



THE IMPACT OF INDUSTRY 4.0 TECHNOLOGIES ON SUSTAINABLE INDUSTRIAL DEVELOPMENT: A SURVEY OF TECHNICAL OPINIONS FROM MANAGERS IN PRODUCTION COMPANIES IN NINEVEH GOVERNORATE

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Abstract. The present study seeks to identify the impact of selected Fourth Industrial Revolution technologies on achieving sustainable industrial development through an exploratory study of the opinions of a sample of technical managers working in production companies in Nineveh Governorate. The importance of the study lies in examining the theoretical aspects of the study variables, identifying their related concepts, and highlighting the significance of the Fourth Industrial Revolution and its technologies as applied in several companies selected as the field of study. This was achieved by understanding the descriptive background of the investigated companies and obtaining information regarding the practical reality of the dimensions of sustainable industrial development and their impact on productivity.

The study adopted the descriptive and analytical approach in developing the theoretical and practical framework, which facilitated the collection of data and information relevant to the research, the use and interpretation of various analytical methods, and the attainment of results based on observations and comparisons. To meet the aim of the study, data and information was collected and analysed using a questionnaire as the main tool for gathering and analysing of the data.

The study has derived several conclusions, including that companies' use of technology from the Fourth Industrial Revolution helps provide an integrated digital infrastructure that can help improve the efficiency and transparency of industrial systems, and support the intelligent management of the resources of both production and service companies. This can be done by providing a balance between economic growth and resource and environmental sustainability for the future generations, ensuring the attainment of sustainable industrial development.

Keywords: Fourth Industrial Revolution Technologies, Internet of Things (IoT), Cloud Computing, Blockchain Technology, Sustainable Industrial Development.

Introduction

With the progressive regulatory requirements and the growing eco-awareness of the customer (consumer), the shift towards sustainable industrial development is therefore becoming an unavoidable strategic option and a real necessity for any organization, both private and public entities and even governments. Although great efforts have been made to achieve sustainable industrial planning for the United Nations Sustainable Development Goals (SDGs) of 2015, including the goal to reach a "net-zero" carbon emissions target (Zero CO₂) by 2030, many countries are still not on track to fulfill their vision in this area.

Thus, cooperation is needed from all concerned to make real progress towards these goals and strategic plans. To speed up this process, the mechanisms and practices of the Fourth Industrial Revolution should be implemented, due to their direct link to industrial processes, inputs and outputs. This can be made possible by offering green incentives; giving extensive support for the adoption of Fourth Industrial Revolution (Industry 4.0) requirements; and restructuring company and factories towards digital transformation. Additionally, it is crucial to link these technologies into organizational strategies in order to be able to implement sustainable and effective measures along the entire industrial value chain, thereby fostering long-term impact and helping to shape visions of a sustainable technological future based on renewable energy, lower emission, reduced costs, higher quality and greater material, human and financial resource efficiency.

The 4th Industrial Revolution or Industry 4.0, is the latest phase in the progression of technology that follows the 1st, 2nd, and 3rd Industrial Revolution. It is supported by the high level of intellectual capital, knowledge economies and technologies like Internet of Things (IoT), cloud computing and blockchain technology. All these innovations have brought a significant change to the economy, social and operational environment, at an unprecedented rate, compelling institutions and governments to quickly adapt to embrace the concepts, technologies, tools and methodologies of the Fourth Industrial Revolution (Industry 4.0).

Accordingly, this study investigates the impact of Fourth Industrial Revolution technologies on sustainable industrial development by addressing the following main research question: Do companies, their departments, and employees utilize some of the technologies of the Fourth Industrial Revolution, and is there a relationship of correlation and influence between these technologies both collectively and at the level of their sub-dimensions in achieving sustainable industrial development within the investigated fields?

The study was conducted on a sample of (109) respondents comprising a group of technical managers working in production companies in Nineveh Governorate, Iraq. Data were collected through a specially designed questionnaire prepared to answer the research question, on the basis of which the main and subsidiary hypotheses of the study were formulated as follows:

The First Main Hypothesis: There is a statistically significant correlation between Fourth Industrial Revolution technologies and sustainable industrial development at both the overall level and the level of the sub-dimensions within the investigated field.

The Second Main Hypothesis: Fourth Industrial Revolution technologies, collectively, have a statistically significant effect on sustainable industrial development within the investigated fields. The following sub-hypotheses are derived from this main hypothesis:

- a. The Internet of Things (IoT) technology has a statistically significant effect on sustainable industrial development within the investigated fields.
- b. Cloud computing technology has a statistically significant effect on sustainable industrial development within the investigated fields.
- c. Blockchain technology has a statistically significant effect on sustainable industrial development within the investigated fields.

Section Two: Theoretical Framework of the Study

This section is devoted to presenting the theoretical framework of Fourth Industrial Revolution technologies and sustainable industrial development, drawing upon a range of previous studies and the perspectives of scholars and researchers, as follows:

First: The Concept of the Fourth Industrial Revolution

In 2011, the Fourth Industrial Revolution was born out of an initiative by the German government to computerize manufacturing. The adoption of the term since then has spread globally as a description of smart and networked industrial systems, which are at the heart of

this new revolution. It has ushered in a qualitative change to the manufacturing and industrial processes by integrating cutting-edge digital technology into production lines, which allows physical systems, cyber security, the Internet of Things (IoT) and big data analytics, cloud computing and artificial intelligence to converge.

This transformation has been a driver of innovation, which has led to opportunities for growth and economic development, and facilitated the development of complete and sustainable solutions to solve multidimensional problems and contribute to the attainment of social and economic development objectives. In addition, it has completely transformed the world by providing new ways to do business that are more flexible and productive; production processes, maintenance practice, designing new production lines, and the ways in which employees use, develop and share operational plans. As a result, it has improved the use of available resources and production based on customers' needs which leads to shared infrastructure systems.

The Fourth Industrial Revolution also has brought about significant shifts in the nature of the job that human workers are expected to perform, from greater human machine interaction to greater flexibility and real-time customer requirements. Furthermore, it has been instrumental in advancing sustainability in its three pillars economic, environmental, and social by implementing innovative technological solutions and data-driven solutions, especially in the industry, agriculture, and food sectors.

Thus, the fourth industrial revolution can be described as a continuous process of automation of manufacturing processes using advanced technologies. It combines large volume machine-to-machine (M2M) communications and the Internet of Things (IoT) to enhance automation, communication and self-monitoring capabilities, and create smart machines that can analyse and diagnose problems without the involvement of humans.

Klaus Schwab defines the Fourth Industrial Revolution as an amalgamation of technologies that have developed out of the Third Industrial Revolution and attempts to merge the physical, digital and biological worlds. Key technologies are genetic engineering, Nanotechnology, Internet of Things, three-dimensional (3D) printing, cryptocurrencies, Artificial intelligence, and Robotics.

On the other hand, it is regarded as the integration of Information and Communication Technology (ICT) into every aspect of manufacturing and other application fields such as personal devices, home systems, vehicles, enterprises, and infrastructure. But it is not simply a continuation or acceleration of the development of ICTs, it is a paradigm shift to a fully data-driven economy.

Second: Fourth Industrial Revolution Technologies

Numerous studies and researchers have examined the technologies of the Fourth Industrial Revolution from different perspectives and theoretical foundations. Based on the areas of consensus identified in the literature and considering their suitability to the field under investigation, the present study focuses on the following technologies:

1. Internet of Things (IoT)

The term Internet of Things (IoT) was first coined in 1999 and the use of the term was made part of a Coca-Cola vending machine, which was wirelessly connected to the Internet. Since then, IoT devices have been growing to cover most or all commercial and retail sectors. The Internet of Things is regarded as a system that uses sensors and digital actuators to convey pertinent data that can be collected, analyzed, and acted upon.

With IoT, machines, sensors and management systems can communicate in real-time, allowing for a continuous stream of data to be used for monitoring energy usage, optimizing energy use, predicting equipment failures, and minimizing waste. This positively contributes to the relation of digital transformation and business sustainability from the environmental, social and economic perspectives.

In addition, the technologies of IoT offer real-time information regarding air quality and water quality, thereby facilitating prompt measures and better pollution control. In energy management, IoT enables better integration of renewable energy resources and optimises energy flows, helping to lower carbon footprints and increase energy efficiency.

IoT has been described as the network of physical devices that are embedded with sensors and are connected to each other to gather, share and exchange information via the Internet. It is also referred to as a "powerful technology" that is transforming a wide range of industries, from homes to healthcare, transportation, education to industry. These devices connect and share

information via the embedded sensors, generating intelligent and responsive environments.

Further, IoT is considered as an ecosystem of physical objects that are connected to one another and outfitted with a range of different technologies such as sensors, processors and software, working together to observe and communicate data without the need for significant human interaction. Consequently, any non-living object turns into a smart, data-producing object.

2. Cloud Computing

The cloud network and cloud computing began to be used in the early 1990s and were originally terms that referred to a virtual layer of network that would bring corporate clients and their businesses together from afar via a Virtual Private Network (VPN) through public Internet service providers. Users could connect to the resources in the office remotely via this cloud-based environment. Salesforce launched the first cloud-based services in 1999 by providing a collection of applications and services via its homepage.

Recent research reveals that the cloud computing industry has seen significant growth over the past few years. Around 81% of firms are using cloud computing as part of their operations, up from 62% in 2020. This shift could be attributed to the growing demand for digital transformation initiatives which has grown over 150% from before the COVID-19 pandemic. As a result, efficient storage and processing power has become a more and more important need.

Cloud computing has become a big trend in running and scaling large applications, in managing large service sets and in improving flexibility in organizations. It is viewed as a valuable technology that provides added values to organizations in terms of productivity, efficiency, reliability and cost-effectiveness, allowing them to concentrate on their core activities and business strategies to support their mission.

Cloud computing has been described as an approach where users can access and use a shared set of potentially customizable computing resources over a network with minimal management and deployment efforts or direct user intervention. It's also been called infrastructure that delivers resources and services through the Internet with service clouds to host services, data management clouds to handle data, and computing clouds that offer software and computational services. The components work together to form an integrated application platform.

In addition, cloud computing is considered an information technology service model that delivers scalable resources on demand and is typically offered in public, private, community or hybrid cloud options.

3. Blockchain Technology

Blockchain technology has appeared as a new technology method in the 80s and 90s. It was first formally described in a pioneering paper published by Satoshi Nakamoto in 2008 where he describes a distributed transaction ledger that records Bitcoin cryptocurrency transactions between users.

Blockchain has been described as a distributed ledger that records, shares and executes all transactions within a network of multiple nodes that share the data to update and modify it. It has also been touted as a possible means of securing sensitive data and ensuring data integrity. Another defining feature of blockchain is that it is a distributed ledger technology that is decentralized, allowing for the secure and transparent making of transactions without intermediaries. Its features are decentralization, immutability, and transparency. These features allow for transactions to be verified through a network of users, not central authorities, making them secure and tamper-proof.

Therefore, blockchain technology is being used in many industries such as real estate, insurance, healthcare, EHR, copyright, music, and renewable energy. It remains decentralized and trustworthy, and is gaining in influence and significance in these sectors.

Blockchain is a combination of a database and a protocol, from a functional point of view, that enables the addition of new data to the system without the need to modify previous data. This means that the entire community of users will know about the changes made in the information on the blockchain, using powerful cryptographic methods. Thus, blockchain proves to be a useful transparency tool, aimed at boosting consumer confidence in the brand's products, especially in the wake of electronic fraud worries.

Besides, blockchain can be applied to business, strategic and sustainability goals. It helps to increase environmental efficiency, gives accurate data on the use of resources in production

processes, lowers transaction costs, decreases carbon footprints, and improves communication in the complicated supply chain.

Third: Sustainable Industrial Development

From the literature and previous studies, it could be concluded that the sustainable industrial development is about enhancing the quality of life and environment with the aim of providing suitable infrastructure for purposeful human activity. The topic of the interdependencies between economic development and environmental protection has been thoroughly debated on the international level since the 1970s. Traditionally, sustainable industrial development was seen primarily as focusing on the environment; but over time it has come to be seen more broadly as a three-fold concept related to the economy, technology and the environment. The economic aspect highlights policy instruments which stimulate organizations to use natural resources in a responsible way, while the technical aspect highlights new technologies that require lower raw material and energy consumption.

In today's world, we are in a series of interconnected and heightened crises. Seven of the nine planetary boundaries are already surpassed, taking the biophysical systems of the Earth to tipping points. When these limits are exceeded, environmental, hydrological and climatic changes become irreversible, are fast and are marked by abrupt changes and rich interactions. At the same time, the social institutions and economic structures are reaching their own critical thresholds due to growing inequality, debt crises and instability.

What is more important is that these crises are not single and isolated events. Climate change, environmental pollution and biodiversity loss pose a threat to both ecosystems and the livelihoods, public health and economies of people. Poverty weakens the capacity of nations to respond to environmental risks and opportunities for sustainable change and transformation across environmental, social, economic and technological dimensions, and can impact on individual, population and community well-being, human dignity and economic development.

Similarly, domestic and international economic inequality contributes to lower social trust, to lower cooperation, and greater uncertainty in domestic and international policymaking. This makes it all the more imperative that there are bold, transformative and sustainable policies to solve these crises and promote inclusive and sustainable development everywhere.

National, regional and international strategies based on mechanisms of solidarity and international cooperation are needed to go beyond incremental interventions in order to tackle the structural drivers of inequality and environmental degradation. This challenge requires us to address the economic, social and environmental challenges that the world is facing by changing how economic value is created, captured and distributed. This transformation is defined by technological innovation and implementation in the context of the Fourth Industrial Revolution, restructuring of energy/energy resources systems, reorganisation of local/regional/global supply chain, and redesign of labour markets and skills infrastructure.

These goals can be realized by sustainable industrial policies, which are in line with modern production systems. Most global environmental problems stem from current production systems, and the current production and consumption patterns of the advanced economies. Also, climate change, caused by the rising levels of greenhouse gases in the atmosphere, has caused hundreds of millions of people to experience more heatwaves, floods and storms each year, and many other negative impacts.

Climate change is closely associated with fossil fuel-based energy systems, industrial processes, and deforestation. The irrational and intensive use of fossil fuels and other production-related activities has become a major source of greenhouse gas emissions. The principal greenhouse gases include carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O), whose concentrations have increased by approximately 50%, 200%, and 25%, respectively, compared with pre-industrial levels.

Furthermore, wildlife populations have declined by approximately 73% since 1970, and nearly one million species representing more than 10% of all described species are currently threatened with extinction. The use of extracted and non-renewable material resources, including minerals, has tripled since 1970 and is projected to double again by 2060.

Sustainable industrial development involves formulating an appropriate industrial development strategy by policymakers and decision-makers, with the participation and approval of stakeholders, and implementing it across different levels of the industrial system within a given industrial region. This process requires maintaining a balance among the three dimensions of

sustainability through the application of guiding principles and practical tools. Among the tools available to decision-makers are the Sustainable Balanced Scorecard and Porter's Value Chain, which can be integrated with sustainability guidelines. In addition, certain variables should be analyzed at each iterative level, including firms, industrial clusters, and cluster governance structures. Ultimately, sustainable industrial development should take into account the interconnections among local industrial clusters while considering national and international market opportunities at reasonable cost.

All stakeholders aspire to create sustainable change. There is increasing awareness of their responsibility toward ecosystems and the environment, accompanied by efforts to become leaders in sustainable transformation. Historically, sustainability was regarded as an economic principle that assumed a quality of life commensurate with the prevailing level of civilization. The concept of sustainable development is encapsulated in the opening statement of the report of the World Commission on Environment and Development, *Our Common Future*, which defines sustainable development as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs."

Therefore, sustainable development, including sustainable industrial development, should be to achieve the balance between economic growth, protection of environment, quality of life and human health. This view is not only limited to the natural world, but also the built world. With the ongoing transformation in the world due to advanced technology, 4th industrial revolution and the general spread of Industry 4.0 concepts, the effects of industry, transportation, cities and related sectors on climate change have rendered the need to take the ecosystem as a whole.

The need to meet the demands of the present generation in a sustainable way, while also ensuring the protection of the environment and opportunities for future generations has become a strategic goal of modern civilization. Business sectors are becoming more and more digital, artificial intelligence (AI) is increasingly making its way into the corporate world, and companies are moving toward Industry 4.0 and implementing 4IR technologies within sustainable environments and following their own digitalization journey. As a result, factories are transforming to be smarter, safer, efficient and environmentally friendly by integrating production technologies and information and communication systems, data and services into interconnected network infrastructures.

The Fourth Industrial Revolution (4IR) or Industry 4.0 is an era of human history that builds on the foundations of the first three industrial revolutions. The Fourth Industrial Revolution, driven by advances in knowledge and intellectual capital, knowledge-based economies and new technologies like artificial intelligence and the Internet of Things, is revolutionizing all economic sectors, and changing the way institutions and governments work to an unprecedented degree. This novel revolution brings together a slew of digital, physical and biological assets in a complex mix and presents unprecedented possibilities for human development.

But there's a big caveat with these opportunities. The Fourth Industrial Revolution, if not handled in a sustainable manner, could also have significant costs. Increased industrial activity tends to be linked to increased consumption of resources and more emissions and GHGs. A very pertinent question to ask is: How long can the global ecosystem continue to support such fast industrialization? Therefore, industrial organisations are putting in a considerable effort to make the industry sustainable in every segment of business. Multinational companies are taking steps to address the sustainability with regards to SDG 9, Resilient Infrastructure, Inclusive and Sustainable Industrialization and Innovation, in their value chains.

Meanwhile, the industrial revolution has brought new challenges most notably in oil and gas driven industries. Some 65% of global GHGs are emitted by fossil fuels and industrial processes. Furthermore, the social effects are overshadowed onto the poorest and most vulnerable populations. Hence, the need of the hour is to take action to curb the environmental degradation due to industrial pollution and also to foster decent work and equitable social welfare as a prerequisite for sustainable and inclusive economic development.

Manufacturing value added (MVA) is the most commonly used measure to evaluate the level of industrialization that a country has attained, in terms of its ability to manufacture goods and offer services to satisfy social need. However, the post-2030 Sustainable Development Agenda and the United Nations Sustainable Development Goals call for integrating environmental and social indicators in addition to economic ones. This is why ISID is a framework that brings together the three aspects of sustainable development – economic, social and environment – in

the field of industry.

Countries would like to have sustainable industrial development, and they want to get the most out of manufacturing industries, thereby increasing their economic output, while decreasing the carbon dioxide emissions produced by the industries and limiting the inequalities in society. The approach used is the one that assesses the impact of industrialization on the overall environmental and social performance of the economy. It is based on the principle that industrialisation plays a central role in the economy, with positive spillovers effects throughout the economy. It basically measures how much manufacturing-based economic development is degrading the environment and society.

Unlike broader measures of inclusive and sustainable development, industrial development indicators focus specifically on the economic, social, and environmental performance of the manufacturing sector itself.

The indicators of Inclusive and Sustainable Industrial Development (ISID) are achieved when industrialization is promoted in parallel with the development of green industries and social improvements that are closely and directly linked to the manufacturing sector. Furthermore, the dimensions and indicators of Inclusive and Sustainable Industrial Development can be identified in accordance with Sustainable Development Goal 9 (SDG 9), as presented in Table (1).

Table (1)
Sustainable Development Goal 9 (SDG 9)

Dimensions	Inclusive and Sustainable Industrial Development (ISID)	Inclusive and Sustainable Industrial Development in Accordance with Sustainable Development Goal 9 (SDG 9)
Modern Manufacturing Systems	Value Added to Operational Performance	Manufacturing Value Added (MVA)
Social Inclusion	Inequality Index: An indicator that reflects inequality in income distribution among the citizens of a single country.	The gap between each region and the best-performing region in terms of the ratio of industrial labor force to the total labor force in other sectors.
Environmental Sustainability	Total CO ₂ Emissions per Worker	Carbon dioxide emission intensity in manufacturing (kg per US dollar of value added).

Source: INDSTAT2 Rev.3 (United Nations Industrial Development Organization, 2018); World Development Indicators (The World Bank, 2018); Standardized World Income Inequality Database (Solt, 2018)

Innovation for industrial sustainability is of critical importance for achieving the Sustainable Development Goals (SDGs), which call for cooperation between the public and private sectors and for bridging gaps through the Fourth Industrial Revolution (40). After the COVID-19 pandemic caused global factories and supply chains to be badly affected in early 2020, one issue arose - the scarcity of key materials affecting the industry on a broad scale and causing anxiety among manufacturers. A key element of their work was, however, the issue of industrial sustainability, namely their approach to using energy, how they source and how they make use of consumables – raw materials – which is a fundamental starting point for a strong sustainability plan.

Energy is regarded as a significant input in the activities of industry, and the consideration of its importance in the development of industry is a strategic necessity. The U.S. Energy Information Administration estimates that around 75% of GHGs are emitted by traditional energy sources, which are usually hydrocarbons or electricity from non-renewable resources. As a result, in the context of transitioning to Fourth Industrial Revolution technologies, renewable and

environmentally friendly energy sources are increasingly being used, as they have lower emission parameters, which is a critical issue in enhancing the sustainability of industries. According to reports from international governments, more than 30% of total greenhouse gas emissions are attributed to industrial processes. It has also been demonstrated that focusing on improving industrial operations can significantly enhance energy efficiency. The use of modern Fourth Industrial Revolution technologies can lead to a reduction in emissions and gases by approximately 8%, as illustrated in the figure below.

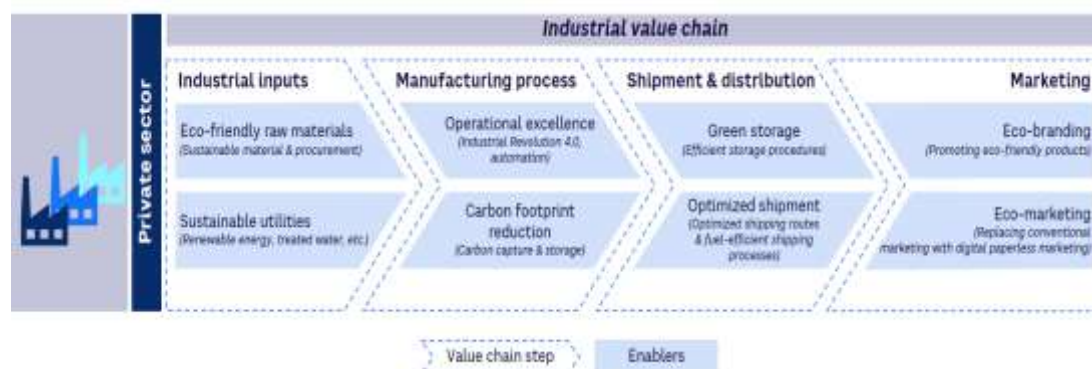


Figure (1)
Sleiman, A., Najem, R. N., Hage Chahine, A., & Nasr, R. (2023). Imperatives for sustainable industrial development: The KSA case Balancing economic growth and environmental care.

It is evident from Figure (1) that industrial facilities can reduce their carbon emissions by applying practices that improve manufacturing processes and make them more environmentally friendly through enhancing the quality of sustainable industrial inputs. This can be achieved by following several key steps, most notably:

- Adopting lean production principles, known as "waste-free production by design," which represent one of the mechanisms and practices of Industry 4.0.
- Pursuing operational excellence to improve efficiency across all stages of manufacturing processes.
- Strengthening the 3R philosophy: Reduce, Reuse, and Recycle.
- Enhancing and improving technological systems and workforce capabilities.
- Improving energy efficiency through heat recovery and reducing energy losses.

BMW has provided a leading example in this field by effectively integrating advanced automation Spanning numerous factories, and smart systems, a 30% reduction in resource use and emissions over the last decade. In the same way, IKEA has a sustainable development strategy and is a model for sustainable practices. It has already started to buy 50% of its wood from forests that are sustainably managed, and aims to use 100% renewable energy in stores by 2030.

Moreover, investment in Fourth Industrial revolution technologies has risen considerably, and their focus is the development of advanced technologies and innovation initiatives, aiming for productivity. The Saudi investment authorities have reported that the kingdom is backing the use of digitalization in the various sectors of its industrial sector with a fund worth 453 billion dollars, among which are the sectors of mining, industry, logistics and energy.

Section Two / Applied Aspect of the Study

This section is devoted to presenting the applied aspect of the study, which includes describing and diagnosing Fourth Industrial Revolution technologies and sustainable industrial development, in addition to examining the strength of the correlation and impact relationships between the research variables and testing the study hypotheses, as follows:

First: Description and Diagnosis of Fourth Industrial Revolution Technologies

1. Description and Diagnosis of the Items of the Internet of Things (IoT) Dimension

Table (2) was designated to present frequency distributions, percentages, arithmetic means, standard deviations, response rates, and coefficient of variation for the Internet of Things dimension. The results indicate that there is a strong level of agreement (agree and strongly agree) among the surveyed sample regarding the adoption of IoT technology in the targeted

companies, with a percentage of (87.5%). The results also show an arithmetic mean of (4.242), a standard deviation of (0.527), a response rate of (84.8%), and a coefficient of variation of (12.423).

Table (2)
Description and Diagnosis of the Internet of Things (IoT) Dimension

Coefficient of Variation (%)	Response Rate (%)	Standard Deviation	Arithmetic Mean	Response Measurement										Questions	Internet of Things (IoT)
				Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree			
				%	F	%	F	%	F	%	F	%	F		
16.046	88.6	0.711	4.431	0.9	1	0	0	7.3	8	38.5	42	53.2	58	X1	
20.164	82.9	0.836	4.146	1.8	2	1.8	2	11.9	13	48.6	53	35.8	39	X2	
22.166	82.7	0.917	4.137	1.8	2	5.5	6	8.3	9	45.9	50	38.5	42	X3	
14.189	88.2	0.626	4.412	0	0	0.9	1	4.6	5	46.8	51	47.7	52	X4	
22.881	81.6	0.934	4.082	1.2	2	6.4	7	9.2	10	46.8	51	35.8	39	X5	
12.423	84.8	0.527	4.242	1.4		2.9		8.2		45.3		42.2		Overall Average	
				4.3						87.5		Total			

Source: Prepared by the researchers based on SPSS software.

2. Description and Diagnosis of the Cloud Computing Dimension

Table (3) presents the description and diagnosis of the cloud computing dimension through frequency distributions, arithmetic means, standard deviations, response rates, and coefficients of variation for the items of this dimension. The results presented in the aforementioned table indicate a high level of agreement (strongly agree and agree) of (92.3%), which represents the highest agreement rate among the Fourth Industrial Revolution technologies adopted in the current study. This reflects that most of the surveyed companies utilize this technology in performing their production and service activities.

The results further show an arithmetic mean of (4.401), a standard deviation of (0.405), a response rate of (88%), and a coefficient of variation of (9.202).

Table (3)
Description and Diagnosis of the Cloud Computing Dimension

Description and Diagnosis of the Cloud Computing Dimension										
Coefficient of Variation (%)	Response Rate (%)	Standard Deviation	Arithmetic Mean	Response Measurement					Questions	Cloud Computing
				Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree		

				%	F	%	F	%	F	%	F	%	F		
12.879	93	0.599	4.651	0	0	0.9	1	3.7	4	24.8	27	70.6	77	X6	
16.307	86.2	0.703	4.311	0	0	2.8	3	5.5	6	49.5	54	42.2	46	X7	
14.482	87.1	0.631	4.357	0	0	0.9	1	5.5	6	50.5	55	43.1	47	X8	
16.316	86.4	0.705	4.321	0	0	1.8	2	8.3	9	45.9	50	44	48	X9	
17.793	87.3	0.777	4.367	1.8	2	0	0	7.3	8	41.3	45	49.5	54	X10	
9.202	88	0.405	4.401	0.3		1.3		6.1		42.4		49.9		Overall Average	
				1.6						92.3				Total	

Source: Prepared by the researchers based on SPSS software.

3. Description and Diagnosis of the Blockchain Dimension

The results presented in Table (4) indicate that the positive agreement rate regarding the blockchain dimension reached (85.3%). This is supported by the arithmetic mean value of (4.207), a standard deviation of (0.713), a response rate of (84.1%), and a coefficient of variation of (16.948). These results indicate that the surveyed companies have adopted this technology and consider it one of the most important tools used in the execution of their production processes.

Table (4)
Description and Diagnosis of the Blockchain Dimension

Coefficient of Variation (%)	Response Rate (%)	Standard Deviation	Arithmetic Mean	Measuring response										Questions	Blockchain
				Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree			
				%	F	%	F	%	F	%	F	%	F		
21.316	86	0.917	4.302	0.9	1	5.5	6	9.2	10	31.2	34	53.2	58	X11	
21.827	81.5	0.889	4.073	2.8	3	3.7	4	8.3	9	54.1	59	31.2	34	X12	
21.286	84.9	0.904	4.247	1.8	2	3.7	4	9.2	10	38.5	42	46.8	51	X13	
21.777	83.3	0.907	4.165	1.8	2	4.6	5	9.2	10	44	48	40.4	44	X14	
21.286	84.9	0.904	4.247	1.8	2	4.6	5	6.4	7	41.3	45	45.9	50	X15	
16.948	84.1	0.713	4.207	1.8		4.4		8.5		41.8		43.5		Overall Average	
				6.2		85.3				Total					

Source: Prepared by the researchers based on SPSS software.

Second – Description and Diagnosis of Sustainable Industrial Development

The data presented in Table (5) indicate that the items of the sustainable industrial development variable achieved an agreement rate (agree and strongly agree) of (82.5%), with an arithmetic mean of (4.099), a standard deviation of (0.538), a response rate of (82.00%), and a coefficient of variation of (13.125). These results indicate that the surveyed companies are exerting their utmost efforts to reduce the consumption of natural resources, carbon emissions, and environmental pollution, improve energy efficiency, achieve a balance between organizational returns and environmental protection, enhance product quality, and assume social responsibility toward society through the use of the latest tools and technologies to implement their manufacturing activities and ensure sustainability.

Table (5)
Description and Diagnosis of Sustainable Industrial Development

Coefficient of Variation (%)	Response Rate (%)	Standard Deviation	Mean	Measuring response										Questions	Sustainable Industrial Development
				Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree			
				%	F	%	F	%	F	%	F	%	F		
19.555	83.7	0.818	4.183	0	0	1.8	2	20.2	22	35.8	39	42.2	46	X16	
22.661	79.1	0.896	3.954	1.8	2	7.3	8	9.2	10	56.9	62	24.8	27	X17	
17.689	89.0	0.787	4.449	0	0	1.8	2	7.3	8	33	36	57.8	63	X18	
17.904	85.1	0.762	4.256	0.9	1	0.9	1	11	12	45.9	50	41.3	45	X19	
21.632	81.6	0.883	4.082	0.9	1	6.4	7	10.1	11	48.6	53	33.9	37	X20	
25.601	77.4	0.991	3.871	2.8	3	8.3	9	14.7	16	47.7	52	26.6	29	X21	
22.214	82.9	0.921	4.146	0.9	1	6.4	7	11	12	40.4	44	41.3	45	X22	
18.840	80.4	0.757	4.018	0.9	1	3.7	4	11	12	61.5	67	22.9	25	X23	
25.822	79.1	1.021	3.954	3.7	4	6.4	7	12.8	14	45	49	32.1	35	X24	
21.557	81.5	0.878	4.073	3.7	4	1.8	2	7.3	8	57.8	63	29.4	32	X25	
13.125	82.0	0.538	4.099	1.5		4.5		11.5		47.3		35.2		Overall Average	
				6						82.5		Total			

Source: Prepared by the researchers based on SPSS software.

Third: Testing the Research Hypotheses:-

1- Results of the overall correlation between the study variables:

The data presented in Table (6) reflect the correlation between Fourth Industrial Revolution technologies and sustainable industrial development at the overall level. It is evident from the correlation coefficient, which reached (0.801*) at a significance level of (0.05), that there is a strong, positive, and statistically significant relationship between the two study variables. This indicates that the use of Fourth Industrial Revolution technologies by companies will effectively enhance sustainable industrial development.

Table (6)
Results of the Overall Correlation between the Study Variables

Dependent Variable	Sustainable Industrial Development

Independent Variable	
Fourth Industrial Revolution Technologies	*0.801
Sample Size	109

Source: Prepared by the researchers based on SPSS software.

*=significant $P \leq 0.05$

2- Results of the Partial Correlation between the Study Variables:

Table (7) presents the results of the partial correlation between each dimension of the study variables at the level of the investigated field. The findings indicate the existence of a positive correlation between each dimension of Fourth Industrial Revolution technologies and sustainable industrial development at a significance level of (0.05). The correlation coefficients between the Internet of Things, cloud computing, and blockchain technologies were (0.504*), (0.385*), and (0.696*), respectively. These results indicate a positive relationship, meaning that as companies increase their attention to these technologies, this will positively and variably contribute to achieving sustainable industrial development. Accordingly, the first main hypothesis is accepted, which states: (There is a statistically significant correlation between Fourth Industrial Revolution technologies and sustainable industrial development at the overall level and at the level of sub-dimensions in the investigated field).

Table (7)
Partial Correlation Coefficients for the Study Field

Dependent Variable		Sustainable Industrial Development
Independent Variable		
Fourth Industrial Revolution Technologies	Internet of Things (IoT)	*0.504
	Cloud Computing	*0.385
	Blockchain	*0.696
	Sample Size	109

Source: Prepared by the researchers based on SPSS software.

*=significant $P \leq 0.05$

3- The Effect Relationship between Fourth Industrial Revolution Technologies and Sustainable Industrial Development:-

The results presented in Table (8) indicate a statistically significant effect of Fourth Industrial

Revolution technologies on sustainable industrial development. The calculated F-value was (190.903), which is higher than its tabulated value of (3.930) at degrees of freedom (1, 107) and a significance level of (0.05). The coefficient of determination (R^2) was (0.641), indicating that 64.1% of the variation in sustainable industrial development is explained by Fourth Industrial Revolution technologies. Furthermore, the calculated t-value was (13.817), which is higher than its tabulated value of (1.989). Accordingly, the second main hypothesis is accepted, which states: (There is a statistically significant effect of Fourth Industrial Revolution technologies collectively on sustainable industrial development at the level of the investigated field).

Table (8)
Overall Effect Coefficients for the Study Field

Independent Variable Dependent Variable	Fourth Industrial Revolution Technologies			F	
	B_0	B_1	R^2	Calculated	Tabulated
Sustainable Industrial Development	0.925	0.801)13.817(	0.641	190.903	3.930

Source: Prepared by the researchers based on SPSS software.

Calculated t-value, $df = (1,107)$, $N = 109$, $P \leq 0.05$

Tabulated t-value = 1.989

4- The relationship of influence between each dimension of Fourth Industrial Revolution technologies and sustainable industrial development:

a. The relationship of influence between the Internet of Things (IoT) technology and sustainable industrial development

The results of Table (9) indicate that there is a statistically significant effect between IoT technology and sustainable industrial development, where the calculated F value (3.930) is higher than its tabulated value of (3.930) at degrees of freedom (1, 107) and a significance level of (0.05). The coefficient of determination (R^2) was (0.252), meaning that (25.4%) of the explained variations in sustainable industrial development are attributable to the influence of IoT technology. The calculated t value was (6.039), which is higher than its tabulated value of (1.989). Accordingly, the first sub-hypothesis is accepted, which states that there is a statistically significant effect of IoT technology on sustainable industrial development at the level of the surveyed field.

b. The relationship of influence between cloud computing and sustainable industrial development

The results of Table (9) show that there is a statistically significant effect between cloud computing technology and sustainable industrial development, where the calculated F value (18.649) is higher than its tabulated value of (3.930) at degrees of freedom (1, 107) and a significance level of (0.05). The coefficient of determination (R^2) was (0.148), meaning that (14.8%) of the explained variations in sustainable industrial development are attributable to the influence of cloud computing technology. The calculated t value was (4.318), which is higher than its tabulated value of (1.989). Accordingly, the second sub-

hypothesis is accepted, which states that there is a statistically significant effect of cloud computing technology on sustainable industrial development at the level of the surveyed field.

- c. The relationship of influence between blockchain technology and sustainable industrial development

The results of Table (9) indicate that there is a statistically significant effect between blockchain technology and sustainable industrial development, where the calculated F value (100.681) is higher than its tabulated value of (0.485) at degrees of freedom (1, 107) and a significance level of (0.05). The coefficient of determination (R^2) was (0.148), meaning that (48.5%) of the explained variations in sustainable industrial development are attributable to the influence of blockchain technology. The calculated t value was (10.034), which is higher than its tabulated value of (1.989). Accordingly, the third sub-hypothesis is accepted, which states that there is a statistically significant effect of blockchain technology on sustainable industrial development at the level of the surveyed field.

Table (9)
Impact coefficients of each dimension of Fourth Industrial Revolution technologies on sustainable industrial development in the study field

F value		T value	R ² value	B1 value	B0 value	direct effect path		
tabulated	calculated							
3.930	36.457	6.039	0.254	0.504	0.515	sustainable industrial development	---<	Internet of Things (IoT)
3.930	18.649	4.318	0.148	0.385	0.512	sustainable industrial development	---<	cloud computing
3.930	100.681	10.034	0.485	0.696	0.526	sustainable industrial development	---<	blockchain

Source: Prepared by the researchers based on SPSS software.
df(1,107) $P \leq 0.05$ N = 109

Section Three / Conclusions and Recommendations

The present study reached a set of conclusions and recommendations as follows:

First: Conclusions

1. The adoption of Fourth Industrial Revolution technologies by manufacturing companies contributes effectively to improving the efficiency of production processes and increasing production volume.
2. The results showed that companies using modern technologies in their production processes are able to adapt to and cope with changes in the internal and external business environment, as these technologies provide data and information that support timely decision-making.
3. The descriptive and diagnostic results indicated a consensus among the research sample regarding Fourth Industrial Revolution technologies, where cloud computing ranked highest in terms of agreement compared to other technologies, indicating that the surveyed companies give sufficient attention to this technology and continuously work on its development.
4. The results related to the dimension of sustainable industrial development showed a high level of agreement among the surveyed companies on its items, indicating their

efforts to seek the latest technologies and tools to reduce waste levels, pollution, and carbon emissions, address disruptions in the supply chain, and improve product quality.

5. A statistically significant correlation was found between Fourth Industrial Revolution technologies and sustainable industrial development at both the overall level and the sub-dimensions level.
6. A statistically significant effect was found between Fourth Industrial Revolution technologies and sustainable industrial development at both the overall level and the sub-dimensions level.

Second: Recommendations

1. The present study recommends that the management of the surveyed companies develop strategies that support digital transformation through the adoption of Fourth Industrial Revolution technologies.
2. It is necessary for the surveyed companies to give sufficient attention to Fourth Industrial Revolution technologies due to their impact on data collection, analysis, transformation into information, and dissemination across all parts of the organization, in a way that improves energy and resource efficiency, enhances process monitoring, and reduces waste in materials, emissions, pollution, bottlenecks, failures, and production line stoppages, through the provision of adequate financial resources to develop existing production systems.
3. Develop the skills of employees within the surveyed companies in using Fourth Industrial Revolution technologies by enrolling them in intensive training programs and courses, enabling them to deal with these modern technologies.
4. Encourage the surveyed industrial companies to adopt sustainable production principles by reducing energy and raw material consumption and lowering pollution levels associated with production processes through the use of advanced technologies.
5. Work on spreading a culture of sustainable innovation across all departments and units of the surveyed companies through data and information exchange and conducting joint studies, in a way that contributes to improving productivity levels and achieving sustainable competitive advantage.
6. Conduct further studies on each Fourth Industrial Revolution technology independently to measure the extent of its impact on achieving sustainable industrial development objectives.

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