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Industry Revolution 4.0: The Challenges in Oil and Gas Industry in Saudi Arabia

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Abstract

The 4th industrial revolution (4IR) has caught the attention of many researchers and organizations around the world and they have started to work towards the implementation of such technological advancement. Saudi Arabia has caught the attention of local industries in the implementation of 4IR technologies. However, local oil and gas companies may encounter challenges that affect their business in implementing 4IR technologies. This paper aims to identify challenges affecting the implantation of 4IR technologies in the oil and gas sector. Several challenges have been identified in this study based on the literature and experts interviewed. Data were collected and analyzed using descriptive analysis, exploratory factor analysis, and hypothesis testing to identify, analyze and justify the main challenges affecting the implementation of the 4th industrial revolution technologies in oil and gas companies in Saudi Arabia. The top 5 ranked challenges were identified as having 'security issues as the first and main challenge, following are 'low 4IR understanding', 'Lack of integration of technology platform', 'Lack of global standards and data sharing protocols, and 'Lack of government support and policies. Tackling these top 5 main challenges now will provide a clear path to implementing the 4th industrial revolution technologies in local oil and gas companies.

Keywords
Industry 4.0, Oil and gas, Challenges and Industry revolution.

1. Introduction

Organizations have recently focused on finding new ways to improve their business methodologies in order to reduce costs and increase productivity. They try to improve and modernize their work procedures and information-gathering methods. Oil and gas industries tend to digitalize and incorporate the technology in tier processes. In the upstream sector, the oil and gas industry relies heavily on technology for identifying geological locations and heavy equipment to extract oil and gas, as well as raw data and statistics. The downstream sector, on the other hand, can be more complex because it relies on the upstream sector to provide enough raw data to manipulate the source of material into a meaningful product.

Nowadays, the use of the internet has been growing dramatically, where all things can be connected. A thriving element that is believed to be the beginning of the 4th industrial revolution (4IR), connecting most of the physical aspects with digital technologies such as Artificial Intelligence (AI), Robotics and Drones, Automation, Industrial Internet of Things (IIOT), Cloud Computing, Virtual and Augmented Reality, Cybersecurity and more. This defines the objectives and aspects of the 4th industrial revolution, which focuses solely on transforming the way we live and work from the current habits that we now abide by to a more advanced and easier lifestyle.

Saudi Arabia, the world's largest oil producer which caters to around 17% of the world's petroleum reserves announced the development of the project NEOM in October 2017, which is heavily involved in the 4th industrial revolution technologies and is part of Saudi Arabia's vision of 2030. This announcement, along with other similar projects, encourages the implementation of new technologies in businesses, which will hopefully result in a better business outcome. Implementing the 4th industrial revolution technologies in the oil and gas industry may encounter challenges that frustrate the industry in achieving the goals of 4IR.

Businesspeople broadened their way of thinking upon the introduction of the steam engine in the late 18th century which was a new way of producing energy that lead manufacturers to accelerate their manufacturing processes and improve economies. The introduction of the steam engine in the late 18th century was also known as mechanization, which is the beginning of the industrial revolution, also known as the first industrial revolution. The second industrial revolution was introduced in the late 19th century which was a huge breakthrough in technological advancement and a new method of generating and utilizing energy which is the introduction of Electricity, Oil, and Gas. The second industrial revolution (also known as the electrification era) lead to mass production for manufacturers and energy-generating companies. In addition to that, transportation vehicles were invented in this era as well which helped in transporting equipment, labor, and materials. The third industrial revolution, also known as the automation era introduced computers, electronics, and communication systems in the mid-20th century. This was also a big breakthrough in which communication and business processing became much easier and faster.

Nowadays, there is a greater breakthrough in technological advancement by combining physical and digital aspects for a greater outcome. The new era is known as the 4th industrial revolution which started with the introduction of the internet. A trend that many have started to have interest in recent years with regards to Internet of Things (IOT) and Cyber-Physical Systems (CPS) (Liao, 2018). The 4th industrial revolution consists of the internet, artificial intelligence, virtual and augmented realities, cloud computing, the industrial internet of things, big data, system automation, 3D printing, etc. The 4th industrial revolution will reshape society and businesses with the technological concepts of digitalization, transparency, Autonomation, availability of real-time information, and collaboration (Hans, 2017). Through each era, people will have to go through a lot of challenges and hardships to open new opportunities for the betterment of society and businesses. Each industrial revolution is a timespan of a century, and with the advancement in technology. Figure 1 illustrates the industrial revolutions development.

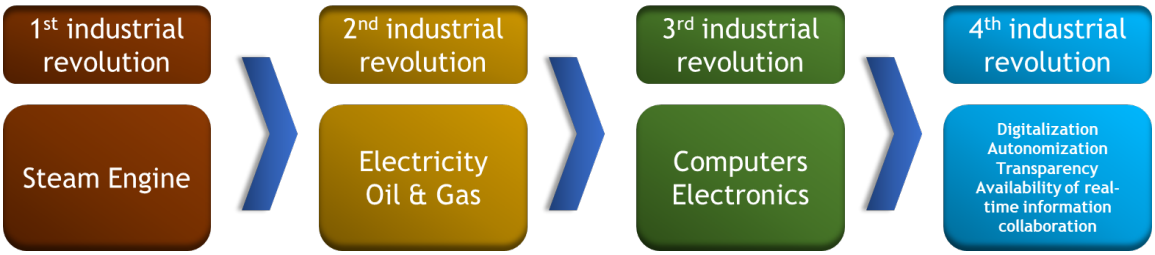

Figure 1. Industrial Revolution

The objective of this paper is to identify the challenges of industry 4.0 in the oil and gas industry. The challenges are identified based on the literature and experts reviewed. Then, a survey is well-developed and distributed to experts in oil and gas companies and services to collect data. Several statistical analyses and hypothesis testing are used to determine the top most effective challenges of the implementation of the 4th industrial revolution technologies in oil and gas companies.

2. Literature Review

Many challenges have been identified in implementing the industrial revolution in different industries. These challenges include security issues, finance issues, lack of management support, etc. (Xu, 2018) discussed one of the most challenging aspects of implementing the 4th industrial revolution, which is the security issues since the future shows that everything is connected and we cannot avoid that fact with the implementation of the IoT. The author also stated that there are benefits to this implementation such as cybersecurity, but it comes with a greater risk. (Sommer, 2015) discussed how security is becoming more vulnerable for businesses when adapting the 4th industrial revolution technologies. 59% of the responders agree that the challenge when adapting to the 4th industrial revolution would be the IT security problems. The more advanced we become in the networking and internet infrastructure, the more complex it gets for security in our businesses (Pereira, 2017). The 4th industrial revolution technologies such as cloud-based systems, the internet of things, Big data, and other IT-related technologies are not only beneficial but also have

a downside in the security aspects of things due to the fact that security measures will be more complex and will have higher security risks.

Branke (2016) addressed how security is a challenge when connecting everything to the internet which relates to data security of intellectual property and company data, this is in relation to the bio-pharmaceutical industry which is a very serious matter to handle sensitive health-related information. The more connected, the risker it is to prevent cyberattacks. (Panchal, 2018) illustrated that the industrial internet of things (IIOT) is a very important technical aspect that connects industrial machines with their instrumentation attributes to function in an efficient and smart manner for manufacturing companies. The author highlighted the cyberattacks on cyber-physical systems which is a great security threat. According to the findings, the author categorized Information Technology (IT) and Operation Technology (OT) which defines the IIOT integration system. This categorization has provided layers of security risks for each category and the possibility and causality of attacks if not taken responsibly. Therefore, the finding of this work falls under the security category.

Fuchs (2018) considered a large-scale agile transformation when approaching the implementation of the 4th industrial revolution technologies in the overall aspects of businesses and society. The author revealed three challenges, however, the main challenge is the coordination of different organizations. This shows the difficulties of how multiple teams from different organizations perceive the 4th industrial revolution concept, which makes it difficult for parties to agree on certain standards and terminologies. Lee (2014) discussed the importance of the advancement of machines in manufacturing companies, that in order to achieve 4th industrial revolution standards of machines, manufacturers need to consider five categories related to a collaborative self-aware and self-learning machine. The five categories are manager and operator interaction, machine fleet, product and process quality, big data and cloud, and sensors and controller network. These five categories result in a very challenging collaboration aspects for machines in manufacturing companies to do the work precisely without faults.

Branke (2016) presented that data-sharing protocols and international standards will be a very challenging task in order to understand one another when implementing the 4th industrial revolution technologies. Since the future seem to have everything interconnected, it will be easy for the mechanism of data transfer, however manufacturers, vendors, and other organizations will have to abide to a common understanding by having some kind of global standard for all to abide by and data transfer protocol. Yucel, (2018) discussed how complex digital transformation (part of 4th industrial revolution) is with regards to understanding, business, management, support, culture, technology implementation, and strategy. And the difficulties that comes with measuring risks and mitigation plans for the success of digitalization. The author discussed how things needs to be characterized and identified to measure digital transformation benefits, and for the betterment of the success of this matter is for the corporation to develop a sound strategy and evaluate it.

Chandrasekara (2020) conducted a study based on the literature on technologies that would be appropriate for the procurement processes with the full support of all procurement functions. However, according to the literature, no interoperability of systems or applications are yet to be found that can withstand all procurement functions. Most of what was found are web-based applications that carry out procurement activities. Hoffmann (2017) presented 4IR logistics application model and the core components. Various logistic scenarios were presented to industrial experts. Studies have shown that there is a low understanding of the 4th industrial revolution concept. The literature utilized in the paper also shows that the definition of the 4th industrial revolution is still unclear among researchers and practitioners. This is due to the fact that managers are most likely unaware of its consequences on whether it sustains supply chain objectives. Hermann (2015) studied the definition of the 4th industrial revolution through literature and provided a solid definition of the subject matter. However, the author identified six design principles for its implementation: interoperability, virtualization, decentralization, real-time capability, service orientation, and modularity as shown in Table 1.

Table 1. Design principles of each 4th industrial revolution component (Hermann, 2015)

	Cyber-Physical Systems	Internet of Things	Internet of Services	Smart Factory
Interoperability	X	X	X	X
Virtualization	X	-	-	X
Decentralization	X	-	-	X
Real-Time Capability	-	-	-	X
Service Orientation	-	-	X	-
Modularity	-	-	X	-

Table 1 shows the implementation of each technology and its contribution to the defined categories. It can be seen that not all 4th industrial revolution technology has the capability of covering most of the 4IR defined categories to be labeled as a 4IR technological material. The research and development point of view is not yet developed to the stage where it can contribute to cyber-physical systems. (Schröder, 2016) studied the implementation of the 4th industrial revolution technologies and how there are certain constraints and obstacles that are preventing that from happening and have to be taken into consideration to overcome these obstacles. These obstacles are:

- Lack of a digital strategy alongside resource scarcity
- Lack of standards and poor data security

However, new technologies to be implemented tend to have a certain challenges when it comes to society, legal, and ethical obstacles. Will this technology benefit, harm, and assist society, is it built, designed, and purpose of used for legal purposes? Legal issues should be considered when adopting new technological ideas.

Savtschenko (2017) discussed the importance of Cyber-Physical Systems (CPS) for business in which all physical aspects are interconnected with the virtual world, or the internet. The concern is that enterprises are worried about internal data being sent to external systems for storage such as cloud-based systems. Since data can be sensitive, however, they lack confidence in such technologies hence management support is not provided as much as it requires. (Ras, 2017) presented the challenges augmented reality technology may encounter in the complexities of a cyber-physical system. The author stated that the current factories are more used to the work they do now than being introduced to a more sophisticated technology. Introducing these new technologies to them would take a long learning curve to get used to, simultaneously, they are more hesitant to utilize modern technology as they are unaware of its concept or use. The challenges provided in this article were four, and one of them is related to the implementation of the AR technology which is complex. This demonstrates the lack of digital culture in the current day workforce. (Kiel, 2017) have studied the implementation of the industrial internet of things (IIOT) in the manufacturing industry through economical, ecological, and social terms. The author has identified many challenges of implementing IIOT technology by conducting 46 interviews with experts from different manufacturing companies. The study shows that most experts agree that the most challenging aspect of implementing IIOT is the technical integration of this technology which demonstrates the complexities of implementing new technologies which deter manufacturing companies and find it as a threat rather than a solution.

(Marques, 2017) discussed how the current manufacturing companies will face some difficulties meeting customer requirements in the near future, hence a strategic plan requires implementation. The challenge which manufacturers face today is how customers are willing to customize their products which requires manufacturers to comply with customer needs. In western countries, mass production is becoming less reliant and mass customization is being more preferable to customers. The manufacturers will require to upgrade their machines and other systems to meet customer needs and requirements. This is a challenge for manufacturers to decide based on the complexity of the situation as it is unclear how economically this will benefit them.

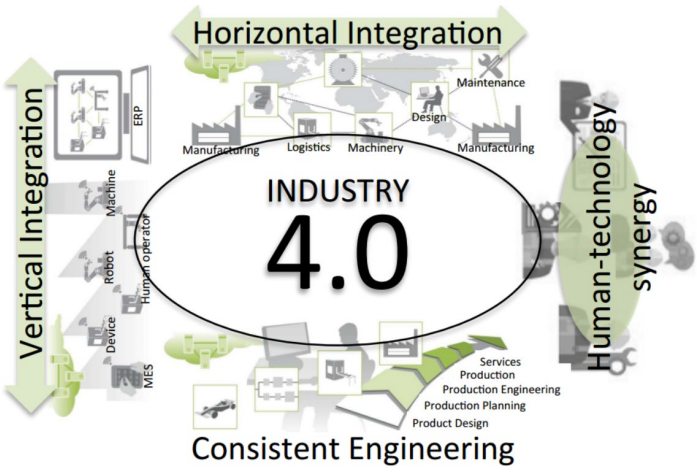

Figure 2. Main Characteristics of 4IR (Marques, 2017)

The author proposed a strategy that will answer the challenges of which was identified in the article as shown in Figure 2 , which relates to vertical integration, horizontal integration, consistent engineering, and human technology synergy. All four categories need to be well planned to have the full potential of a skilled-based workforce to deliver the product to the consumer accordingly. (Leita˜o, 2016) highlighted the importance of Cyber-Physical Systems (CPS) implemented in the workforce. However, the implementation of CPS requires tackling major challenges, and one of the major challenges which is the most relevant to our study approach is the CPS infrastructure or in other words the infrastructure and internet-based networks. To have a high-quality network infrastructure, having a strong internet connection is a very important element to have CPS services work properly with their technology integration in applications.

(Saucedo, 2017) showed how the 4th industrial revolution is perceived as a challenge for current manufacturing companies as it requires a massive change in the ideologies of current management in approaching the implementation of 4IR technologies. Knowing that requires to have strong logistical data to overcome 4IR obstacles in the business of today. These changes require the adoption of new business models to adapt to the 4IR atmosphere due to the fact that future businesses will look at people's talents rather than skills. (Gökalp, 2016) stated the importance of having necessary data that develops the foundation and infrastructure of Big Data technology. Big Data relies heavily on well-structured network infrastructure and database systems. Challenges that big data technology may encounter are a large amount of unstructured data from the Internet of Things (IoT) devices, expertise barriers, resource management, and delivery of results to appropriate channels as stated in the article. A conceptual framework was developed to tackle these challenges to be utilized in a smart enterprise to prevent users from low-level complexities. (Gigova, 2019) stated that the opportunities the 4th industrial revolution can provide for businesses, but is a very expensive investment. This requires a change in processes and upgrades in machines in the manufacturing industry with high technological equipment with automated systems. Qualified employees are required to maintain the machines that will lead the production industry. The staffing requirements will be digital competence-based, and business models will be rearranged to accommodate the more modern digitalized business needs.

The literature indicated that the is a lack of identifying the challenges of industry revolution 4.0 in the oil and gas sector. Consequently, the purpose of this paper is to identify the challenges of implementing the Fourth Industrial Revolution in the oil and gas sector. The challenges are identified based on the literature. In addition, a survey is distributed to oil and gas companies, as well as oil and gas-related service companies, to identify the challenges they believe will be a burden in achieving 4IR implementation goals. Survey results are analyzed using Exploratory Factor Analysis (EFA) and hypothesis testing to determine the ranking of the challenges oil and gas companies.

3. Research Methodology

This section describes the methods used for this paper. The method utilized is a qualitative survey approach that covers the challenges identified in the literature review. Table 2 summarizes the challenges based on the literature as well as the experts interviewed, with different authors having different opinions and conclusions about the challenges of 4IR

implementation. After identifying the challenges and obtaining survey results, an Exploratory Factor Analysis (EFA) shall be used to eliminate challenges that are not significant to the main causality of the oil and gas companies' struggle, and hypothesis testing will be implemented to insure the ranking according to the survey results are reasonable to obtain the final ranking of the challenges towards the oil and gas industry in Saudi Arabia.

Table 2. Challenges identified based on literature and experts interviewed

No.	Challenges	Authors
1	Low 4IR Understanding	(Hoffmann, 2017)
2	Poor Research and Development on 4IR Adoption	(Hermann, 2015)
3	Legal Issues	(Schröder, 2016)
4	Poor Company's Digital Operation vision and strategy	(Erol, 2016)
5	Low Management Support and dedication	(Savtschenko, 2017)
6	Profiling and complexity issues	(Yucel, 2018),
7	Lack of digital culture	(Ras, 2017)
8	Hesitant towards 4IR	(Kiel, 2017)
9	Unclear economic benefit of digital investments	(Marques, 2017)
10	Lack of global standards and data sharing protocols	(Branke, 2016),
11	Lack of infrastructure and internet-based networks	(Leita˜o, 2016)
12	Lack of competency in adopting new business models	(Saucedo, 2017)
13	Poor existing data quality	(Gökalp, 2016)
14	Lack of integration of technology platforms	(Chandrasekara, 2020)
15	Problem of coordination and collaboration	(Fuchs, 2018), (Lee, 2014)
16	Security issues	(Xu, 2018), (Sommer, 2015), (Branke, 2016), (Panchal, 2018)
17	Financial constraints	(Gigova, 2019)
18	Lack of government support and policies	By experts
19	Can't leave old habits	By experts
20	Doesn't make a difference	By experts

The questionnaires of the survey were studied and reviewed by subject matter experts in this field. The questions were prepared using google forms to develop the survey questions and then distributed to oil and gas companies and services to participate in the survey. A detailed graph of this methodology is shown in Figure 3. The survey is divided into 3 sections, Demographics, 4th industrial revolution and Company (this is with regards to awareness, and how the company behaves towards 4IR), and 4th industrial revolution Challenges.

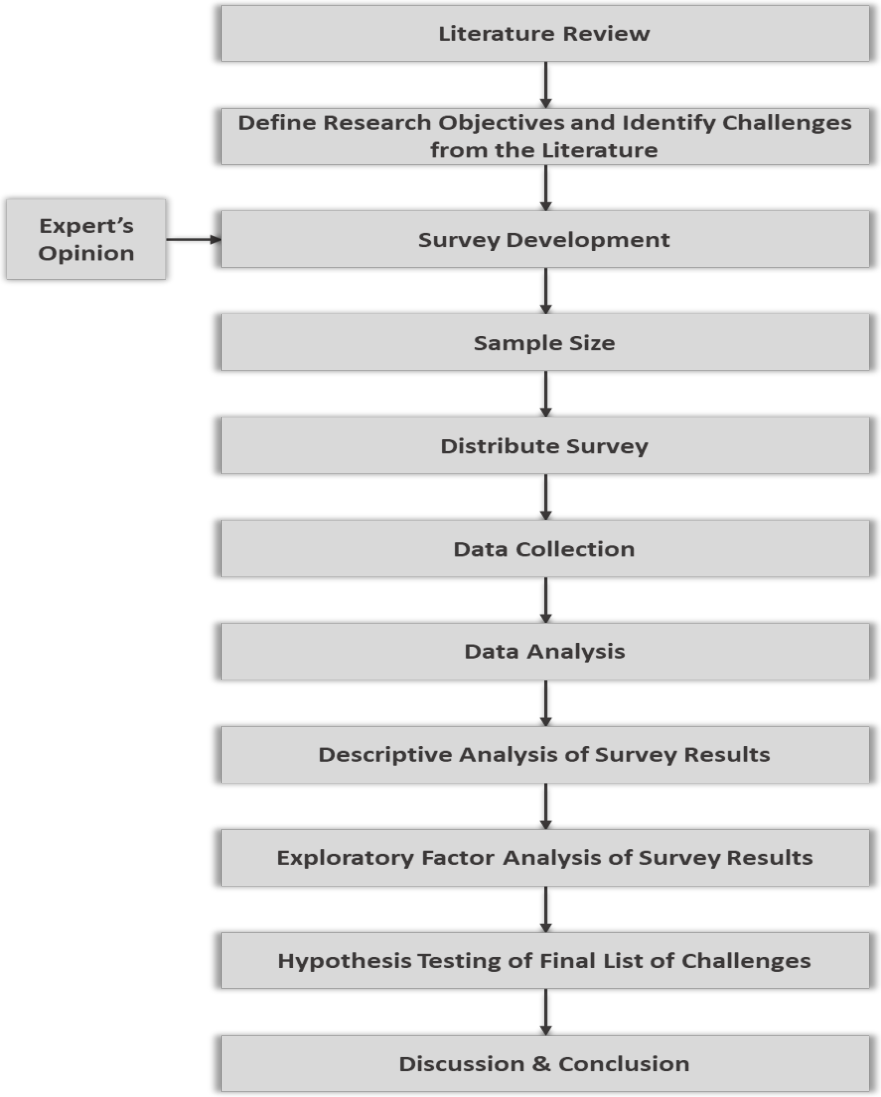

Figure 3. Research Methodology

4. Results and Discussion

This section discusses the findings from the survey and the statistical analysis implemented of the data collected from the responders. The results and analysis consist of six sub-sections, demographic analysis, survey results, descriptive analysis, exploratory factor analysis, hypothesis testing, and summary of findings. First, the sample size for this survey was determined by utilizing the following equation:

$$n = \frac{\left(z_{\frac{a}{2}}\right)^2 \times p \times (1-p)}{E^2} \qquad (1)$$

The Z-value or ($Z_{\frac{a}{2}}$) is 1.645 which is the confidence level of 90%. p is the population proportion of 50% which in this case ($p \times (1-p)$) will equal 0.25, E is the marginal error equal to 10%, adding all these values in the equation would provide us with:

$$n = \frac{(1.645)^2 \times 0.5 \times (1-0.5)}{0.1^2} = 67$$

The total number of responders to the survey is 68.

4.1 Demographic analysis

The first part of the questionnaire is designed to gather information about the participants' demographic characteristics. Participants in the survey are asked closed-ended questions about their years of experience and level of education. A total of 68 surveys were collected from oil and gas industry experts in Saudi Arabia. Figure 4 depicts the respondents' various years of experience in the oil and gas industry. As can be seen from the figure, more than 63% of reconsents have experience of more than 6 years. In addition, Figure 5 depicts the number of respondents according to their level of education. Based on Figure 6, more than 97% have at least a bachelor's degree.

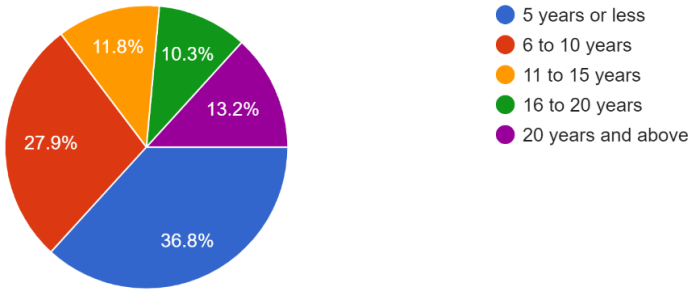

Figure 4. Work experience of the participants

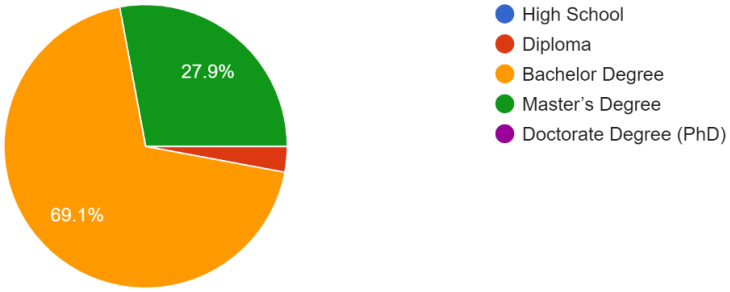

Figure 5. The academic level of participants

4.2 Survey Results

Figure 6 shows the raw data of survey results for the challenges of the industrial revolution 4.0 in the oil and gas companies in Saudi Arabia. It can be seen that the oil and gas companies' most challenging category towards the industrial revolution 4.0 technological implementation is the 'Lack of Infrastructure and internet-based networks' with a score of 230. Following that is the 'Security Issues' with a score of 226, 'Unclear economic benefit of digital investment' with a score of 223, 'Low 4IR understanding' with a score of 222, and then 'Lack of integration of technology platforms' with a score of 220. These are the top 5 most challenging categories that prevent 4IR implementation in the oil and gas industry in Saudi Arabia according to the raw data results from the survey. However, raw data survey results don't necessarily mean it is the most reliable and factual answer to the question at hand. A random number of responders with different background experiences involved in the survey requires to be considered. Therefore, the response to the survey results determines the quality of the actual answer to the problem. Statistical analysis is used to eliminate challenges that are not reliable to be the cause of struggle, and to identify the main ones that are the root cause of the problem which will be discussed in the following sub-sections.

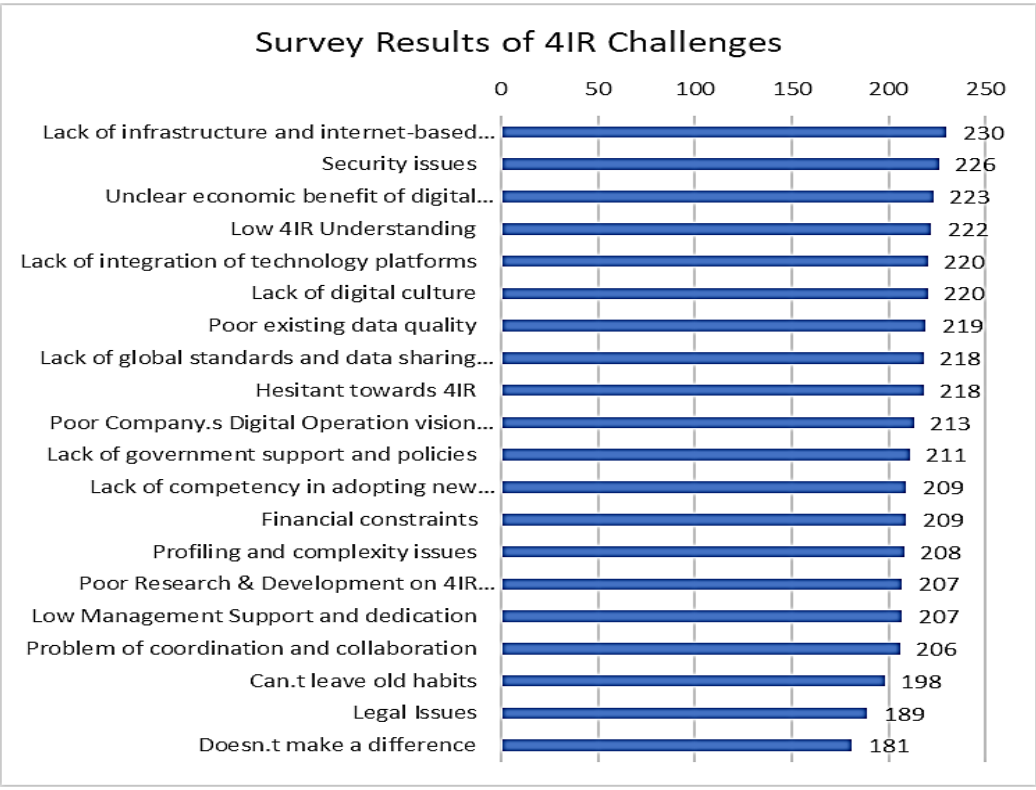

Figure 6. 4IR Challenges Survey Results

4.3 Descriptive Analysis

Prior to starting the actual statistical analysis of EFA, there is a need to determine if the survey results distribution is acceptable and filtered by removing outliers and cleaning up the data from errors. This method consists of two stages in this sub-section, descriptive statistics and regression analysis to understand the relationship between each challenge to another, and the way the regression analysis graph would look to be acceptable or not. Table 3 shows the descriptive statistics of the survey results. The descriptive analysis section was performed using Microsoft Excel. As shown in Table 3, all challenges are in the same mean range, and also, they are in an acceptable standard deviation level.

Table 3. Descriptive Statistics of Survey Results

	Low AIR Understanding	Poor Research & Development on AIR Adoption	Legal Issues	Poor Company's Digital Operation Vision and Strategy	Low Management Support and Dedication	Profiling and Complexity Issues	Lack of Digital Culture	Hesitant toward AIR	Unclear Economic Benefit of Digital Investments	Lack of Global Standards and Data Sharing Protocols	Lack of Infrastructure and Internet-based Networks	Lack of Competency in adopting new business models	Poor existing data quality	Lack of Integration of Technology Platforms	Problem of Coordination and Collaboration	Security Issues	Lack of Government Support and Policies	Financial Constraints	Can't leave old habits	Doesn't make a difference
Mean	3.265	3.044	2.779	3.132	3.044	3.059	3.235	3.206	3.279	3.206	3.382	3.074	3.221	3.235	3.029	3.324	3.103	3.074	2.912	2.662
Std. Error	0.134	0.132	0.139	0.136	0.136	0.131	0.122	0.121	0.145	0.133	0.119	0.133	0.139	0.133	0.131	0.152	0.160	0.147	0.146	0.152
Median	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Mode	3	3	3	3	3	3	3	3	3	3	3	3	4	3	3	4	2	3	3	3
Std. Dev.	1.101	1.085	1.144	1.118	1.125	1.077	1.009	1.001	1.195	1.100	0.978	1.097	1.144	1.094	1.079	1.251	1.317	1.213	1.206	1.253
Smpl. Var.	1.212	1.177	1.309	1.251	1.267	1.161	1.018	1.002	1.428	1.211	0.956	1.203	1.309	1.198	1.163	1.565	1.736	1.472	1.455	1.570
Kurtosis	-0.234	-0.200	-0.586	-0.523	-0.560	-0.475	0.012	-0.389	-0.726	-0.479	-0.564	-0.710	-0.851	-0.590	-0.170	-1.179	-1.130	-0.884	-0.655	-0.733
Skewness	-0.066	-0.234	0.265	-0.137	-0.089	0.028	-0.495	-0.154	-0.241	0.061	0.045	0.270	-0.080	-0.135	-0.060	-0.126	0.047	0.010	0.016	0.206
Range	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Minimum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Maximum	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Sum	222	207	189	213	207	208	220	218	223	218	230	209	219	220	206	226	211	209	198	181
Count	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68

4.4 Exploratory Factor Analysis (EFA)

The exploratory factor analysis is used to eliminate data not significant and not reliable to be the main challenges for 4IR implementation. After identifying the validity of the raw data collected from the survey, JASP software was utilized to perform exploratory factor analysis. The factor analysis and reliability tests were conducted and importing all challenges in EFA resulted in 55% of the challenges being eliminated and 45% maintained. Figure 7 shows the scree plot of the final eigenvalues of the challenges after eliminating the non-significant challenges. The eigenvalues with a massive variance between the two challenges show the rate of change to be high which resulted in two factors identified within the finalized list of challenges.

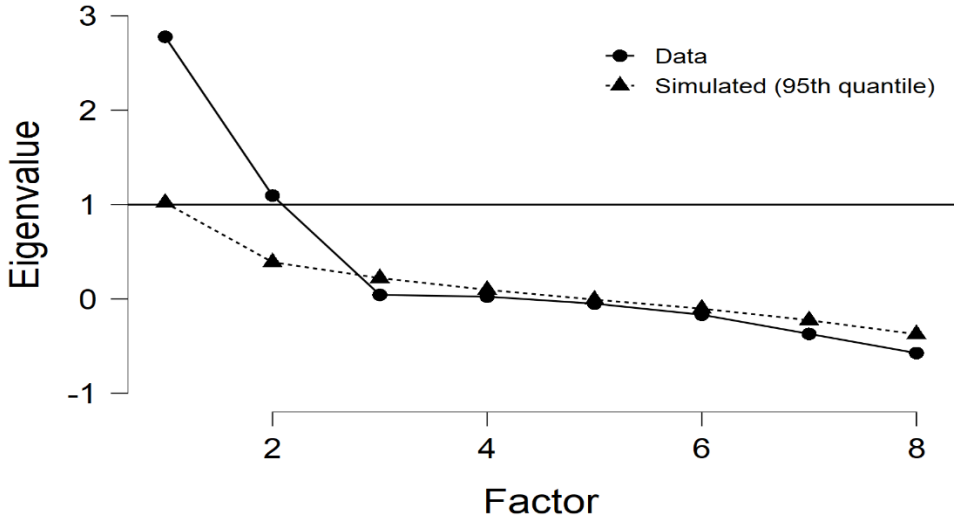

Figure 7. Scree Plot Displaying Challenges Eigenvalues

The reason behind eliminating the challenges is due to the factor loading being less than 0.5, factor loading of 0.5 and above is the acceptable range for the challenge to remain, anything lower than that should be eliminated according to (Hair, 2009) and (Robert, 1994). Second reason is due to the factor loading of a challenge is distributed to more than one factor which is unacceptable in our study due to its complexity, keeping it will have us dive deep into more complicated analysis of challenges with more than one-factor loading. Our focus of the analysis is simplicity; therefore, complexity should be eliminated. This leaves us with 45% of the challenges as shown in table 4.

Table 4. Factor Loadings of 4IR Challenges

Factor Loadings			
	Factor 1	**Factor 2**	**Uniqueness**
Low 4IR Understanding	0.609		0.654
Legal Issues	0.631		0.559
Low Management Support and dedication	0.725		0.389
Lack of global standards and data sharing protocols	0.744		0.481
Lack of integration of technology platforms		0.903	0.236
Problem of coordination and collaboration		0.617	0.503
Security issues		0.832	0.216
Lack of government support and policies	0.631		0.578

The challenges identified were utilized in a single test reliability analysis according to Cronbach's α, Cronbach's α acceptable range should be 0.7 or above, and 0.8 or above is more preferable (Robert, 1994). However, the identified

challenges all pass the reliability test. As shown in Tables 5 and 6, each group with its own factor loading. The reliability test shows the high consistency of the challenges identified which takes us to the next process of conducting hypothesis testing to determine the difference between challenges and finalize the ranking.

Table 5. Single-Test Reliability Analysis (Factor 1)

Frequentist Scale Reliability Statistics			
Estimate	**Cronbach's α**	**mean**	**sd**
Point estimate	0.798	3.079	0.188

Frequentist Individual Item Reliability Statistics	
	If item dropped
Item	**Cronbach's α**
Low 4IR Understanding	0.786
Legal Issues	0.766
Low Management Support and dedication	0.736
Lack of global standards and data sharing protocols	0.741
Lack of government support and policies	0.768

Table 6. Single-Test Reliability Analysis (Factor 2)

Frequentist Scale Reliability Statistics			
Estimate	**Cronbach's α**	**mean**	**sd**
Point estimate	0.836	3.196	0.151

Frequentist Individual Item Reliability Statistics	
	If item dropped
Item	**Cronbach's α**
Lack of integration of technology platforms	0.728
Problem of coordination and collaboration	0.853
Security issues	0.720

4.5 Hypothesis Testing

In this subsection, hypothesis testing was conducted on the identified challenges from the exploratory factor analysis as discussed above. According to the survey results, Figure 8 shows the score of the identified challenges from highest to lowest.

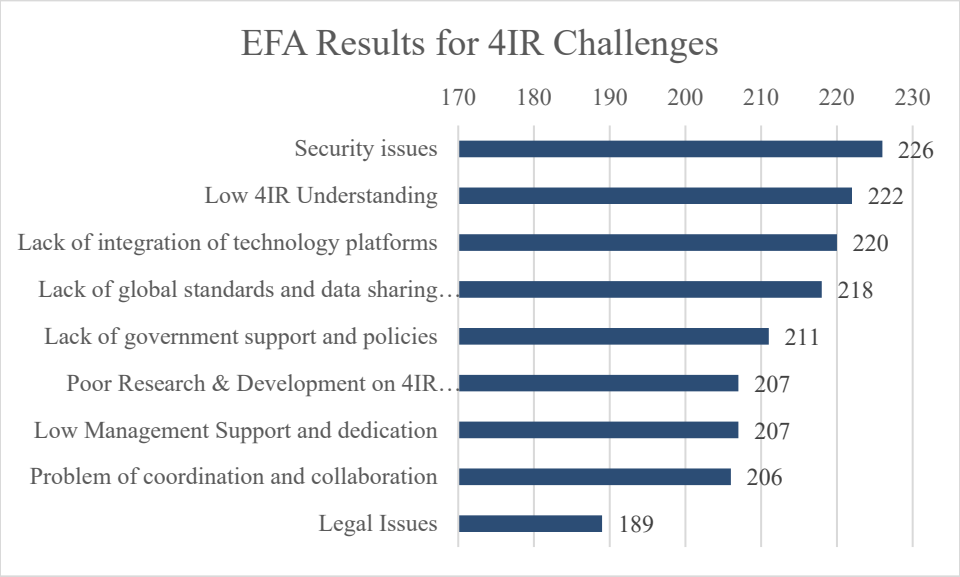

Figure 8. EFA Results for 4IR Challenges

Hypothesis testing was conducted between each pair of challenges having close scores and compared them as shown in Tables 7 and 8 as an example. First, we conducted the F-test to check if the variance difference is almost equal or unequal. For the first two challenges 'Security issues' and 'Low 4IR understanding', they are of equal variances, we utilized the t-test of equal variances with a standard α value of 0.05 and have found that the null hypothesis should not be rejected, having the t critical one-tail value to be 1.656, the t-stat is 0.291 which is a lower value, and having the one-tail P value 0.386 being greater than the α value of 0.05, results in not rejecting the null hypothesis. The same test was conducted on the remaining challenges having close results and established the same results of not rejecting the null hypothesis which indicates maintaining the ranking of the challenges obtained from the EFA.

Table 7. F-Test Two-Sample for Variances (Security Issues, Low 4IR Understanding)

	Security issues	Low 4IR Understanding
Mean	3.323529412	3.264705882
Variance	1.565408253	1.212467076
Observations	68	68
df	67	67
F	1.291093411	
P(F<=f) one-tail	0.149092072	
F Critical one-tail	1.49895461	

Table 8. t-Test: Two-Sample Assuming Unequal Variances (Security Issues, Low 4IR Understanding)

	Security issues	Low 4IR Understanding

Mean	3.323529412	3.264705882
Variance	1.565408253	1.212467076
Observations	68	68
Hypothesized Mean Difference	0	
df	132	
t Stat	0.29103764	
P(T<=t) one-tail	0.385739669	
t Critical one-tail	1.65647927	
P(T<=t) two-tail	0.771479337	
t Critical two-tail	1.978098842	

4.5 Findings Summary

Survey data was collected and conducted descriptive analysis, exploratory factor analysis, and hypothesis testing to identify, analyze, and justify the challenges respectively. The findings of this study show that the top five most challenging factors for implementing the 4th industrial revolution technologies in oil and gas companies in Saudi Arabia as shown in Table 9 are: (1) Security issues, (2) Low 4IR understanding, (3) Lack of integration of technology platform, (4) Lack of global standards and data sharing protocols, and (5) Lack of government support and policies.

Table 9. Ranking of Identified Challenges

Challenge	**Rank**
Security issues	1
Low 4IR understanding	2
Lack of integration of technology platform	3
Lack of global standards and data-sharing protocols	4
Lack of government support and policies	5

Identifying the main challenges that are impacting the growth of 4IR implementation in oil and gas companies in Saudi Arabia shows that finding a resolution to tackle these issues would open up greater paths to successful and achievable 4IR implementation goals.

5. Conclusion

This paper identified and highlighted the challenges of Industry 4.0 implementation in the oil and gas sector. These challenges were identified based on the literature and expert interviews. A survey/questionnaire was then developed which consists of 3 sections, demographics, company behavior towards 4IR, and 4IR challenges. The main purpose of this paper was to identify the main challenges affecting the 4th industrial revolution implementation in local oil and gas companies. The identified 17 challenges from the literature were utilized in the survey, in addition to a few more reasonable challenges added which accumulates to 20 challenges in total. The survey results were then collected and analyzed through descriptive analysis, exploratory factor analysis, and hypothesis testing to identify, analyze, and justify the main challenges affecting 4IR implementation in local oil and gas companies.

The findings indicated that ‘security issues’ is the main challenge towards the implementation of 4IR technologies in local oil and gas companies, along with ‘low 4IR understanding’, ‘Lack of integration of technology platform’, ‘Lack of global standards and data sharing protocols’, and ‘Lack of government support and policies. Tackling these top 5 main challenges now will provide us with a clear path in implementing the 4th industrial revolution’s technological goals. Oil and gas companies in Saudi Arabia don’t seem to have any financial issues, their main concern is more about the adaptability of applications which may affect the security of such implementation.

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Biography

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