

Adoption of Fourth Industrial Revolution to Attain Efficiency and Sustainability: Thematic Analysis Approach

Fahad Alhumaid
Mangement and Marketing
University of Bahrain
Sakhir, Kingdom of Bahrain
20180070@stu.uob.edu.bh

Elsayed Elamir
Management and Marketing
University of Bahrain
Sakhir, Kingdom of Bahrain
shabib@uob.edu.bh

Abstract—This article aims to investigate the adoption level of 4IR technologies to attain sustainability and efficiency in Saudi Arabia and the use of 4IR technologies to promote Sustainable Development Goals (SDGs). The challenges facing 4IR technologies in relation to sustainable development are examined, and the solutions to address these challenges are proposed. The advantages and challenges of adopting 4IR technologies are discussed, as well as their applications in promoting sustainability, socio-economic development, and training. The research methodology and the procedures used in the study are presented, including the research variables and the data collection method. Thematic analysis is used to analyze the data, and the results are presented in detail.

From the thematic analysis, the major challenges are identified as the skills gap and maintaining a full picture of the business not the technologies. Many other challenges are also identified such as infrastructure requirements and training.

Keywords—4IR, sustainability, SDG, socio-economic, smart cities, thematic analysis.

I. INTRODUCTION

The Fourth Industrial Revolution (4IR) is characterized by the integration of physical, digital, and biological systems. This integration is made possible by emerging technologies such as AI, IoT, robotics, and advanced materials. The 4IR is expected to have a significant impact on the global economy, society, and the environment. One of the key features of the 4IR is the emergence of cyber-physical systems, which combine physical and virtual components to create intelligent systems that can communicate with each other. According to Klaus Schwab, the founder and executive chairman of the World Economic Forum, "cyber-physical systems represent a new phase in the integration of technology into the physical world, resulting in the creation of smart factories, smart grids, smart homes, and even smart cities" [1]. The 4IR is also expected to have a significant impact on employment and the labor market. According to the book "The future of employment: how susceptible are jobs to computerization?" by [2], "the rapid pace of technological progress, particularly in areas such as AI and robotics, is likely to lead to significant disruptions in the labor market, with many jobs being automated or transformed".

Finally, the 4IR has the potential to address some of the world's most pressing challenges, such as climate change and poverty. According to the book "The Fourth Industrial Revolution" by Klaus Schwab, "the integration of physical, digital, and biological systems can help to create more sustainable and inclusive societies, by improving the efficiency of resource use, reducing environmental impact, and increasing access to education and healthcare". Sustainable development goals are currently adopted at the

global level, thus creating the need to align them with the current 4IR wave. The technologies of 4IR are critical to emerging sustainable cities and to promote Sustainable Development Goals that established by "the United Nations in 2015 as part of the 2030 agenda for sustainable development". These objectives aim to classify a wide range of interconnected global defiance, including poverty, climate change, environmental degradation, peace and justice. Nevertheless, 4IR adoption presents risks that could widen the disparity gap between countries and further advance unintended harmful effects [4]. For example, Saudi Arabia is among the largest oil producers and has ability to adapt the innovative technologies to reduce carbon footprint [5]. Hence, it can be said that with the adoption of 4IR technologies, this impact can be drastically reduced. In this article, we investigate the adoption level of 4IR technologies in various industries, focusing on sustainability on organizations in enhancing the socio-economic status, training and development, and Health, Safety, Security, and Environment in Saudi Arabia.

This article proceeds as follows: In Section 2, the literature review is presented. In Section 3, we introduce the research methodology and the data collection process. In Section 4, we report the data analysis and results. In Section 5, we draw the conclusions of the paper.

II. LITRETURE REVIEW

The first industrial revolution was the beginning of the mass transformation from outdated production methods to mechanization. This industrial revolution lasted for about a century between the mid-1700s and mid-1800s [6]. In the first industrial revolution, which began in Europe, industrialists replaced manual labor in the feudal system with mechanization. During the first industrial revolution, water and steam were the primary energy sources used to run machines [7]. The second industrial revolution, also known as the technological revolution, replaced steam power with electricity as the primary source of energy [8]. This industrial revolution advanced from the first industrial revolution and is considered the most significant milestone in industrialization history [6]. The development of electric-powered machines was far more efficient than steam-powered machines and human labor, resulting in increased mass production and improved product affordability [9]. The third industrial revolution, also known as Industry 3.0, marked a significant milestone in the history of industrialization. The revolution began in the latter half of the 20th century and was characterized using advanced computerization and automation technologies. During this period, the power of electricity was combined with computerized automation to improve the efficiency and effectiveness of industrial

processes [10]. The ability to program machines was a significant advancement from the previous industrial revolution, allowing for greater precision, accuracy, and reliability in manufacturing processes.

The fourth industrial revolution, also known as 4IR, is the current stage in the evolution of the manufacturing industry. It is characterized by the integration of advanced technologies like AI, IoT, and robotics [11]. One of the primary advantages of 4IR is the increasing need for flexibility, agility, and responsiveness in manufacturing processes [12]. To achieve its ambitious goals, Saudi Arabia introduced Vision 2030, a comprehensive blueprint for economic and social transformation. Vision 2030 envisions a prosperous and vibrant Saudi Arabia, driven by innovation and knowledge-based industries. It identifies digital transformation as a crucial pillar for achieving its objectives [13]. The Saudi government has actively pursued digitalization initiatives to enhance public service delivery and increase efficiency. Projects like the National Digital Transformation Program and the e-Government Program have been implemented to streamline government processes, improve transparency, and provide seamless online services to citizens [14].

III. RESEARCH METHODOLOGY

A. Data collection

Because the research topic comprises subtle and context-specific information that is difficult to adequately capture using standardized questionnaires, interviews are employed as an alternate data gathering strategy. This qualitative approach is better adapted to capture the depth and complexity of the research issue, resulting in richer, more detailed data. Furthermore, they enable real-time interaction, which helps resolve many of the participations and ethical concerns highlighted by participants. Several people were interviewed in many sectors to be able to get insights on their experiences around the area of the 4IR. Moreover, it was seen to approach people or employees with more than 5 years of experience to be able to have employees that indeed had the opportunity to obtain some insights on information related to the transition or potential transition towards the adoption of 4th industrial revolution technologies [15] and [16].

There were 21 interviews conducted, covering several sectors such as manufacturing, oil and gas, health, and communication. These participants are considered convenience based on the suggestions given in [17], who recommended that this size is sufficient to obtain 80 percent power to detect themes with a prevalence of 60 percent, ensuring sufficient depth and reliability in the findings. Additionally, [18] highlight the suitability of thematic analysis for examining perceptions and experiences, making it an ideal choice for this study. Moreover, interviews provide flexibility in data collection, allowing researchers to probe deeper into responses and explore new areas that emerge during the conversation. This adaptability is crucial for capturing a comprehensive view of how 4IR technologies are influencing sustainability efforts.

These interviewees had relatively high exposure on their organizations' structure and insights on organizations around the world in addition to insightful information about

applications of the 4th industrial revolution technologies around the world. Moreover, the sample chosen was to somehow list down potential plans to be implemented in organizations in Saudi Arabia to be able to adopt technologies to attain sustainability and efficiency. The selection does not cover all sectors but does cover a wide variety of industries which does provide a good outlook on organizations across Saudi Arabia. It is worth mentioning that initially there was a challenge to find people who are willing to participate as the subject is relatively complex and requires good knowledge about 4IR and its technologies. Most of the interviewees were employed at oil and gas companies, which in my opinion are more exposed to technologies related to the 4IR.

Most of the interviews were conducted face to face, however some were performed over the phone. All the interviews were recorded, then transcribed using MS Word, which were then further scrutinized manually. While performing the interviews, some questions were modified and the sequence of some were adjusted due to match the expected outcomes from the interviewees and to ease the thinking process when answering the questions. Moreover, the questions were structured in a way which gives more room to answer and are considered open-ended. At the end of some interviews, an additional question was provided to interviewees who could provide recommendations to organizations to better adapt with transitions brought by the 4IR.

B. Thematic analysis

Thematic analysis is a method of analyzing qualitative data that involves identifying and analyzing patterns or themes within the data. A theme is a pattern or recurrent idea that is significant to the research question. Thematic analysis is used to understand the meaning and significance of the data in a way that allows researchers to develop a rich and detailed description of the research topic. The process of thematic analysis involves data preparation, data coding, theme development, theme refinement, and interpretation; see, [19].

The first step in the process of thematic analysis is data preparation. Data preparation is essential for making the data more accessible for analysis. This step involves transcribing, translating, or summarizing the data, depending on the data type and research question. Data preparation is a time-consuming process but is critical for ensuring that the data is manageable and understandable. The second step in the process is data coding. Coding involves identifying and labeling sections of the data that relate to a particular theme. Coding can be done manually or using software, such as "NVivo" or "ATLAS.ti". Coding is an essential step as it enables researchers to identify patterns in the data and develop themes based on these patterns. The third step in the process is the theme development. This step involves analyzing the codes and grouping them into themes. Themes should be coherent, clear, and meaningful. [19] suggests that themes should be defined based on the patterns or relationships that exist in the data. Theme development is a critical step in the process as it enables researchers to identify and understand the key patterns or themes that emerge from the data. The fourth step in the process is theme refinement. Theme refinement involves reviewing and revising the themes to ensure that they accurately represent the data. This

step is essential for ensuring that the themes are coherent and accurate. [20] suggests that theme refinement involves reviewing the themes and revising them until they accurately represent the data. To ensure the reliability of the data, we consulted experts in the field to review the initial codes and themes, incorporating their feedback to refine the analysis. In this regard, two experts in the field are involved in reviewing the coding scheme and identifying themes. Their feedback was instrumental in refining the analysis, ensuring that the themes were both accurate and relevant. This approach leverages the specialized knowledge of experts to enhance the validity and reliability of the findings. This approach ensures that the findings are both reliable and validated by those with specialized knowledge, providing a robust and credible analysis of sustainability practices influenced by 4IR technologies [21].

Finally, the fifth step in the process is interpretation. Interpretation involves drawing conclusions from the themes and relating them to the research question. This step is essential for understanding the meaning and significance of the themes that have emerged from the data. [22], [23] and [24] suggest that interpretation involves reflecting on the themes and drawing conclusions based on the patterns that have emerged.

C. Study framework

The framework in Figure 1 looks at a generic overview of the perception of the 4IR and its applications throughout various organizations across the world. Then after that, the perception of linking it towards sustainability and how sustainability can be enhanced through implementing 4IR technologies. Then the dissection into the three different sections of organization which are the socio-economic status, training and development, and health, safety, security, and environment. Within each block of the framework applications, opportunities, and challenges are examined to identify a path forward for organizations to gain better insights on how to better attain efficiency and sustainability through adopting 4IR technologies; see, [25], [26], [27] and [28].

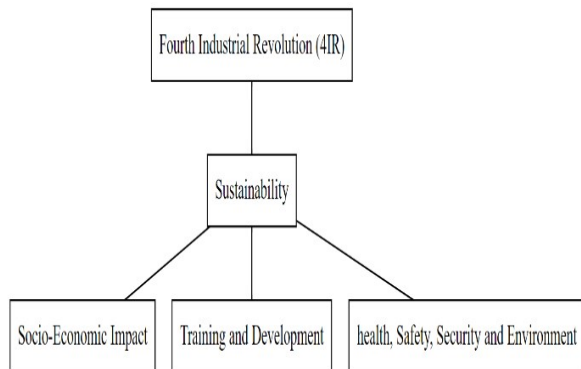


Fig. 1. Study framework

TABLE I. THE STUDY VARIABLES

Variable Name	Abbrev.	Definition
Fourth Industrial Revolution	4IR	The latest technological advancements, including AI, IoT, cloud computing, blockchain, and robotics, reshaping the world and transforming various industries
Sustainability	-	The ability of organizations to meet present needs without compromising the ability of future generations to meet their own needs, encompassing environmental, social, economic, and institutional dimensions
Socio-Economic Status	SES	A complex construct reflecting an individual's access to resources, opportunities, and social networks, influencing health, education, and economic outcomes
Training and Development	T&D	The process of improving employees' knowledge, skills, and abilities through learning activities, crucial for organizations to adapt to the rapid changes brought by 4IR technologies
Health, Safety, Security, and Environment	HSSE	Measures and protocols implemented by organizations to ensure the well-being and safety of employees, customers, and the environment, contributing to sustainability and reputation

IV. ANALYSIS AND RESULTS

This section shows the method of analyzing the interview scripts along with some in-depth analysis of the

answers and perspectives based on the understanding and experience of the interviews. The different participants and their various backgrounds and experiences provided a wide mixture of perspectives and experiences in the field of adopting 4th industrial revolution technologies in the identified sections of the research. After reading the interviews multiple times, the structure of the responses helped in the next step of the analysis. After that, the thematic analysis method was chosen to conduct the interpretation of the data collected to have a better interpretation of the data collected. The steps taken in the thematic analysis were creating sets of codes which were then combined into themes; see, [29] and [30].

A. Interview Questions

The interview questions below were gathered by analyzing many literatures around each aspect of the research. Hence, these were developed based on gaining an understanding of each section in general then diving in the implementation or adoption level of 4IR technologies to attain efficiency in each of the five sections. In addition, an added section to some of the interviewees provides some guidance or recommendation to organizations to be able to better adopt 4IR technologies; see, [25] and [26]. The first part of the interview covers some generic demographic questions to better understand the level of experience each interviewee has. Then, the five sections are covered, each having similar but slightly different questions.

1) Demographic Questions

- a) What is your occupation? And what is your role in your organization?
- b) How many years of service do you have in your current occupation and what is your previous work experience?
- c) What is your gender?

2) Fourth Industrial Revolution

- a) What do you know about the 4IR? And what are the technologies that fall under it?
- b) How do you believe that organizations around the world are adapting with the transformations brought by the 4th Industrial Revolution? Can you give some practical applications?
- c) What are the challenges that come with 4IR in your view?

3) Sustainability

- a) How would you define sustainability in your view?
- b) What is the impact of sustainability on organizations and people in organizations in your opinion?
- c) How can adopting 4IR technologies enhance sustainability in your view? Can you give me some practical applications?
- d) What are some challenges that are associated with adopting 4IR technologies to enhance sustainability?

4) Socio-Economic Status (SES)

- a) What defines the Socio-economic Status of an organization in your view?

- b) How can the 4IR technologies help enhance the socio-economic status of an organization? Can you give some practical applications?
- c) What are the challenges of adopting 4IR technologies to enhance the socio-economic status of an organization? And in your organization?

5) Training, and Development (T&D)

- a) What is the significance of training and development in an organization in your view? And how can it be measured?
- b) How can 4IR technologies enhance the effectiveness of education, training and development? Can you give some practical applications?
- c) What are the challenges of implementing 4IR technologies in education, training and development?

6) Health, Safety, Security, and Environment (HSSE)

- a) How can you measure Health, Safety, Security, and Environment Impact in an organization? And what is its significance?
- b) How can 4IR technologies enhance the effectiveness of HSSE? Can you give some practical applications?
- c) What are the challenges of implementing 4IR technologies in HSSE?

B. Creating Codes

Since all interviews were transcribed, MS Word was used as the means of creating certain codes that simplify the answers into phrases. Once that was completed, relevance between many interviews and the perception of interviewees was seen and additionally helped with the interpretation of the data sets. The data was re-arranged by each of the five pillars and their respective questions. Hence, each question had all 21 interviewees answers under it which helped with the consistent coding and eventually the arrangement of the codes for further analysis.

C. Creating Themes and Sub-Themes

After arranging the set of codes for each interview pillar and questions, it was easier to translate these codes into themes. And within each pillar a sub theme of that pillar was selected for reference during the presentation of the results. This resulted in generating a total of five main themes: definition, significance, advantages, challenges, and applications of 4IR in each respective pillar of the research. MS Excel was used to better arrange the codes with their respective texts and combining these codes into the themes and sub-themes.

D. Themes Interpretation

1) General Definition and Significance of 4IR

This was the most difficult question to be comprehended by some interviewees as they did not have a complete understanding of the 4IR in specific and its significance but were mainly leaning towards some positive feedback. Among many, several interviewees identified 4IR as the path forward and that it is gaining momentum in addition to having the ability to connect worlds. Some other interviewees had more

information and details explaining it as a precedence from the previous industrial revolutions.

Many interviewees related 4IR with cyber related work, quoting from interviewee 5 *“And it's based off the cyber related work, the first industrial revolution, it's called like a cyber related work and cyber physical system, which is called the cyber physical system, I think, I think this moves to the next level of Era, I think. It started in the new version around the world.”*

An interesting combination of some of the responses were that 4IR is a change in business models, and in the way decision making is based on data. They defined it as automating processes within businesses based on digital information. One quote from interviewee #20 states *“The fourth Industrial Revolution I like to define it as a change in business models rather than technologies, where data is driving decision making and driving analysis and driving a lot of business aspects.”*. As for the significance, many stated that it is the way to go soon. Two interviewees identified it as a necessity, saying that organizations must implement 4IR technologies to keep running your business.

2) Sustainability and its significance

Many interviewees defined sustainability as the ability to continue business without interruptions. One elaborative definition by interviewee #16 states, *“When you are in a business you are looking for growth in some phases in your cycle, I mean business cycle. After that you will reach maturity. Usually after the mature phase decline phase starts. So, sustainability will prolong that phase and will cut some costs that's associated with your regular business. And will make your business profitable for the longer period.”*

3) The Socio-Economic Status and its significance

Most of the interviewees agreed that the socio-economic status is comprised of both society and employees and how organizations treat and contribute towards employees internally and with the communities surrounding it. One quote from interviewee # 11 states, *“the higher the contribution of an organization, to the society, to the economy it will be the higher the social economic status. I can look at a clear example of companies like organizations or companies like Aramco in serving the contribution they have to society, to the economy, and to the environment around them. It's definitely an indication of how well their social economic status is.”*

4) Training and Development and its significance

I believe this section covers only the significance of T&D, for which all interviewees unanimously agreed on it being a major and critical part of organizations. Many even mentioned that only with T&D can an organization succeed and become sustainable. One quote from interviewee # 8 on giving organizations a competitive advantage saying, *“For an organization to invest heavily in the training and development, it is clear that this organization is always trying to stay above the curve and add ahead of the curve, ahead of competition to be able to adapt whatever is new in the industry.”*

5) HSSE and its significance

Multiple interviewees in this section were focusing on the security aspect of HSSE and mainly the cybersecurity threats. Interviewee # 2 mentions the significance of security in terms of patient records and how it is critical to ensure its safety by saying, *“Entering that of patients or information about patients, how that information will be delivered? is it completely confidential would it leak, would it not leak. I think this is a big challenge and even if you can put it in the challenges, it is a big challenge for the medical field, especially because. You don't know to what extent is the confidentiality secured in those technologies”*. On the other hand, interviewee # 10 provides some sort of guidance to how HSSE should be looked at by saying, *“The environments as much as I believe there are lots of organizations that have that consciousness and that want to have a healthy environment and a low carbon emissions but it I think it's more of a mandate so if you don't have government mandates on environmental emissions and footprints.”*

V. CONCLUSION

In terms of defining the technologies or the fourth industrial revolution, we can see multiple approaches, but all interviewees mentioned some of the technologies as the main ones from the 4IR such as AI, IoT, 3D printing, big data analytics, and others. When it comes to advantages, we saw various industries benefiting from these technologies, and out of which each organization should look for their respective weakness and can find a way to strengthen it using these prementioned technologies. Some of these advantages are the potential creation of jobs, being able to enhance the reputation and pride of organizations, providing more efficient and less efforts on labor operations, and improving the overall knowledge transfer experience. Moving towards the challenges, the interviews enlightened several aspects of organizations that should work around to ensure the efficiency of these implementations. The major challenge sought was the potential unemployment that could be caused by 4IR. Another major challenge is the potential cybersecurity risk, and the infrastructure required. Moreover, the resistance to change was also mentioned in several themes during the interviews as being a major challenge. In addition to the prementioned challenges, the technical requirement of skilled professionals in both 4IR and each discipline within an organization causes the greatest obstacle during the implementation process. As for application, a wide variety was mentioned by interviewees that each organization could utilize as success stories. We believe when looking for an application, an organization should always benchmark other similar organizations within the same industry to benefit from the successful stories happening around them.

In a way to provide recommendations to organizations when implementing or adopting 4IR technologies in various disciplines within their structure, several steps need to be taken during the planning phase of the implementation process. One major recommendation is to always maintain a full picture of the business and not the technologies, this was mentioned earlier by many interviewees where they stated that they focus on business and not technology. One can provide perspective in that area where some organizations try to enhance the number of technologies to gain a better reputation but miss the actual reason the technologies were

implemented. Hence, identifying the gaps or potential enhancements in your organization is the initial step and should always be clear throughout the implementation process and should be one of the most important objectives of the 4IR technology deployment. A second recommendation is to evaluate in depth the potential impact of this technology on other aspects of the organization. This can be seen that some deployments affect multiple disciplines within organizations that are not necessarily related to the benefits generated for that deployment.

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