Supply chain digitalization as a strategy for the implementation of industry 4.0 in the Algerian oil sector

La digitalisation de la chaine d'approvisionnement comme stratégie d'implémentation de l'industrie 4.0 dans le secteur pétrolier algérien

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Abstract:

This paper is intended to explore the complexity in managing the supply chain in the Algerian oil sector and to seek articulation of technologies that respond to current needs. It aims to illustrate the current trends and needs in industry 4.0 technologies, which serve as the basis for developing different activities related to the supply chain in Algerian companies.

Keywords: *supply chain; industry 4.0; advanced technology; oil sector.*
Jel Classification Codes: L86 ; M11; O33

Résumé:

Cet article explore la complexité de la gestion de la chaîne d'approvisionnement dans le secteur pétrolier algérien et en cherche l'articulation des technologies qui répondent aux besoins actuels. Il vise à illustrer les tendances actuelles en technologies de l'industrie 4.0, qui servent de base au développement des différentes activités liées à la chaine d'approvisionnement dans les entreprises algériennes.

Mots clés: *chaine d'approvisionnement ; industrie 4.0; technologies ; secteur pétrolier.*

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1. INTRODUCTION

Recently, manufacturing and service industries have undergone major changes, leading to a new manufacturing concept: Industry 4, transforming traditional manufacturing systems into advanced manufacturing and service systems. The use and the evolution of emerging technologies in Industry 4.0 have also led to profound changes in the industrial and social landscapes respectively (Barreto et al., 2017). Technologies like the internet of things (IoT), big data, cloud computing, artificial intelligence, among others, have changed how plans and executions are carried out and the interaction between process actors.

Companies in developed countries incorporate the technological advances of the fourth industrial revolution by implementing programs that support the Industry 4.0 applications, which generates the best supply chain practices. In the oil industry and the provision of supply chain processes, it is clear that these changes present a series of challenges that require the optimization of the value chain. The management of the supply chain and logistics play a crucial role in developing oil companies, as they ensure the availability of products and services (Gligor and Holcomb, 2012). Their management is not an easy task to complete since many internal and external factors affect their process.

The growth of the Algerian Oil Production Industry is considered important in the economic sectors. In recent years, it provides almost 22% of the Manufacturing Gross domestic product (GDP) forms double with Industry 4.0 technologies creating a solid sector that augurs an important economic positioning of Africa. As the world's digitization applications continue to evolve and grow, as does the oil sector's importance to the Algerian economy, it is essential to carry out an analysis of the context of Industry 4.0, evaluating its effects on the improvement of the provision of oil companies product and services, and determining the challenges and the difficulties that arise in the industry.

This paper aims to: (i) carry out and determine the impact and effects generated by the application of Industry 4.0 technologies in the supply chain; (ii) understand the different opportunities and challenges of this new

paradigm; (iii) describe the current state of Algerian oil companies concerning Industry 4.0 integration in the supply chain; and (iv) identify the impacts that industry 4.0 technologies have on the supply chain in the oil companies, and indicate actions to be taken. The paper also compares the evolution of supply chain strategies with those that incorporate emerging technologies. It aims to illustrate current trends and needs in advanced technologies which serve as the basis for developing the different activities related to the supply chain in the Algerian companies.

The rest of the paper is organized as follows: The study begins by analyzing the effect of industry 4.0 in the digital transformation of the supply chain (section 2). Section 3 presents the current situation of the supply chain in Algerian oil companies. Section 4 describes how advanced technologies can help to address several issues. Section 5 details the roadmap to formulate initiatives that would accelerate the digitalization of the supply chain in industry 4.0. Based on the assessment of the situation in the country, recommendations are made in section 6 to accelerate the digital transformation of the supply chain.

2. Industry 4.0 and supply chain transformation

Throughout history, both industry and society have undergone significant changes. The first industrial revolution was characterized by using new energy sources, such as motor engines, to increase efficiency in production and transportation (industry 1.0). The second industrial revolution began with electric power and petroleum derivatives replacing steam power and bringing better methods of organizing work, known as serial production, which reduced manufacturing costs and increased productivity (industry 2.0). Undoubtedly, the implementation of electronics and computing marked a great change (industry 3.0), facilitating the inclusion of autonomous and intelligent systems. Thus, consolidating the path for the current fourth industrial revolution (Xu et al., 2018; Lu, 2017).

Globally, the main objective of Industry 4.0 is to allow the creation of communication systems, intelligent and self-controlled. It can be described as conceptual approaches of Industry 4.0 to cyber-physical system (CPS), internet technology, carrier components information, and comprehensive security, including the protection of privacy and knowledge (Sedkaoui and

Khelfaoui, 2020; Jeschke et al., 2017). This revolution has generated profound changes in the industrial environment and society (Barreto et al., 2017). This new paradigm is being adopted by the majority of companies in different industries, including the oil industry and its suppliers.

Tools such as: IoT, cloud computing, big data, among other advanced technologies of industry 4.0, have integrated new opportunities and challenges for oil companies and have transformed the style of doing business processes business (Manocha et al., 2020) so that they have directed them towards a digital supply network. Regarding the systemic interaction of actors and activities included in the supply chain process, digital transformation must involve all supply chain components. Among them are logistics service providers, carriers, infrastructure nodes (ports, airports, etc.), customs agencies, and trade control bodies.

The transformation of the supply chain in the framework of the 4th industrial revolution is called "Supply Chain 4.0". This transformation results from the incorporation of the advanced technologies of industry 4.0 in different supply chain processes. For example, additive manufacturing allows companies to design and produce custom items thanks to 3D printing. These technologies will also benefit the company's environment (Sedkaoui and Khelfaoui, 2020), as the supply chain is also the link between the company and its environment via suppliers, customers, and other stakeholders.

In current times, with unprecedented events such as the appearance of the global COVID-19 pandemic, the importance of advanced technologies to facilitate the functioning of economic systems become evident, and the digitization of production is a fundamental factor to keep this system operating. In this scenario, to stay competitive, it must redesign strategies that allow operations to be carried out most efficiently and effectively.

The technologies' uses in the supply chain have been widely addressed in the literature. Along these lines, cloud-based solutions for the supply chain are being adopted as a supply method (Truong, 2014). However, it is essential to analyze the risks and associated costs, presenting a grave concern. This situation forces the company to plan the use of

technology and invest in cybersecurity adequately. Another Industry 4.0' technology in the supply chain is the IoT, which connects electronic objects through the internet and generates a large amount of information.

However, this innovation raises two questions: (i) the first one is associated with the amount of technology required to analyze this massive amount of data, (ii) and the second is related to the challenge posed by security and privacy challenges (Sedkaoui, 2018). For this, to test the security measures before launching products, companies must simulate the technology's operation before its use (Stock et al., 2018; Micheli et al., 2020).

3. Introduction to the current situation of the supply chain in Algerian oil companies

By sharing data and securely integrating systems and processes, advanced technologies transform the traditional supply chain into an integrated value chain of beneficial interrelationships (Barreto et al., 2017). For its part, the specialized technology for the oil industry is found in three main areas:

- Digital twins, whose use consists of extracting production data from a natural process, this type of simulation allows the observation of how the process will behave and the optimization of tasks such as regulating process variables and production parameters.
- Drones for inspection of platforms can reduce, for example, the exposure of workers in high danger areas.
- The production of a vast volume of data and their analysis at real-time speed. This improves production and its reserves, generates new processes and practices, and increases efficiencies while reducing financial amounts.

Table 1 illustrates a few examples of how Industry 4.0 is transforming the traditional oil supply chain.

Table N°1: Industry 4.0 technologies in the oil supply chain

Operation	Technology	Example	Effect
Exploration	Data Analysis & 3D visualization	Real-time geolocation Seismic imaging	Integrate production data to map changes in oil and gas reserves Determine if the field is productive and/or optimal to carry out soil drilling
Production	Sensors electrical and storage system	Automated drillers and production levels Optimize production	Combining sand, water, and chemicals using data from software sensors Reducing downtime in production operations
Storage	Data analysis	Automate control	Developments in data processing to track levels of inventory and monitoring systems
Transportation	Smart sensors	Automations material transporting	Transmit the transport coordinates Determine in which route the oil batches are moving
Refining	Smart sensors	Monitoring	Improve the safety and functionality of all processes Early leaks detection and monitoring temperature
Distribution	Predictive analysis	Forecasting	forecast demand

Source: authors' elaboration

A wide range of participants is involved in the oil supply chain, from exploration to distribution. As a result, the success of the company is heavily dependent on communication. In addition, the processes of the oil

industry are not static, nor they are limited to the exploitation phase, so a system that is capable of tracing the flows of data and materials of the entire life cycle of the product, from exploration to distribution, passing through the stages of gathering materials, construction, testing, and operation, it would add much value to all the involved agents.

The development of the supply chain in Algeria is still embryonic. This situation is due to the following:

- ICT infrastructure and limited availability of advanced technologies.
- A gap in skills and availability of a qualified workforce.
- A supply chain is vital and has to be agile and efficient.
- Lots of poorly automated processes, burdensome administrative tasks, and mounting regulatory requirements.
- Multiple intermediaries to obtain the products from the exploration to the final customer: suppliers, processors, logistics companies, regulators, … etc.
- Data exchange is limited to value chain participants who have direct contact with each other and none have a complete and up-to-date view of the supply chain.
- Non-comprehension the industry 4.0 technologies benefits.
- Limitations in the supply chain facilitators: Algeria has a deficient infrastructure of roads and railways, combined with factors such as: congestion in access to ports, unequal adoption of technology by logistics service providers, and inefficient customs operations.
- Limited coordination of government programs and plans: the lack of a comprehensive framework for a national supply chain strategy and limited coordination between public sector entities diminish the possibility of implementing advanced technologies in the supply chain.
- Business context characterized by a low level of awareness and preparation of Small and Medium Enterprises (SMEs), with lack of the financial and human resources to innovate. Programs are placed on adopting mature technologies, and they rarely address the concept of digitalization of the supply chain.

Facing this issue, three essential elements should be considered by

Algerian companies: (i) emerging technologies, (ii) changes in business models and consumption habits, and (iii) the legal, juridical, and ethical aspects implied by the contexts generated by advanced technologies. Therefore, supply chains must be more precise to adapt to current changes and take advantage of new technologies.

The examples cited in the previous table indicate that each level of the supply chain can be improved by deploying advanced technologies, which can increase the benefits of each oil company. However, when these technologies are combined, i.e., connected and communicated, a shared data ecosystem can be created, transforming the country's oil industry, the true power of digitization, and the core of Industry 4.0.

4. Industry 4.0: An essential element to face supply chain problems

The pandemic's economic crisis is a continuation of the slowdown in GDP growth that Algeria has experienced from 2015 to 2019, after falling oil price in 2014. As of 2019, the oil sector presented 21% of the total GDP and 94% of the country's exportation (National Statistics Office, 2021; African Economic Outlook, 2021). Because of the oil industry's contraction, Algeria's growth model is based on a sprawling public sector, while the private sector is struggling to become a new growth engine.

The post-COVID economic recovery will be marked by stiff competition. The collapse in the oil price during mid-2014 once again opened an era of austerity for the Algerian economy. With a value passing from around 110$ to 50$ in less than six months, the oil industry's revenue has been reduced. In the context of moderating crude oil prices in the short term, it has once again become imperative to act on operating costs, productivity, and production start-up times to maintain reasonable margins.

For this, disruptive investments in existing assets are necessary by integrating and then exploiting digital technologies. As a result of this sector's economic importance, its value chain and competitiveness must be developed, and the transition to the intelligent industry must be accelerated. In addition, Algerian oil companies generate a large volume of data that must be managed. For the industry, ICT solutions are fundamental because of the need to generate cleaner energies and the complexity of the industry's

environment.

In the same sense, industry 4.0's first "smart manufacturing platform" was announced in February 2019 by the Advanced Technologies Development Center and Siemens. A considerable number of companies are already using new technologies, such as: IoT devices, big data analytics, cloud computing, and other intelligent tools, to transform their production process (Sedkaoui and Moualdi, 2020b). In this global transformation, which includes cyber-physical manufacturing systems, collaborative robots, the internet of industrial objects, and cognitive computing, this platform will provide the framework necessary to assist industrialists and innovative companies.

Table N°2: Sonatrach's ICT infrastructure: Capability and limits

Problem	Capacity	Difficulty	Results
Resource silos	5 data centers operating separately	Enable to manage and schedule themselves in a unified manner Core services deployed in a single data center	Difficulties in introducing new services Challenging to guarantee service continuity
Information silos	More than 200 subsidiaries More than ten horizontal functional departments	IT hardware provided by different vendors The information transferred manually and analyzed using Excel Difficulty in monitoring data	Compatibility issues Limits mobile access, and creates data silos between departments and subsidiaries Low operational efficiency

Source: authors' elaboration

For example, in Sonatrach, the largest company in Africa and the 11th largest oil consortium globally, upstream and downstream levels and the functional departments were served by Sonatrach's ICT infrastructure

(Hongyuan, 2019). This infrastructure supports various workloads, but this is not enough because the legacy ICT system leads to many problems as displayed in Table 2 above.

Sonatrach intends to improve its production efficiency and increase profits by implementing advanced technologies to enhance the different operations. In this context, the company places the digital transformation of its activities as a fundamental axis of its "SH2030" strategy. This strategy aims to harness new technologies and artificial intelligence tools to optimize the performance of the company.

As part of the company's digital transformation, "Cloud Sonatrach" was launched to share and exchange documents efficiently and safely while maintaining data security. This initiative is completed with innovative service platforms, big data services, and the Enterprise Resource Planning (ERP) system. These solutions allow the company to strengthen its digital infrastructure and cover its entire industrial chain, from exploration, production, storage, and transportation to distribution, while managing several issues.

Production and distribution of oil products require large logistical deployments from the exploration stage to the final consumer, but different supply chains are established for each family of refining products and physical-chemical treatments. Advanced technologies, for example, have the potential to revolutionize the management of the supply chain and the logistics of exploration and distribution, simplifying connections between different links as well as capital investments required from exploration to fuel pumps, lubricants, and more.

Together, these advanced technologies revolutionize the mechanics of exploration, production, and design. On the other hand, one of the key aspects to be addressed in supply chain and logistics in recent times are the environmental impacts caused by industries around the world, which is attracting more and more the attention of organizations to incorporate aspects of sustainability in their processes (Tumpa et al., 2019; Roy et al., 2020). It is up to Algerian oil companies to adopt the correct strategy without neglecting one fundamental aspect: the human factor.

5. Redesigning supply chain in Algerian oil companies by industry 4.0

The Algerian government must prioritize investments in exploration, refining, and updating of machinery, where the first thing required is a level of automation that allows the extraction of information from all processes. Later, the use of big data, analytics, the cloud, and different intelligent tools would be beneficial for predictive and preventive maintenance (Sedkaoui, 2018), which would lead to greater efficiency in petrochemical processes.

Such results would translate into better costs and, therefore, a more competitive price of oil products. Also, input needs in the primary other industries, such as manufacturing, electronics, depend on oil industry products. In this context, we think that the implementation of Industry 4.0 technologies in the different processes of companies must be gradually and following three main stages:

In the first stages, the goals must be concentrated more on adapting the existing ICT infrastructure and establishing physical structure aimed at the subsequent exploitation of the information. It should include all the hardware installation and essential equipment for data collection and traditional management software, such as ERP, MPR, CRM, etc.

The second stage must focus on developing the digital infrastructure that enables the implementation and installation of advanced technologies, such as the installation of systems that can collect data from sensors and integration available robots with information systems, to establish improvement actions and increase the automatic control of the processes.

The final stage must expand the different technologies and autonomous systems that allow companies to interact with the environment, predict operations, and act in feedback. This is where big data and predictive analytics software are put into practice and the beneficial use of the IoT and other intelligent and advanced technologies.

It is essential to highlight that the inclusion of technologies for the digitization and automation of the supply chain process is required in the first stage to facilitate the transition to Industry 4.0. In this context, the development of a digital ecosystem, a socio-economic and industrial context resulting from the massive adoption of digital information and

communication technologies, is a determining factor to achieve an effective transformation towards the 4.0 era.

At this level, the concept of Industry 4.0 becomes real and requires a new step in management. For this, Algerian companies need digital decision-makers who help them plan this digital ecosystem and extend technological integration to their entire field of activity.

From a practical point of view, the Algerian oil companies can gradually integrate these trends because companies may adopt a specific technology, but it is relevant to apply it only to one level or a limited group of supply chain processes and not to another level of the process. It is also possible that it will be productive and profitable for the company to apply some of these technologies and not others.

It is essential to promote the digitalization of the oil industry through support for investment and capitalization projects that provide the productive units with sufficient machinery, equipment, and infrastructure, which allow raising the level of productivity and profitability and make them more competitive in terms of traceability and quality systems.

On the other hand, the oil industry should be more competitive in implementing new technologies in the development of oil production. This is possible by using effective solutions in the industrial processes that manage related activities such as exploration, drilling production, refining, and transportation. This industrial process is made up of the regulation and administration of these activities, which are mainly:

- Upstream: made up of activities related to the exploration and production area.
- Downstream: carries out transportation, refining, and marketing activities.

The digital transformation that oil producers must implement throughout the value chain is essential to move towards Industry 4.0 technologies, such as IoT, big data, etc. These technologies can be adapted to deal with the significant challenges that the oil industry faces since they refer to a set of related applications that provide a shortcut in decision-making and an efficient capture of data. However, the storage and analysis of large volumes of generated data require special processing techniques,

considering their treatment's speed and/or complexity (Sedkaoui, 2018).

It should be mentioned that talking about technological investments for the industry does not only mean buying and implementing solutions in the companies' plants. It also requires a particular approach and investment in the training of personnel for the operation and interaction with digital platforms. In addition, the approach to the design of supply chains must be given under economic, environmental, and social criteria, such as job creation, social welfare, energy performance, or resource consumption, to respond to market requirements (Matos and Hall, 2007; Sedkaoui and Khelfaoui, 2020).

6. Critical actions to advance the digital transformation of the supply chain in Algeria

In recent years, criteria and technologies have emerged that have altered managing supply chains and logistics worldwide. In the search to improve performance, reduce operating costs, increase surpluses, and the ability to respond to changes and market demands, companies inevitably depend on the ability to acquire and implement technology for the development of planning processes, execution, and control of the flow and storage of goods and services through the supply chain (Attaran, 2020).

The analysis of the level of development of Industry 4.0 technologies integrated into a different level of supply chains makes it possible to identify specific critical actions to be taken, mainly:

• Algerian companies must implement comprehensive strategies aimed at implementing industry 4.0. In Algeria, most digital transformation efforts associated with advanced technologies focus on the company without considering the interrelationships with suppliers, distributors, and logistics agents.

• The companies leading this transformation did not have a clearly defined roadmap for developing the supply chain through emerging technologies. This transformation must consider not only the adoption of industry 4.0’s technologies but also the leadership of senior management, as well as a change in the company’s business model.

• Assuming a waiting position until the logic ‘4.0’ breaks onto the scene is a dangerous strategy. Therefore, Algerian companies should

experiment and explore technologies with supply chain partners to assess the potential involved in this transformation.

• When it comes to technological experimentation, Algerian companies must monitor local SMEs and start-ups to identify new technologies, applications, and innovative business models. In this context, it should be mentioned that the country already has a vibrant community of innovators, especially in logistics and e-commerce.

• Algerian companies must also explore technological applications adapted to the ICTs infrastructure conditions of the country. If telecommunications networks cannot provide ultra-fast broadband or high-speed wireless communications, companies must consider technologies that can operate under limited operating conditions.

• Governments also have a role to play in developing the supply chain, supporting the definition of data communication standards between companies, and accelerating the digitization of public services.

• In addition, companies should work with workforce representatives to reduce the disruption associated with the lack of training resulting from the implementation of industry 4.0. These initiatives include continuous communication and training programs, which could be implemented in coordination with the public sector. Governments should emphasize the deployment of technology centers focused on specific industrial sectors (Sedkaoui, 2019), offering training and laboratories for SMEs with the objective of capacity development in support of advanced technologies and their integration in the supply chain. The private sector, academia, and the public sector should collaborate to develop roadmaps to guide better the digitalization of the different levels of the supply chain.

• These public initiatives should be complemented with measures to stimulate innovation, such as the reduction of taxes on innovation and tariffs on the importation of developed technologies and equipment.

• Algeria has embarked on programs to develop transportation infrastructure, but these initiatives must be complemented with a concerted effort to modernize the technological capacity of agencies involved in trade and logistics. Also, digitization companies that demonstrate the benefits of

technology adoption should be promoted to generate a demonstration effect. Creating technology policymakers in ministries focused on infrastructure development to raise awareness of the industry 4.0 should also be considered.

• The development of public policies aimed at implementing Industry 4.0 technologies needs to be supported and coordinated with efforts and initiatives focused on Industry 4.0 and Logistics Plans.

• Finally, the study of the experience of advanced economies and oil producers around the world helps formulate initiatives that would allow the implementation of advanced technologies in the development of the supply chain in Algerian oil companies.

While the multiplicity of actors and processes involved in supply chains has increased management complexity and, with it, the probability of disruptions, new technologies promise to generate unprecedented gains inefficiency.

7. CONCLUSION

This paper addresses the importance of supply chains, their main characteristics, and the technologies that can revolutionize their management in oil companies. These technologies emerged within industry 4.0 and, to generate the expected benefits, they must be adopted by the different actors and processes that make up a supply chain. The paper indicated that Algerian companies are currently facing challenges that can limit the digitalization of the supply chain. Barriers including the lack of integration and multi-sector coordination between public and private companies, public policies that encourage the integration of technologies, the characteristics of the SMEs, and a lack of qualified human factors, which limits the advancement toward the 4.0 era in Algeria.

It was concluded that the external factors that hinder the implementation of the industry, mainly government support for high-tech machinery, are the barriers that Algerian oil companies constantly face. It is established that the lack of ICT infrastructure, the use of obsolete technologies, and the lack of knowledge of the benefits of technological advances, present the elements that have limited technological development and the digitalization of the supply chain process in Algerian companies.

Therefore, the governments must establish the regulatory framework and the ideal technological infrastructure ecosystem that allows the harmonious development of Industry 4.0 and supply chain initiatives.

This implies considerable challenges at the level of conceptual appropriation, particular adaptations in the country, and the characteristics of the Algerian companies. These challenging factors must be considered when considering how to transform the supply chain and logistics in Algeria, toward Industry 4.0, which goes far beyond the acquisition of advanced technologies and management models. The inclusion of academic processes is required as an organizing axis of the research activity. The integration of efforts by teams and institutions committed to developing knowledge in the application of Industry 4.0 technologies in supply chain processes is required.

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