach 8,79 Trillion US Dollars in 2034.[17]

The potential scope of supply chain management in this industry includes the following:[18]

- Strategic supplier relationships.

- Customer relationships.
- Green purchasing and production management.
- Information sharing.
- Internal environmental management.
- Distribution and logistics.

Lisitsa et al.[19] in their article "Supply-chain management in the oil industry" identified the following as the main factors for reducing costs and increasing company profits in supply chain management:

- Demand management.
- Efficient distribution of petroleum products among customers.
- Better transportation scheduling.
- Warehouse management.
- Quality and timeliness of data.

And it accepted all of these as parts of a unified process.

Technological Approaches in Supply Chain Management

A number of innovative approaches have been adopted to improve supply chain management in the oil and gas industry. Recent developments in the oil and gas industry include the increasing demand for better and faster customer saervice, the globalization of the oil and gas business, and the availability of information technology to facilitate information exchange.[20]

Overall, supply chain management in this industry is being improved by the integration of a number of technologies and is driven by digitalization. Technological advancements such as the Internet of Things (IoT), blockchain, big data analytics (predictive analytics), and artificial intelligence (AI) have revolutionized SCM in the oil and gas industry.[21,22]

Internet of Things in Supply Chain Management

IoT is being applied in the oil and gas industry for various purposes: Asset Management, Supply Chain Management, Monitoring and Control, Predictive Maintenance

Supply Chain Management and Logistics Optimization: IoT can optimize supply chain management and logistics by tracking shipments in real time and automating commercial documents and payments. The oil and gas industry can benefit greatly from using IoT in supply and inventory management, including higher efficiency, reduced costs, improved security, and increased sustainability.[23]

The increasing complexity of logistics and supply chains in the oil and gas industry highlights the need for improved operational visibility and efficiency, which is fueling growth in this sector. Monitoring and control, with a market value of this sector expected to grow to US$12,5 billion by 2032, also plays a crucial role by enabling real-time monitoring of operations, quickly eliminating inefficiencies, and ensuring compliance with industry safety regulations.[24]

Blockchain in supply chain management

Blockchain is a chain of interconnected blocks that continuously grow by storing transactions in blocks.[25] Blockchain technology generally has the key features of decentralization, consistency, anonymity, and auditability. With these features, blockchain can significantly save costs and increase efficiency.[26] There are two types: permissioned and permissionless blockchains.

A good example of the permissionless classification is public blockchains. In a public blockchain, any user can enter or exit the chain at any time. Permissioned blockchains themselves are divided into two main groups: private blockchains and consortium blockchains.[27]

Some of the applications of blockchain in oil and gas are:[28]

- Optimizing Control of Physical Assets.
- Improving Transactions with Smart Contracts.
- Improved Land Registry Management.
- Improved Data Storage.
- Seamless Supply Chain Management.
- Transparency and Accountability in Transactions.

Most of the systems designed to control and manage trade in the oil industry are centralized, unreliable, and highly opaque.[29] Blockchain acts as a key tool in solving these problems. One of the main problems of blockchain is the financial issue. Because blockchain technology is a new technology for supply chain management and requires high investment.[30]

The supply chain segment is expected to grow at a CAGR of 40,8 % from 2025 to 2034 due to greater transparency and improved operational efficiency in oil and gas transportation. Blockchain technology enables end-to-end tracking and anti-fraud records, eliminating fraud and errors in the supply chain.[31]

Blockchain and smart contracts, combined with IoT devices, can transform the traditional supply chain for oil and gas with the advantages of transparency and immutability. Blockchain takes the supply chain of oil and gas companies to the next level by providing a secure system for recording data and implementing and executing smart contracts. With the power of smart contracts and IoT devices, the oil supply chain can have the ability to source and secure.[32]

Big Data Analytics in Supply Chain Management

Large data sets that are unmanaged, unmaintainable, and unusable for analysis using typical database systems are often described as "big data."[33] This type of data can be found in various sectors and, if properly managed, can be highly beneficial. Many processes such as statistical analysis, forecasting, and strategy development rely on well-managed large data sets. Big data analytics is the process of analyzing large data sets to uncover unknown relationships and associations, market trends, and valuable insights.[34] It has types such as Prescriptive Analytics, Predictive Analytics, Diagnostic Analytics, Descriptive Analytics.[35]

One of the areas where big data analytics is used is the oil and gas industry. Big data analytics helps to regulate key oil and gas operations such as exploration, drilling, production, and supply across three sectors – upstream, midstream, and downstream.[36]

The emergence of big data allows for the consideration of complex factors in supply chain design, thus enabling the development of a robust supply chain network.[37,38]

The successful use of big data analytics in the oil and gas supply chain requires a strategic approach to address these challenges, enabling organizations to develop the dynamic capabilities needed to thrive in a volatile and complex industry. Big data analytics has the potential to transform supply chain management in the oil and gas industry by delivering real-time insights, improving demand forecasting, and improving decision-making.[39,40]

Artificial Intelligence in Supply Chain Management

Since the 1970s, artificial intelligence has been theoretically studied in the oil and gas industry. This includes widespread artificial intelligence methods such as fuzzy logic, artificial neural networks and evolutionary algorithms, etc. It is applied to solve many problems in each sector of the oil and gas industry - upstream (exploration and production), midstream (transportation and storage) and downstream (oil refining and sales). Artificial intelligence already today allows you to increase the efficiency of field exploitation: parameters such as well flow, waterlogging, and bottomhole pressure are analyzed, and optimal operating methods are selected to increase production and reduce costs.[41]

Currently, the application of Artificial Intelligence in the oil and gas industry is developing rapidly, as the concept of artificial intelligence is gradually integrated into various stages of the industry, such as smart drilling, smart production, smart pipeline, intelligent processing, etc. Areas such as digitalization, automation, forecasting, security, intelligence, supply chain management can be examples of the application of Artificial Intelligence in the oil and gas industry.[42]

From the point of view of Artificial Intelligence, the exploration of oil and gas resources is a set of operations that result in the creation of a 3D geological model of an oil/gas field or reservoir.[15,43]

AI in supply chain management is being applied to solve many issues such as improved efficiency, cost reduction, and improved customer satisfaction. In the oil and gas sector, AI optimizes supply chain processes by forecasting demand, managing inventory, and improving logistics operations. AI-based solutions analyze historical data, weather conditions, and market trends to predict supply chain disruptions and adjust logistics accordingly. This improves resource allocation, reduces delivery delays, and ensures more efficient supply chain flow.

In general, the impact of artificial intelligence in the oil and gas industry can manifest itself in several ways. These are:

- Improve Safety.
- Optimize Supply Chain.
- Increase Operational Efficiency.
- Minimize Environmental Impact.
- Reduce Carbon Footprint.

Along the supply chain, it can support sustainability by improving the efficiency of resource extraction, refining, transportation, and energy use. Artificial intelligence (AI) can uncover overlooked energy-saving opportunities by examining operational variables and historical data. Furthermore, by simplifying transportation routes and schedules, AI can reduce fuel consumption in logistics and greenhouse gas emissions associated with the transportation of goods, gas, and oil.[44,45,46,47,48]

CONCLUSIONS

The process of supply chain management in the oil and gas industry is further improved by integrating modern technologies and approaches. These technologies and approaches include the Internet of Things, Big Data Analytics, Blockchain, Artificial Intelligence. Integration in the oil and gas industry allows the supply chain to improve in the following areas:

- Within the framework of the Internet of Things, higher efficiency, reduced costs, improved security, and high sustainability are achieved.

- End-to-end traceability and anti-fraud records are achieved within the blockchain framework, eliminating fraud and errors in the supply chain.
- Big data analytics enables real-time insights, demand forecasting, and improved decision-making.
- Within the framework of Artificial Intelligence, it is possible to support sustainability by increasing the efficiency of resource extraction, purification, transportation and energy use, enable energy savings, simplify transport routes and schedules, and reduce fuel consumption in logistics and greenhouse gas emissions associated with the transportation of goods, gas and oil.

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