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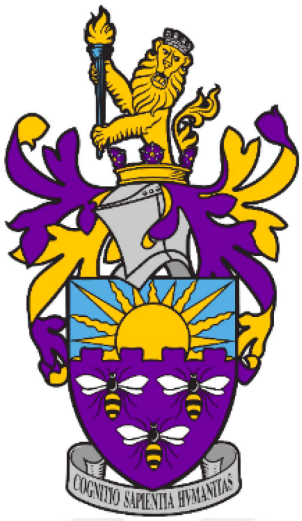

Systematic Literature Review of Industry 4.0 Technologies in Oil and Gas Logistics Management

A dissertation submitted to The University of Manchester for the degree of Master of Science in the Faculty of Humanities

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Abstract

As energy is an indispensable part of life, its worldwide demand is increasing day by day. The oil and gas industry plays a key role in meeting that demand. However, due to the challenges oil and gas companies are facing, they need to cut costs, optimise processes and increase efficiency and safety. To achieve these goals, the industry needs to attach importance to digitalisation and start benefiting from Industry 4.0 technologies. This dissertation aims to portray the ways the Internet of Things (IoT) and Big Data can improve oil and gas logistics management. It also addresses the barriers to implementing these technologies and some recommendations to tackle these barriers. The study used a systematic literature review approach to achieve this aim. Seven-step procedures were followed, and 35 chosen papers were analysed for the review. The study focused on four critical development areas of IoT and Big Data, which will improve logistics management. These are pipeline safety, fleet management, equipment maintenance and real-time monitoring. Additionally, the studies analysed identified some barriers to implementing these technologies, such as cybersecurity, high investment cost, data storage and analytics, technological readiness, people, and adaptation. Lastly, the study pointed out some recommendations to mitigate these barriers from the literature and suggestions were identified for future research. The results of this study support the view that oil and gas companies should adopt IoT and Big Data technologies for logistics management. Thus, it is possible to benefit from these advanced technologies in the long term to decrease costs and harm to the environment and increase performance and safety.

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1. Introduction

Today, energy is needed for both the growth of many sectors and the maintenance of life. It is practically impossible to survive without energy, which plays a significant part in human life. Energy is also crucial to national and international politics in terms of competition, alliance, war, convergence, divergence, and interstate relations. In the modern world, energy is delivered through several carriers, including renewable energies, coal, nuclear power, oil, and gas (Ebrahimi and Bagheri, 2022).

There is growing worldwide demand for energy, and even though the global energy structure is changing dramatically, and renewable energy sources are becoming more popular, oil and natural gas will continue to make up a significant portion of the world's energy supply (Lu, Guo and Zhang, 2019). The industry cannot function without the oil and gas (O&G) sector. However, the oil and gas business has not been steady due to the decline in oil prices in recent years. Additionally, as a result of decreased oil and gas production, many petroleum companies have found it challenging to maintain their balance of payments. In this situation, many oil and gas businesses have been under intense pressure to speed up their goal of efficiency in order to reduce costs and increase revenues (Lu et al., 2019).

Despite the fact that logistics is a crucial function that ensures the right product reaches the right customer at the right time, many managers have a tendency to regard logistics as an expense that has to be controlled and frequently fail to recognise that logistics can make or break a company. Therefore, investing in logistics is the key to reducing costs (Tang and Veelenturf, 2019). Technologies like Big Data and the Internet of Things are slowly being applied to the industry due to Industry 4.0's rapid development, and old industrial technologies will gradually change and be replaced. In order to grow, the oil and gas sector must rely on Industry 4.0 (Lu et al., 2019). By transforming the logistics function into a competitive advantage, a generator of social value, and a sustainability enabler, businesses may use Industry 4.0 technologies to generate economic, environmental, and social benefits (Tang and Veelenturf, 2019).

In this research, as an improvement of the logistics management in the oil and gas industry, the Internet of Things (IoT) and Big Data technologies are proposed. Four areas where these technologies can be applied have been determined.

1.1. Research Aim

This study aims to bring together different studies to comprehend the advantages of Industry 4.0 technologies (IoT and Big Data) for the oil and gas industry logistics management.

1.2. Research Objectives

- To show which areas IoT and Big Data can improve oil and gas logistics.
- To address the challenges of implementing these technologies for the oil and gas companies and offer recommendations for those challenges.
- To prepare a guide for future development.

1.3. Research Questions

- How do Industry 4.0 technologies (IoT and Big Data) improve the logistics in the oil and gas industry?
- What are the barriers faced by oil and gas companies in applying Industry 4.0 (IoT and Big Data) technologies to logistics management?
- What are the adaptation recommendations for implementing Industry 4.0 technologies (IoT and Big Data) that oil and gas companies can follow?

1.4. Research Structure

The rest of this paper is organised as follows. Section 2 is the background section explaining key concepts such as Industry 4.0, IoT, Big Data, oil and gas industry and logistics. Section 3

is the methodology section and discusses in detail the steps taken in conducting the systematic literature review. The keywords used, the databases searched, and the inclusion-exclusion criteria for the articles are given in this section. Section 4 is the literature review part describing the areas where IoT and Big Data can improve the logistics of the oil and gas industry. Section 5 describes the barriers and recommendations for applying these technologies to oil and gas companies, while the conclusion is given in Section 6.

2. Background

2.1. Industry 4.0

In 2011, the German agency for economic development revived the phrase "Industry 4.0." The fourth industrial revolution builds on the third by utilising emerging technologies (or Industry 4.0 technologies) like the Internet of Things, Big Data, Additive Manufacturing, Advanced Robotics, Autonomous Vehicles, Artificial Intelligence, Blockchain, Drones etc. (Tang and Veelenturf, 2019).

The deep integration of industrialisation and information technology has led to the creation of industry 4.0 technologies. The four main concepts of Industry 4.0 are smart factories, smart manufacturing, smart logistics, and smart services. Smart logistics is among them, and it uses integrated intelligent technology to let the logistics system assess and resolve specific logistical issues through thinking, perceiving, learning, and reasoning (Lu et al., 2019).

This study focuses on how IoT and Big Data technologies can improve oil and gas logistics.

2.2. Internet of Things (IoT)

The term "Internet of Things" (IoT) refers to a group of technologies that connect physical items to the Internet so that they can share data without needing human-to-human or human-to-machine interactions. These objects have the ability to sense, identify, process, communicate, and act. They are also programmable with software and other technologies to gather information and carry out specific orders (Zuo and Qi, 2022). The adoption rate of the Internet of Things has been increasing tremendously in recent years because of the major decrease in cost, rise in processing speed for these sensors, and significant advancements in measurement and communication technology (Tang and Veelenturf, 2019).

Since system failures in industrial contexts might result in high-risk scenarios, IoT mainly concentrates on enhancing efficiency and safety. In order to gather, monitor, and analyse data and provide insightful information, it integrates sensors, mobile communication technology, and intelligent analysis technology into every aspect of the industrial processes. This enables industrial companies to make wiser business decisions more quickly and securely (Lu et al., 2019).

2.3. Big Data

Big Data is characterised by its huge data capacity and variety of types, and it can be described as a significant volume of unstructured or structured data from various sources (Lu et al., 2019).

Due to recent technical advancements, several businesses now regularly produce enormous databases. According to reports, oil and gas companies are also quite concerned about maintaining these datasets. These datasets are produced in vast quantities and captured in a variety of formats in various upstream to downstream processes in the oil and gas sector. The complexity of diverse petroleum engineering issues makes the velocity characteristic even more obvious for the oil and gas sector. It is hard for one person to process a large volume of generated data for a complicated topic without substantial delay and uncertainty (Mohammadpoor and Torabi, 2018).

Any sensor or data recording device may provide this data. Due to storage, sustainability, and analysis difficulties, this enormous amount of data is challenging to manage. Many businesses are struggling with the enormous amount of data they have stored in their archives, but they lack the tools to handle it. The primary use of Big Data is to offer processing and analysis capabilities for the growing data volumes (Mohammadpoor and Torabi, 2018).

2.4. Oil and Gas Industry

The oil and gas industry is divided into three segments: upstream, which deals with exploration and production; midstream, which processes, stores, and transports crude oil, natural gas, and natural gas liquids, acting as a crucial link between the producing regions and the population centres; and downstream, which refines and markets hydrocarbon products (Onyeme and Liyanage, 2022).

Oil and gas firms started implementing digital technologies in the 1980s to increase the marginal operational efficiency of oil fields worldwide and to comprehend the reserves and production potential of oil and gas resources more precisely. However, the industry has not fully embraced the chance to use data and technology in a meaningful way for the past ten years. Therefore, digitalisation is still in its early stages for the oil and gas business, although digital technology has been well known over the previous ten years (Lu et al., 2019). The extraction sector has only recently started utilising modern IoT. This development is partly a result of a recent hit in energy costs, particularly because of the coronavirus pandemic. Integration and automation are two of the quickest ways to reduce expenses for the industry. Petroleum firms now have a feasible option for reducing human error and obtaining real-time insights from the wide variety of equipment present on the typical petroleum pipeline. An IoT and Big Data based solution would be able to connect all these various data streams together (Aba et al., 2021).

2.5. Logistics in the Oil and Gas Industry

The term "logistics" describes the complete process of managing the purchase, storage, and delivery of resources to their intended location. There are several modes of transportation that may be used to convey products from one location to another, including pipeline, rail, water, air, and motor transportation. Numerous factors, like the type of product, the travel distance, etc., determine the transport method to use in each situation. There are benefits and drawbacks to each strategy, and all these transport methods can be used for the transportation of oil and gas (Marchenko and Babyr, 2021). Crude oil logistics costs may be impacted by changes in

product demand, crude oil prices, and more stringent environmental restrictions (Atmayudha, Syauqi and Purwanto, 2021).

It's important to remember that processes in the oil and gas sector also harm the environment, in addition to their cost. During the operations of oil extraction, gathering, and transportation, enormous volumes of CO_2 are emitted as well as electricity and heat are used. Therefore, it is vital to implement technological innovation to lower energy consumption and carbon emissions (Sun et al., 2018).

This study mentions some methods that oil and gas companies can use to increase their efficiency and safety and reduce their logistics costs with IoT and Big Data technologies. These technologies can be used in real-time fleet location, pipeline leak detection, real-time monitoring, and equipment maintenance.

3. Methodology

A systematic literature review (SLR), as opposed to a review of earlier works, is an essential research project. It is a process that locates prior research, picks, and assesses contributions, analyses and synthesises data, and publishes the evidence in a form that enables relatively clear conclusions to be drawn about what is and is not known. It answers particular research questions (Thomé, Scavarda and Scavarda, 2016).

A systematic literature review has certain benefits, including the ability to combine essential pieces of information for decision-making, research, and policy. It also helps to reduce enormous volumes of information. Additionally, it is a successful scientific approach that typically costs less than new research. It enables a systematic assessment of the connections between variables (Thomé, Scavarda and Scavarda, 2016).

This systematic literature review set out to identify the impact of the IoT and Big Data technologies in oil and gas logistics management. The O&G industry was chosen because of the importance of the sector and the need for digitalisation of the industry, as mentioned in the background section. It is aimed to conduct a study that can help O&G companies by examining the effects of industry 4.0 technologies on the sector. Before determining the research questions, the subject was narrowed and focused on the logistics part of the industry. In addition, due to the fact that Industry 4.0 technologies are a very broad subject, IoT and Big Data technologies are focused on so that it is possible to give more details. The reason for this is that Big Data and IoT are the two of the most critical technologies for logistics management because it is about managing the movement of materials and information.

For this dissertation, a systematic literature review was conducted. This is because the systematic literature review is an overview of previous studies, and different perspectives can be seen by using the studies of a wide range of experts. The dissertation's limited time is a significant additional factor.

A background study of literature was made to identify key themes. According to the major themes of the literature, four important issues were found. These four topics are pipeline safety, fleet management, equipment maintenance and monitoring. After the themes were identified, a protocol for the systematic literature review was followed to find the papers that addressed these subjects.

This systematic literature review followed the seven procedures shown in Figure 1 in order to answer the research questions mentioned in the introduction chapter. The determination of the protocol was inspired by the study of de Oliveira et al. (2018).

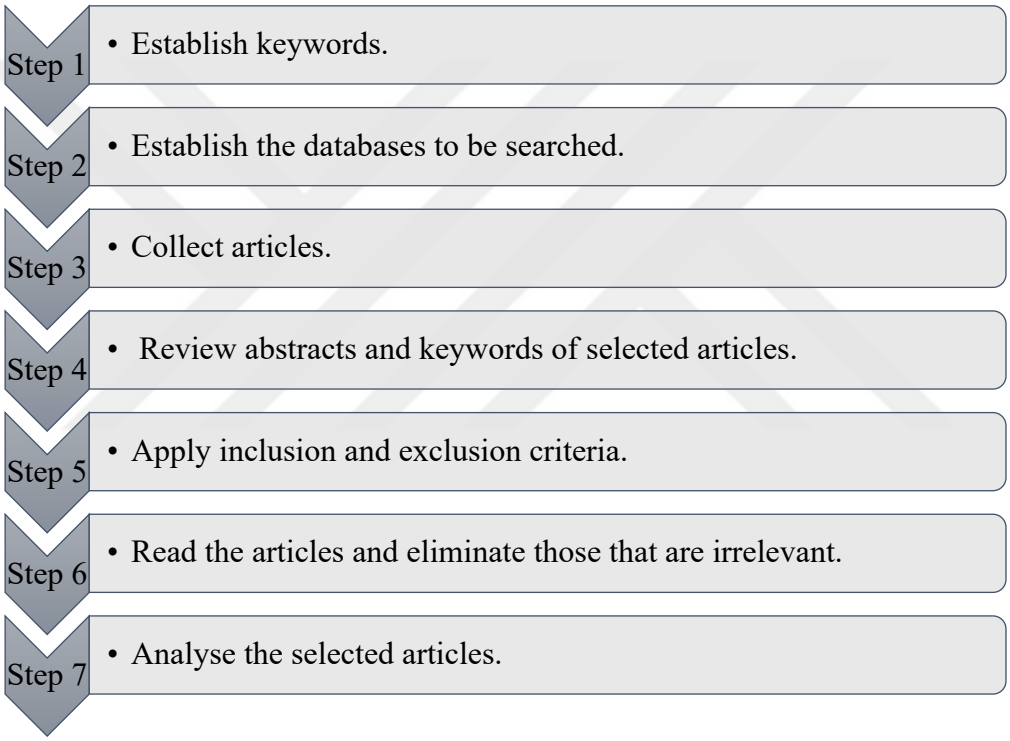

Figure 1 - Research Steps

In the first stage, the keywords used during the search were determined as:

- Oil and Gas
- Oil and Gas Logistics
- Big data
- IoT
- Digitalisation

After the keywords were determined, the databases to be searched were decided. Six different databases were selected for a more comprehensive search. The selected databases are as follows:

- Science Direct
- Emerald
- Web of Science
- Taylor & Francis
- Google Scholar
- Wiley

After the keywords were searched in the selected databases, the abstracts and keywords of the articles were reviewed, and the articles not related to the subject were eliminated. The articles that fulfilled the inclusion criteria were chosen for additional research by using the inclusion and exclusion criteria. These criteria are given in Table 1. After the inclusion-exclusion criteria were applied, the number of papers was reduced from 116 to 35.

The first criterion is the exclusion of non-English works due to the capabilities of both the author and the readers. The second parameter is the year of the study. Since Industry 4.0 technologies are a current issue and to use the latest developments in the literature, the studies done in the last five years (after January 2018) were selected, and the studies published before 2018 were eliminated. In addition, studies that are not available to the public or that are out of the resources provided by the university were excluded in order not to create additional costs for the research. The last criterion is the type of publication. Among the studies, only the articles published in the journal were used. Papers that are gray literature, such as extended abstracts, presentations, thesis, reports, and conference papers, were omitted. Thus, the study was aimed to be of good quality by using peer-reviewed articles.

After the studies that met the criteria were selected, all the articles were read, and those that were not closely related to the subject were removed. In contrast, the remaining articles were read and analysed in detail and used in a systematic literature review. After the articles were read in detail, the similarities, differences, and important information were combined, and a literature review was written within the logic framework.

Table 1 - Inclusion/Exclusion Criteria

Criteria	**Inclusion**	**Exclusion**
Language	English	Non-English
Year of publication	After 2018 (2018-2022)	Before 2018
Type of publication	Published in a journal	Thesis, conference papers
Availability	Available	Unavailable

4. IoT and Big Data for Logistics Improvement

4.1. Pipeline Safety

Currently, pipeline transportation is the primary method of transporting oil and gas, which is crucial to the growth of the oil and gas sector (He et al., 2019). These pipelines are generally harmed by third parties (drilling activities, explosions, vehicular movement, etc.) or by natural disasters (earthquakes, erosion, etc.) (Aba et al., 2021). Pipelines have significant management difficulties, particularly in the area of safety management, because of their length and passage through several complex areas. It is challenging to find and fix a pipeline accident as soon as it happens (Lu et al., 2019).

Leaks in the pipeline system have both significant financial impacts and environmental impacts. In 2012, it was reported that in the petroleum and chemical industries, there had been around 2200 million metric tonnes of accidental CO_2 leaks, and on average, 200 severe events with life-threatening equipment damage or business losses take place each year. Therefore, it is crucial to locate and properly identify leaks to fix them timely and economically (Meribout et al., 2020).

Manual inspection is still the most often used technique to assess the temperature, pressure, corrosion, and deformation section by section throughout the pipeline. Although semi-automatic manual maintenance requires less labour since it is equipped with devices and robotics, it has a high instrumentation cost (Huan et al., 2021). Oil pipeline systems use supervisory control and data acquisition (SCADA) systems, which are not scalable due to low time and space density, expensive to maintain and purchase, non-interoperable in terms of hardware and software, inflexible when it comes to protocol changes, and slow to deliver data and results (Priyanka, Maheswari and Thangavel, 2020).

During the transportation process in a long-distance pipeline, automatic detection, monitoring, controlling, and management must be conducted. Thanks to the rapid development of digital

pipeline construction, it is possible to apply emerging technologies like Big Data and IoT to assure the pipeline's safety (He et al., 2019).

Thus far, several studies have investigated the impacts of these technologies on pipeline security. A recent systematic review by Wanasinghe et al. (2020) reported that it is possible to monitor pipeline networks, find leaks, and locate leaks using IoT-based smart sensor networks. Priyanka, Maheswari and Thangavel (2020) explain that in an existing IoT architecture for remote monitoring and control there are three layers, sensing, networking, and application. A sensor level is reinforced with a variety of sensors, including temperature, vibration, flow rate, pressure, and actuators like pumps, motors, and control valves. The transmission level will be started to gather data and respond to circumstances. A smart IoT module gathers data from pressure and flow rate sensors for remote monitoring and control during transportation through pipelines. The feedback control signals will be delivered to the control valve located at the relevant station to regulate both pressure and flow rate in the case of any anomaly during transportation based on the analysis of the real-time sensors that were received. The established integrated IoT framework's objective is to quickly and accurately identify or diagnose any catastrophic failure caused by fractures, leakage, or obstruction throughout the whole transport system using a smart IoT module.

A study in this area is the work of Yousif and El-Medany (2022). Yousif and El-Medany (2022) developed a real-time IoT robot that can detect gas leaks both indoors and outdoors. The robot was built with a video camera for live video streaming, Bluetooth for indoor applications and tracking, GPS/GPRS for outdoor applications and tracking, microphones, speakers, smart sensors required for patrolling and gas leak detection, and a video camera for live video streaming. After the robot was tested in indoor and outdoor settings, it was discovered that it could identify gas leaks and offer a live video stream of the region, which could be monitored on Google maps. In addition, a mobile app or website could be used to operate the robot remotely. The study concluded that IoT Robot was a low-cost but high-quality solution for gas detection in challenging environments using intelligent gas sensors with a fast response, high sensitivity, low cost, and long life. Another similar study by Aba et al. (2021) explains how to locate the damage on a pipeline and simulate real-time pipeline monitoring using an IoT analytics platform service. For pipeline monitoring, pressure pulses based on vibration in pipes are used. This study also uses the principle of time delays between pulse arrivals at sensor sites. The testing findings demonstrated that, when utilised for real-time

monitoring, the device's performance is capable of locating damage on actual pipelines. Real-time pipeline monitoring is feasible on any internet-connected device from anywhere in the world using this communication device and an analytics platform.

He et al. (2019) argue that it is essential for pipeline management that the various technologies are connected and coordinated effectively. Nguyen, Gosine and Warrian (2020) emphasise the importance of Big Data for monitoring and maintaining pipeline systems and suggest that the technology may identify and locate a pipeline leak by comparing the current data with other data sources such as historical data, maintenance reports, operator data, etc. Also, another systematic review claims that, according to statistics, Big Data analysis is regarded as the most significant technology by 87% of oil and gas companies. This is because every 8000 km of pipeline is expected to accumulate about 27 megabytes of data about asset health and operations every ten years (Lu et al., 2019). Collectively, these studies outline the critical role of Big Data in analysing and evaluating a large amount of data for the security and maintenance of pipelines.

4.2. Fleet Management

One of the main applications of IoT is in supply chain management. An IoT-enabled system can improve managing stores, warehouses, and transportation. IoT technology can help oil and gas companies with fleet management, much like it can with supply chain management. Three main categories can be used to categorise fleets in the oil and gas sector: petroleum products (raw or processed) transportation fleet, field personnel and oilfield equipment fleet and vehicles fleet. IoT sensor networks make it possible to track the specific position of field workers, mobile equipment and field vehicles, and petroleum product transportation systems such as trucks, trains, tankers, and ships in real-time (Wanasinghe et al., 2020).

Anusha et al. (2021) highlight the importance of IoT development in transportation. The paper argues that IoT development helps to tackle many issues. The IoT device precisely measures the fuel level, estimates the number of kilometres of remaining fuel, and utilises a pressure sensor to determine the air pressure in the front and rear wheels. The viscosity sensor continuously detects temperature and engine oil viscosity to monitor oil ageing. Additionally, independent measurements of carbon monoxide (CO) and nitric oxide can be made to detect

pollution. Similarly, Ammar et al. (2022) also point out some advantages of IoT applications. Drivers can now be monitored and adjusted to satisfy environmental and safety requirements thanks to IoT technology. The fleet management sector will be able to increase client satisfaction through quicker delivery and higher-quality service. It is possible to get real-time updates on the vehicles' state, the driver's physical condition, and transportation efficiency while tracking the fleet's location, status, behaviour, and movement. Emergency personnel and other parties can conveniently obtain critical data acquired from the vehicles, such as vehicle operating information, changes to the speed limit, turn-by-turn directions, and collision alarms, from a distance (Ammar et al., 2022).

Another study by Ahmad et al. (2022) draws attention to an important point. The sensors are attached to the trucks transporting oil and gas products to perform shipment tracking. The sensors can also help ensure that any unauthorised effort to unlock the oil and gas tankers can be discovered immediately. Any effort to contaminate oil and gas tankers during shipping can be reported to the relevant authorities. Additionally, the authorities can check the condition of the oil in tankers by using a variety of sensors that record information about temperature, humidity, pressure, volume, and container shaking. Another significant advantage of IoT technology is that an automated data-driven fleet management system can be created using location information from IoT geo-positioning sensors since manually coordinating an entire fleet is difficult for a single fleet management operator (Wanasinghe et al., 2020).

Chen et al. (2021) explain another benefit of real-time logistics defined as Logistic 4.0 in the paper. Travel time changes due to traffic congestion, weather conditions, shifting objects, movable obstacles, or whenever the decision maker might control the vehicle speeds, making it challenging and expensive to estimate time consistently and precisely. A realistic estimate of travel time is more challenging since traffic conditions might alter on numerous roads, especially during peak hours. In unpredictable networks, real-time information can help adapt to traffic circumstances and improve routing decisions.

While previously mentioned studies focus on technical advantages, some of the studies are more concerned with environmental benefits. Along with economic and social values, there is an increasing focus on "sustainability" and a call for using renewable energy sources, reducing carbon emissions, protecting endangered species, and ecological sustainability. The demand for natural resources exceeds availability due to the world's expanding population. Over the

last two decades, this concern has led to a greater public awareness of environmental challenges, including climate change, deforestation, and water and air pollution (Tang and Veelenturf, 2019). Carbon emissions have increased due to the rapid expansion of logistics. By optimising resource allocation, technologies aim to increase the logistics sector's operational efficiency and lower carbon emissions (Pan et al., 2020).

A study by Hepsiba et al. (2021) gives an IoT-based pollution and vehicle control concept. For vehicle performance and pollution control, sensors, communication network, microcontrollers, and servers are used. The IoT-based system is used to monitor various vehicle metrics. The study conducts trials on pollution with and without IoT and compares the results. Hepsiba et al. (2021) claim that insufficient vehicle monitoring and maintenance are the main contributors to vehicle pollution. Therefore, an automated system is required to lower pollution. The IoT-based system plays an intelligent role and periodically checks on the condition of vehicles. It determines engine performance, fuel level, tyre pressure, and speed quickly. Gas sensors additionally detect all emissions and gases. This sensor detects gas quality, temperature, pressure, and smoke levels. The advantages of IoT system-based control include delivering pollution-related information more quickly than conventional systems. As a result, the vehicle's driver may quickly identify the sources of vehicle pollution and make the necessary adjustments without the vehicle creating any new issues. The study's findings suggest that the IoT-based system has improved vehicle pollution and control. Experiments on vehicle parameters and pollution have been done with and without an IoT system. It has been demonstrated that IoT-based system has delivered higher performance. Overall, these studies highlight the need for IoT technology for fleet management.

4.3. Equipment Maintenance

Oil and gas companies experience significant financial losses because of unplanned downtime. To reduce downtime at the facility, regular maintenance is essential. Maintenance can be divided into three categories: time-based, reactive, and predictive. In the case of reactive maintenance, the asset is used until it breaks down, at which point it is repaired or replaced. Time-based maintenance includes replacement and repair at predetermined intervals and according to the data provided by the original manufacturer. The predictive maintenance

approach gathers asset integrity and operation data on a regular basis. In order to evaluate and project the equipment's health, the acquired data is analysed utilising advanced data processing techniques (Wanasinghe et al., 2020). Ayvaz and Alpay (2021) claim that traditional maintenance methods frequently result in additional expenditures since equipment needs to be replaced before its time. When replacement parts are late, unplanned stops occur, leading to significant capacity and product loss. Hence to cut maintenance costs and assure sustainable operational management, predictive maintenance has emerged as a common goal for industries.

Lu et al. (2019) stress the role of predictive maintenance for pumps and compressors, which are the most crucial machinery for transporting oil and gas. They are utilised to provide energy for long-distance oil and gas resources. According to the U.S. Department of Energy, pump systems consume roughly 20% of all motor energy worldwide. Many oil and gas producers are considering employing advanced technologies for fault detection and failure pattern recognition due to the high cost of pumps and compressors. Because it is usually more expensive to repair something after it has failed than to prevent it from happening in the first place, oil and gas businesses can identify early warning indications of failure in advance and conduct preventative maintenance procedures, which allows them to save more money (Lu et al., 2019).

The IoT can help oil and gas operators by offering a long-term prediction of the condition-based maintenance of equipment used in the oil and gas industry to enhance efficiency (Ahmad et al., 2022). Models, historical data, and domain knowledge are the foundation of predictive maintenance. New opportunities for equipment life prediction are presented by data gathered from several sensors. For the future of the industry, the concept that predictive maintenance can create scheduled action based on equipment performance or circumstances over time becomes appealing (Zonta et al., 2020). Both Wanasinghe et al. (2020) and Pilar Lambán et al. (2022) draw attention to some significant advantages of IoT. In the papers, it has been mentioned that smart sensors, actuators, and data-driven predictions provided by the IoT make it possible to lower the number of human interventions, extend the life of assets, perform selective maintenance, adopt a lean operation, improve facility reliability, and reduce downtime as well as increase productivity and quality.

Another significant technology besides IoT for predictive maintenance is Big Data. Big data analytics can assist oil and gas industries in developing predictive maintenance models for

equipment maintenance to prevent unanticipated downtime and lower maintenance costs (Wanasinghe et al., 2021). Data analysis can foresee dangerous situations and show equipment performance trends. These advanced features are helpful in managing safety, risk mitigation, and maintenance scheduling during oil and gas operations (Nguyen, Gosine and Warrian, 2020).

4.4. Monitoring

The oil and gas sector includes a significant level of operating and capital costs, as well as health, safety, and environmental risks. Therefore, it is crucial to run assets as efficiently as possible while maintaining security. The O&G industry is currently implementing IoT solutions to accomplish this goal by remotely monitoring field equipment, analysing field data, collaborating on data-driven decisions, and applying control commands to optimise asset performance while minimising health, safety, and environmental risks (Wanasinghe et al., 2020).

Field staff no longer need to visit an asset for data gathering, equipment maintenance, or actuation, thanks to IoT-enabled systems. This reduces the danger of being present and the expense of travelling to distant/offshore sites. Additionally, robots can be used to handle equipment verification and maintenance in challenging, dangerous, or remote locations. In the end, the adoption of IoT technology enables a new idea known as bringing data to the experts to replace the conventional approach of bringing the experts to the data (Wanasinghe et al., 2020). Similarly, G. Alakbarov and A. Hashimov (2018) point out that IoT sensors are used for monitoring the following: pressure, temperature, humidity, noise levels, lighting condition, soil composition, and the presence of dangerous compounds.

Wanasinghe et al. (2020) highlight some valuable examples of IoT-based remote operation and monitoring for the oil and gas industry, such as well monitoring/optimisation, tank level monitoring, sucker-pump condition monitoring, infrastructure monitoring and corrosion monitoring.

Unlike the financial benefits of sensors, there are also other alternatives where IoT applications are useful, like the well-being of workers. For workplace safety and healthy work practices, the biometrics of a worker and the level of exposure to nearby hazards can be tracked and conveyed to nearby workers. By adopting effective human resource management strategies and lowering workplace accidents, establishing IoT-based safety solutions would increase the overall efficiency of industrial companies (Alabadi, Habbal and Wei, 2022).

Wanasinghe et al. (2021) claim that the oil and gas sector should switch from a business-centric to a human-centric digital transformation approach. Thus, the coexistence of human operators and technology could be utilised to the best advantage. Each worker's physiological state can be tracked thanks to smart sensors. These data are sent from the IoT system to the central station for additional analysis. For each field worker, this system offers real-time health monitoring and prediction. The device can gather information on brain signals that may assess the worker's awareness of states, including concentration, boredom, lack of sleep, and fatigue. The gathered biometric data can also be used to track one's health in real time, including blood pressure, glucose levels, and body position. The system may detect any fall, trip, or slide, resulting in an alarm and quick incident reaction. Advanced healthcare features contribute to reducing occupational health and safety violations and enhancing the safety and well-being of field people. The smart sensor also makes it possible to track employee positions in the O&G workplace. This might be an onshore facility spread out across a big area or an offshore platform with a compact multi-level layout.

The study by Wanasinghe et al. (2021) also proposes that big data analytics may support O&G personnel in making quick operational and strategic decisions. Using real-time data, the organisation can assist operating teams in maximising their efforts and providing new perspectives. Furthermore, big data analytics can forecast future performance using previous and current data.

5. Barriers and Recommendations

The primary aim of this chapter is to identify the barriers to implementing IoT and Big Data technologies for oil and gas companies. This chapter also discusses the recommendations for tackling these barriers.

The oil and gas sector is currently going through a challenging transition as the leader of the conventional energy sector. As a result, the rise of "Oil and Gas 4.0" with the "Industry 4.0" wave is an unavoidable trend driven by various opportunities. The oil and gas sector may significantly increase efficiency and reduce costs by utilising several advanced technologies in "Oil & Gas 4.0." However, there are numerous challenges in the first phases, just like previous sector reforms (Lu et al., 2019). The barriers mentioned in this chapter are given in Figure 2 and SWOT analysis of adopting IoT and Big Data technologies is given in Figure 3.

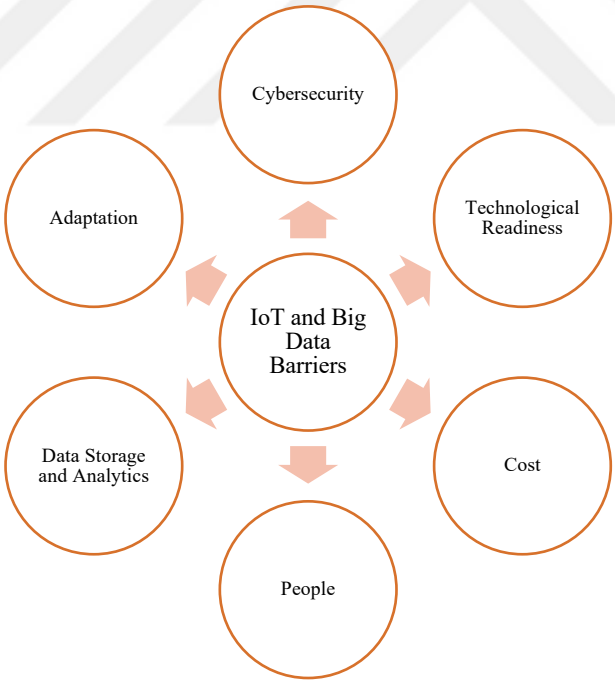

Figure 2 - The Barriers to Implementing IoT and Big Data Technologies

5.1. Cybersecurity

The most important factors that must be considered while creating any system are security and privacy (Alabadi, Habbal and Wei, 2022). Cybersecurity is a growing problem as supply chains become more digitalised and depend on the real-time coordination and communication of various devices such as sensors, robotics, and drones. For instance, digitalised supply chains may be susceptible to assaults since Industry 4.0 contains numerous devices interacting via various operating systems and information systems (Tang and Veelenturf, 2019).

Nguyen, Gosine and Warrian (2020) point out that cyber attackers have been highly advanced and frequent in their attacks on various businesses and organisations in recent years. Security issues became more challenging by the exponential rise of cyber-physical systems. Additionally, Wanasinghe et al. (2020) note that the energy sector was ranked the second-largest target for cyber-attacks in 2016.

G. Alakbarov and A. Hashimov (2018) claim that although the services offered by IoT applications provide enormous advantages, they might severely compromise security and privacy. With the ability to engage from anywhere, IoT devices produce a significant amount of data. The risk to privacy would undoubtedly rise with millions of networks spread over various and scattered locations (Singhai and Sushil, 2021). Therefore, The IoT architecture is vulnerable to security risks and assaults at every layer (G. Alakbarov and A. Hashimov, 2018). Lastly, Wanasinghe et al. (2021) suggest that the conventional disconnected structure is less vulnerable to cyberattacks than real-time human cyber-physical connection.

To show the importance of cybersecurity, Nguyen, Gosine and Warrian (2020) provide an example of pipelines. One of the main problems for midstream O&G is protecting pipeline networks from remote cyber-attacks. The costs associated with cybersecurity pipeline events include expenses associated with business disruptions, property damage to third parties, equipment failure, and control system failure.

5.2. Data Storage and Analytics

Managing the data collection, storage, and analysis is one of the most significant issues facing IoT and Big Data applications in any business, including the O&G sector (Mohammadpoor and Torabi, 2018) (Baig, Shuib and Yadegaridehkordi, 2019). As previously mentioned, IoT sensors produce a large amount of data each day, also referred to as big data. The O&G industry's next major difficulty will be how to store and analyse this vast amount of data (Wanasinghe et al., 2020). The transmission of information between devices is also crucial in IoT since there are so many devices utilised in the industry. The key obstacles to synchronising the actions are communication and device integration (Mishra et al., 2022). Similarly, with the development of digital oilfields, where numerous sensors and recording devices are creating millions of data each day, Big Data's advent in the oil and gas industry has grown more significant. (Mohammadpoor and Torabi, 2018).

Therefore, Alabadi, Habbal and Wei (2022) listed data aggregation strategies, data storage methods, and data analysis techniques as some of the key requirements for IoT and Big data applications. Lastly, Mohammadpoor and Torabi (2018) emphasise that the major difficulties in digital oilfields are data transport from the field to data processing facilities, decision-making based on pertinent data, and a lack of skilled staff.

5.3. Cost

A lot of equipment and systems need to be replaced when operating models change (Lu et al., 2019). Therefore, implementing the technology necessitates significant capital investment and concentrated efforts at every level of the government, legal system, and organisation (Nguyen, Gosine and Warrian, 2020). In contrast to other industries, the O&G sector has unique working circumstances because of the harsh noise, weather, and dangers present in the environment. For instance, the entry of any electronic equipment into an explosive environment must pass extensive tests of health, safety, and environmental concerns (Wanasinghe et al., 2021).

G. Alakbarov and A. Hashimov (2018) pinpoint a number of significant requirements for the devices, such as working in challenged areas with extreme environmental and platform

conditions, being integrated with current IT systems, being dynamic, adaptable, and self-configurable, being able to provide services in a rapidly changing system environment, and being based on transparent, global standards. Considering these requirements, it is clear that applying technologies to the sector will cause a significant cost.

Lastly, Wanasinghe et al. (2020) draw attention to another crucial cost: maintenance. Some asset integrity monitoring tools for the O&G sector gather information from thousands of sites. Keeping track of failures, assessing performance, and carrying out repairs and infrastructure replacements for faulty devices or infrastructure while managing such a sizable sensor network and infrastructure is a challenging and expensive operation.

5.4. People

It is significant to recognise that many people and organisations find it far simpler to continue to operate as usual than to make changes. The danger that comes with change does not sit well with people or organisations. The workforce frequently rejects change and sticks with methods that have worked in the past. This way of thinking is typical of the oil and gas sector and might have a negative impact on attempts to use IoT and Big Data (Wanasinghe et al., 2020). Nguyen, Gosine and Warrian (2020) highlight the need for departmental cooperation to deploy and use the technologies efficiently. Because of the lack of communication between the IT department and others, any issue, such as password reset to access personal accounts of field workers, might take a long time to resolve (Nguyen, Gosine and Warrian, 2020).

Additionally, Choubey and Karmakar (2020) and Wanasinghe et al. (2021) draw attention to workers' lack of knowledge. Choubey and Karmakar (2020) report that most universities/institutions do not include data analytics in their petroleum engineering programs. As a result, petroleum engineers find it challenging to use these techniques. Similarly, Wanasinghe et al. (2021) point out that the operators who will choose whether to rely on experience or machine-based supporting aids for decision-making are probably unaware of how the systems work inside. Particularly during unforeseen and emergent situations, a device's effective use and trustworthiness may be compromised by the operator's lack of understanding of the supporting systems.

5.5. Technological Readiness

There are many technological obstacles to overcome in developing and implementing IoT systems for O&G facilities (Baig, Shuib and Yadegaridehkordi, 2019). Most O&G production, storage, transportation, and refinery facilities are considered hazardous. A variety of regulations apply to any hardware system, such as equipment, sensors, and actuators installed in these zones. This poses several technical difficulties for those creating and implementing IoT-enabled systems for O&G facilities (Wanasinghe et al., 2020).

The study by Wanasinghe et al. (2021) list some difficulties: designing safe, smart, portable, and wearable technology that will be used in O&G workplaces takes months. Prototype testing is not a practical choice at big volatile locations, such as production, storage, transportation, or refinery facilities, making field tests almost impossible. New smart, portable, or wearable technologies may quickly become obsolete after being introduced due to the lengthier product development life cycle and the rapid speed of technological advancement.

The primary goal of the IoT system implementation is data collection to facilitate informed decision-making. The quality, accuracy, and precision of the data that is gathered and delivered, however, may vary depending on the field circumstances. As a result, all IoT devices and communication infrastructure must be created to work in various industrial and environmental circumstances and produce and transmit high-quality data to the control centres (Wanasinghe et al., 2020).

5.6. Adaptations

It takes time to evaluate the implementation of new technology, and it also takes time to adapt the strategy to fit the new environment (Lu et al., 2019). Different IoT platforms, devices, communication protocols, security protocols, and hardware/software combinations may be used by various suppliers. The implementation of end-to-end IoT-based solutions for any sector requires the unification of a sizable number of smart devices from several suppliers into a single network (Singhai and Sushil, 2021). Therefore Wanasinghe et al. (2020) argue that the main problem comes from integrating current IoT tools with legacy systems that are already

deployed on O&G platforms, not from deploying newer IoT devices. These communication protocols could be out-of-date and updating them might require substantial capital expenditure and more facility downtime.

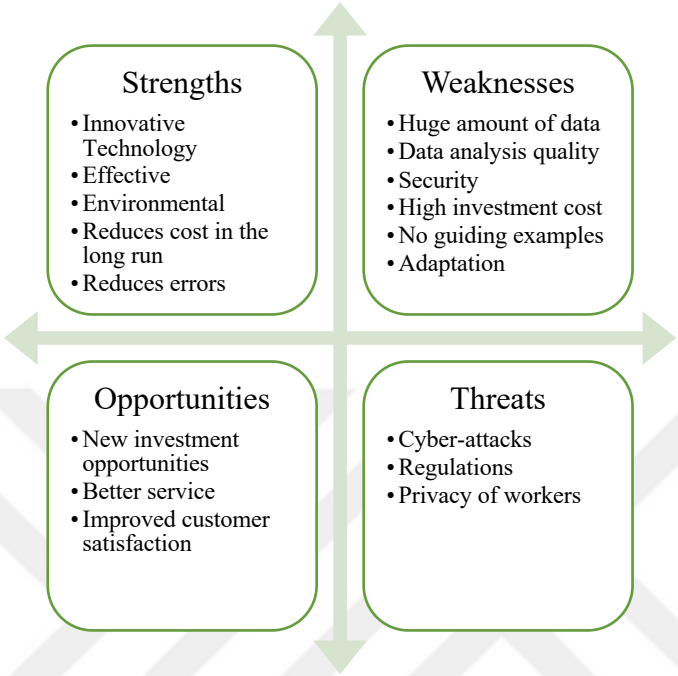

Figure 3 - SWOT Analysis of IoT and Big Data Implementation

The following barriers ranking (see Figure 4) can be made from the findings in the literature. However, the analysis is mostly superficial, based on their cost and effect on the business. Considering how important the oil and gas industry is economically, politically, and socially, the most severe of these barriers is probably cybersecurity. High investment costs can be considered the second most severe barrier because it is one of the main reasons underlying the other difficulties mentioned. Data storage and analytics and technological readiness come next in ranking as they require both the adoption and purchase of new technologies. Finally, people and adaptation, which are more dependent on time and investment, come in the rankings.

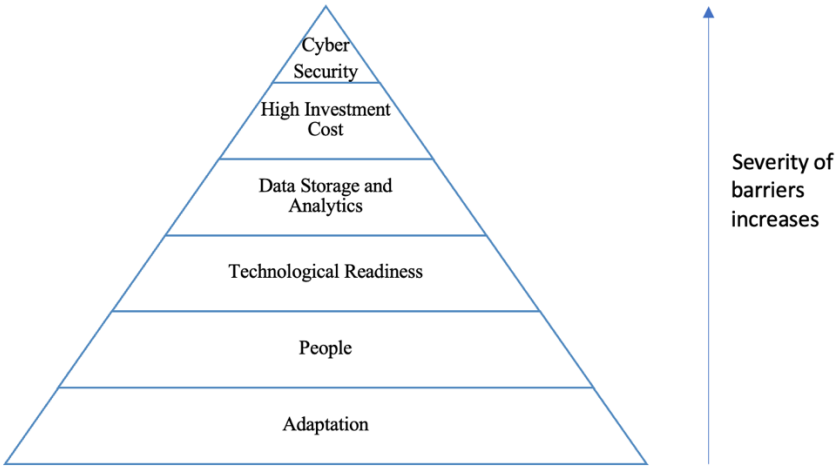

Figure 4 - Severity of Barriers

5.7. Recommendations

Implementing IoT and Big Data technologies in oil and gas logistics management has some barriers. Therefore, followed recommendations are proposed to mitigate these barriers:

For Cybersecurity

- To decrease the response and reset times of the system under cyber-attack, management and communication between IT and other departments must be improved (Nguyen, Gosine and Warrian, 2020).
- A trustworthy and secure decentralised IoT monitoring and control system for the oil and gas sector is achievable with the help of blockchain (Zuo and Qi, 2022).
- In order to store and process data and transactions, blockchain is designed to use a distributed peer-to-peer architecture. The data is successfully protected against a single point of failure issue thanks to distributed storage and processing, which results in a system that is extremely secure, dependable, and available (Ahmad et al., 2022).
- Blockchain helps to secure and simplify the trade of oil and gas, shipment tracking, inventory control, paperwork, billing, and payment processes. By making the involved

business procedures transparent, it streamlines the cumbersome and complicated oil and gas supply chain processes (Ahmad et al., 2022).

For Data Storage and Analytics

- Companies should concentrate on data collecting and improve the ability to distinguish between different data quality levels. Integration and automated data analysis from many sources need to be considered (Lu et al., 2019).
- The government can direct businesses to concentrate on the most critical areas, such as artificial intelligence for data analytics (Lu et al., 2019).
- An O&G company might use a third-party IoT cloud to store and process data. By utilising a third-party IoT cloud, the need for and expense of more extended IT resources and a bigger data warehouse are avoided. However, when outsourcing, the oil and gas company must develop a clear understanding with the outside service provider regarding who owns the data, how it is secured, who has access to it, and who is responsible for what (Wanasinghe et al., 2020).
- Applying real-time data processing tools like artificial intelligence and machine learning algorithms to help the data-driven decision-making process (Wanasinghe et al., 2020).
- Blockchain technology offers transparent and unchangeable data storage to document all transactions (Zuo and Qi, 2022).
- Blockchain-based smart contracts can be developed to assist oil and gas companies in processing data to precisely identify the gas leakage location and preserve the integrity of the pipelines (Ahmad et al., 2022).

For Cost

- To cut costs, the government may implement specific tax laws for companies (Lu et al., 2019).

- Each company can create its own Big Data tools, including data recording, data analytic tools, and storage systems. The price of software ownership would go down as a result (Mohammadpoor and Torabi, 2018).
- Making use of blockchain technology. The oil and gas supply chain is tracked using blockchain, which also audits and records equipment throughout its lifecycle. This increases supply chain transparency, lowers logistics costs, and boosts operational effectiveness (Lu et al., 2019).

For People

- Universities can provide related courses (Lu et al., 2019).
- To reduce the impact on the workforce, the organisation should evaluate the impact of IoT adoption and develop a plan to reskill and restructure the current staff (Wanasinghe et al., 2020).
- Delivering the results as a user-friendly interface by working with a multidisciplinary team of petroleum engineers and computer scientists (Mohammadpoor and Torabi, 2018).
- Training the executive team and staff about new technologies and their applications (Mohammadpoor and Torabi, 2018).
- Blockchain smart contracts guarantee device autonomy and process automation, which reduces the need for human involvement and, conversely, the risk of human error (Aoun et al., 2021).

For Technological Readiness

- To tackle technical obstacles, more companies can collaborate (Lu et al., 2019).
- The standardisation of interfaces and related technologies should be given consideration. The procedures for cooperation and information sharing should be the main emphasis of standardisation (Lu et al., 2019).

For Adaptation

- Under the direction of the government, the O&G and other industries can be connected to create plans and attain standardisation (Lu et al., 2019).
- Universities and research facilities can work on projects together with the oil and gas sector for the adaptation of the new technologies (Wanasinghe et al., 2020).

The suggested order for the implementation of the recommendations is given in Figure 5.

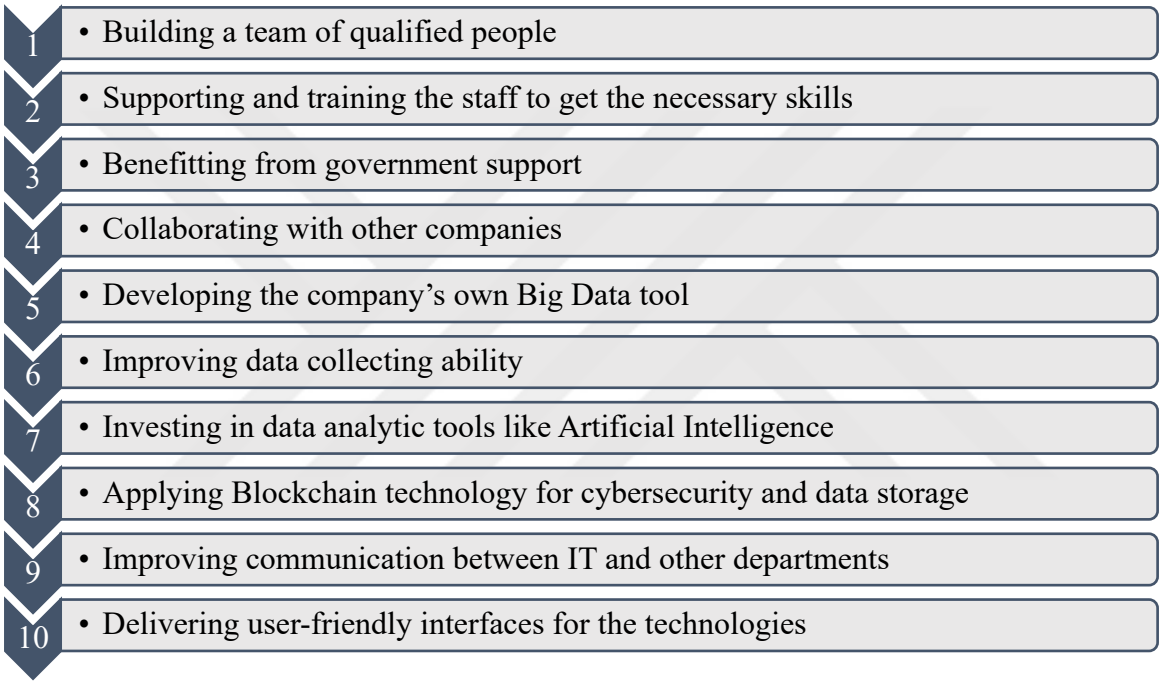

Figure 5 - Order of the Implementation of the Recommendations

6. Conclusion

As far as technological advancements go, the oil and gas sector has significantly improved. The oil and gas companies were compelled to cut their cost because of falling oil prices and more strict regulations. The increasing oil and gas operations and the unpredictable and dangerous working environment have prompted businesses to use Industry 4.0 technologies. Businesses are adopting IoT and Big Data technologies to optimise manual processes, increase operational effectiveness, and reduce costs.

For this dissertation, a systematic literature review was conducted to answer the three research questions: How do Industry 4.0 technologies (IoT and Big Data) improve the logistics in the oil and gas industry? What are the barriers faced by oil and gas companies in applying Industry 4.0 (IoT and Big Data) technologies to logistics management? What are the adaptation recommendations for implementing Industry 4.0 technologies (IoT and Big Data) that oil and gas companies can follow? While many studies in the literature focus on the use of Industry 4.0 technologies in exploration and production, this study focuses on the developments that can be made in logistics management. The study focused on four main themes where logistics could be improved with IoT and Big Data. These are pipeline safety, fleet management, equipment maintenance and real-time monitoring. Although there are benefits mentioned, these technologies have some difficulties for companies implementing them. The barriers mentioned in this study are cybersecurity, high investment cost, technological readiness, adaptation, people, data storage and analytics. In addition, some recommendations that companies can implement to tackle these barriers are mentioned.

A number of limitations need to be acknowledged regarding the present study. Although this study demonstrated the improvement ways, barriers, and recommendations for applying IoT and Big Data, it was also intended to create a road map for O&G companies to implement IoT and Big Data technologies step by step. But due to the limited time, a road map could not be created. Another limitation is the lack of road maps in the literature. Much of the work does not mention how these technologies can be integrated into existing infrastructure. Similarly, since the oil and gas industry has recently started to adopt these technologies, studies in the

literature theoretically talk about how these technologies will improve the system and their benefits. It is challenging to find a study in which IoT and Big Data have been applied in oil and gas logistics management, and the results have been observed. Therefore, all the studies remained theoretical regarding improvement, barriers and recommendations, and no real-life observations were made in practice.

Further research is needed to understand the impact of IoT and Big Data on O&G logistics management and the risks associated with these technologies. Also, further studies need to be carried out to validate the recommendations mentioned in this dissertation from experts and experiments. More research in this field could focus on other aspects of the improvement ways. For instance, studies on leakage detection warning and leak location determination are more common than studies on leakage measurement and leak rate prediction.

Taken together, this study highlights the importance and barriers of advanced technologies (IoT and Big Data) for O&G logistics management. Although there are some barriers, the industry should apply these technologies to increase effectiveness and safety and decrease costs in the long term.

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