

Chapter

Industry 4.0 and Its Implications: Concept, Opportunities, and Future Directions

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Abstract

This chapter aims to analyze the Industry 4.0 framework, identify the definition and drivers of the Industry 4.0 paradigm, discuss its potential effect, and determine obstacles of the Industry 4.0. For the research methodology, a critical literature review is performed, we relied on the recent studies related to industry 4.0. Findings – This study concluded that Industry 4.0 describes a future production system's vision; it is an inevitable revolution and radical change, covering a wide range of innovative technologies, and all sectors. Industry 4.0 brings significant advantages to organizations, including real-time data analysis, increased visibility, autonomous monitoring, enhanced productivity, and competitiveness. The key features of Industry 4.0 are collaboration and integration of schemes, both horizontal and vertical. Innovation performs an essential role in organizations, sectors, countries. Industry 4.0 has enormous potential effect in many areas, and its application will have an impact across transforming the work environment. Industry 4.0 leads to potentials in three dimensions of sustainability. The KUKA corporation is an application for industry 4.0, for instance, smart factories, M-2-M, intelligent robots, etc., these technologies help industry 4.0 to separate rapidly. In contrast, there are some barriers, to implementing Industry 4.0 for example financial constraints, technical competency, organizational restraints.

Keywords: industrial revolutions, components of industry 4.0, impacts of industry 4.0, industry 4.0 drivers, barriers of industry 4.0

1. Introduction

Issues related to Industry 4.0 are constantly discussed among researchers, entrepreneurs, representatives of government agencies, and public organizations. Specifically, the impacts of the Industry 4.0 paradigm in the global and national economies, individual industries, employment, and capital markets are attracting more and more attention from economists. The global industrial environment has transformed dramatically in recent years as a result of technological advances and inventions. Industry 4.0 can be compared to three industrial revolutions that

happened in the previous centuries and represent the most significant disruptive shifts in manufacturing as a result of technology advancements [1].

The advent of the steam engine accelerated the First Industrial Revolution, which began in Britain in the middle of the 18th century. The Second Industrial Revolution arose in Europe and the United States in the second mid-nineteenth century. This revolution had characterized by mass manufacturing and the substitution of chemical and electrical energy for steam. Many technologies and mechanization had been developed to meet the increased demand, allowing productivity to increase [2]. The Third Industrial Revolution was sparked by the creation of the Integrated Circuit (microchip). Using electronics and information technology to accomplish increased automation in manufacturing is a significant characteristic of this revolution, which arose in many industrialized countries around the world in the later years of the twentieth century [1].

Every industrial revolution centered around boosting productivity. The first three industrial revolutions had a significant impact on industrial operations, allowing for increased productivity and efficiency by utilizing innovative technological breakthroughs, such as steam engines, electricity, and digital technology [3]. Industry 4.0, which could ultimately be referred to as the fourth industrial revolution, is a highly complex framework that has been commonly debated and discovered. It has a significant impact on the industrial sector because it introduces relevant improvements related to smart and future factories. This developing Industry 4.0 concept is an umbrella term for a new industrial paradigm that includes Cyber-Physical Systems (CPS), the Internet of Things (IoT), the Internet of Services (IoS), Robotics, Big Data, Cloud Manufacturing, and Augmented Reality, etc. [4].

The adoption of these technologies, which will bring together the digital and physical worlds through embracing a set of future industrial developments, is essential in the development of further smart industrial processes. This adoption includes devices, machines, production modules, and products that can exchange information and control each other independently, resulting in a smart manufacturing environment [5]. This new approach will allow the improvement of productivity and efficiency, carrying enormous potential effects, and it will support a set of economic and social opportunities among the companies that are adopting this new manufacturing paradigm [1].

This chapter intends to provide clear insight into the current developments within Industry 4.0 phenomenon, due to the inconsistency within the existing literature, some stress positive effects of Industry 4.0, while others, negative ones. As a result, the purpose of our research is to provide a full explanation of the Industry 4.0 paradigm, as well as to determine whether or not it is appropriate for businesses, stockholders, and countries to adopt this new approach. This chapter gives a review of Industry 4.0 and definitions in the literature, as well as introduces a brief on Industry 4.0's main components. Additionally, this chapter's research methodology was based on papers related to Industry 4.0, which are the most recent and cited references. As well as this study differs from past studies in several aspects, as shown in 1) It conducts a comprehensive survey of all Fourth Industrial Revolution technologies or applications, whereas earlier literature focused on one or a few technologies. 2) It performs a case study of KUKA Corporation, a pioneer company in the manufacturing technologies and applications of the Fourth Industrial Revolution.

Thus, this chapter is structured in seven sections. After this introduction about the Industry 4.0 phenomenon. Section 2 answers the question "What is the industry

4.0?”, presenting two points: an overview or background about Industry 4.0, and provides a comprehensive definition of this concept, its visions. The key Industry 4.0 technology enablers or components of Industry 4.0 characteristics are described in Section 3, which is divided into ten parts. The characteristics of Industry 4.0 state in Section 4. Section 5 provides an analysis of the impacts and influence of this new industrial paradigm: industrial sector, business models and markets, work environment, work skills, economy and sustainability, the value chains, and supply chains. While Section 6 presents the key drivers and obstacles or barriers of the Industry 4.0 concept; also, this part presents a pioneering experience in implementing the applications of the Fourth Industrial Revolution technology “KUKA corporation.” Finally, Section 7 draws the main conclusions and findings of the Industry 4.0 vision and implications.

2. What is industry 4.0?

2.1 An overview of industry 4.0

There have been three earlier industrial revolutions that have resulted in a transformation in manufacturing patterns: mechanization via water and steam power, mass production in assembly lines, and automating through computer and information technology [6].

The first industrial revolution (*Industry 1.0*) was developed in the United Kingdom at the end of 18th century with the advent of water and steam power and mechanization of production. It was the most significant advancement in human productivity, which considerably aided mechanical production and greatly improved agriculture and trade. Where steam engines could be used for power. Developments such as the steamship or the steam-powered locomotive brought about further massive changes because humans and goods could move great distances in fewer hours [4]. Then, it was followed by the second one (*Industry 2.0*) at the beginning of 19th century which introduced the electrically powered machines and assembly line production, which is described as the period when mass manufacturing became the dominant style of production in general. The introduction of railways into the industrial system was assisted by steel mass manufacturing, which in turn assisted mass production [7]. The third industrial revolution (*Industry 3.0*) took a place in the 1970s by adopting electronics and devices within the machines, which led to developing automation and robots within the manufacturing process. Industry 3.0 developed with the introduction of the Digital Revolution, which is more well-known than Industry 1.0 and 2.0, since most people today are familiar with industries that rely on digital technology in production [4].

The *Fourth Industrial Revolution* is presently being implemented. This is also known as “Industry 4.0,” and it is defined by the use of information and communication technology in the industry. It is based on the Third Industrial Revolution’s advancements. Production systems using computer technology are enhanced by a network link and, in a sense, have a digital twin on the Internet. These enable communication with other systems as well as the production of data about themselves. This is the next phase in the automation of production [8].

All systems are connected, resulting in “cyber-physical production systems” and, as a result, smart factories, in which production systems, components, and people

interact through a network and production is almost autonomous. When these enablers are combined, Industry 4.0 has the potential to offer some amazing improvements in manufacturing environments. Machines that can foresee faults and initiate maintenance operations on their own, for example, or self-organized logistics that adapt to unexpected changes in production are examples (Figure 1) [9].

It also has the ability to alter people's working habits. Individuals can be drawn into smarter networks by Industry 4.0, which might lead to more efficient working. The manufacturing environment's digitization provides for more flexible means of providing the appropriate information to the right person at the right time. Maintenance personnel may now receive equipment documentation and service history more quickly and at the point of use, thanks to the growing usage of digital devices inside factories and out in the field. Maintenance personnel prefer to spend their time addressing issues rather than waste time looking for technical knowledge [10].

In a summary, Industry 4.0 is a game-changer in the industrial world. Manufacturing will alter as a result of digitization, including how things are manufactured and delivered, as well as how products are maintained and enhanced. As a result, it may legitimately claim to be the start of the fourth industrial revolution. Industry 4.0 is presently taking shape and its supporting technologies, such as the Internet of Things (IoT) and Cloud Manufacturing (CM), are, nevertheless, poorly defined, and under-researched.

2.2 Definition industry 4.0

Industry 4.0 is better known as the fourth industrial revolution and describes a future production system's vision. The idea of Industry 4.0 was established by a group of professionals from several professions (such as business, politics, and academia) as part of an endeavor to integrate all manufacturing industries systems to achieve sustainability. The German government initially officially approved and implemented industry 4.0 for supporting automation in manufacturing, and for boosting German competitiveness in the manufacturing industry. Essentially, as a result of Industry 4.0, operations and manufactures will become further efficient and less expensive. These are accomplished through the simple interchange of information, integrated control of industrial goods and equipment, which work synchronously

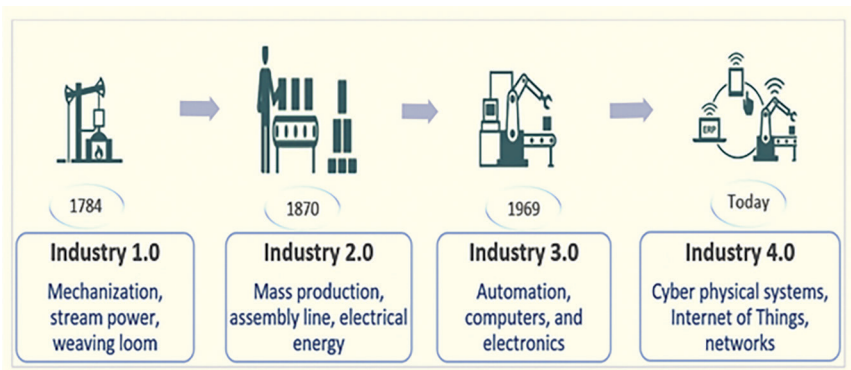


Figure 1.
Represents a graphic illustration of the industrial revolutions overall. Source: Constructed by the author.

and intelligently in interoperability [11]. However, several researchers have different perceptions of the meaning of industry 4.0.

Kagermann, et al. [12] stress that industry 4 utilizes the power of communications technology and innovative inventions to boost the development of the manufacturing industry. Corresponding to Kagermann et al., the primary features of the industry 4.0 idea are characterized by three aspects: (1) horizontal integration, (2) vertical integration, and (3) end-to-end digital integration of engineering. Qin, Liu, and Grosvenor [13] emphasize that industry 4.0 encourages manufacturing efficiency by collecting data, making correct decisions. By using the most advanced technologies, the procedures will be easier. The interoperability operating ability to ensure a stable manufacturing environment. This overall consciousness gives Industry 4.0 the most important aspect of artificial intelligent functions.

The Fourth Industrial Revolution, 4IR, or Industry 4.0 conceptualizes rapid change to technology, industries, and societal patterns and processes in the 21st century due to increasing interconnectivity and smart automation [14]. Schwab pointed out that Industry 4.0 is one of the most important concepts in the development of global industry and the world economy, he accentuates that, Industry 4.0 is differentiated by a few characteristics of new technologies, the improvement in technologies is bringing significant effects on industries, economies, and governments' development plans [15]. Industry 4.0 also denotes a social, political, and economic transformation from the digital age of the late 1990s and early 2000s to an era of embedded connection marked by widespread technological use (e.g., a metaverse). That, in comparison to humans' inherent senses and industrial ability alone, we have constructed and are entering an augmented social reality [16].

Wang et al., [17] defined the fourth industrial revolution as the modern and more sophisticated machines and tools with advanced software and networked sensors that can be used to plan, predict, adjust, and control the societal outcome and business models. Thus, Industry 4.0 is an advantage to stay competitive in any industry. Also, Industry 4.0 can be perceived as a strategy for being competitive in the future. It is focused on the optimization of value chains due to autonomously controlled and dynamic production [18]. Furthermore, industry 4.0 is possible to indicate three future-relevant themes related to it, such as: dealing with complexity, capacity for innovation, and flexibility [19].

According to the concepts above, the majority of the researchers considered Cyber-Physical Systems (CPS), Internet of Things (IoT), Industrial Internet, and other topics to be part of Industry 4.0. Numerous authors also emphasized Industry 4.0 on the cost and profitability of recently created high-tech information and intelligent services. According to previous research on Industry 4.0, the early focus was mostly on the industrial manufacturing sector, but many industries are now adopting Industry 4.0, including automotive, engineering, chemical, and electronics. As a result, Industry 4.0 is aggregating existing ideas into a different value chain that leads to an improvement in transforming entire value chains of goods life cycles while developing innovative products in manufacturing, involving the connection of systems and things that create self-organizing and dynamic control within the organization.

Industry 4.0, often referred to as the fourth industrial revolution, is the vision or scenario of a future production process characterized by new levels of controlling, organizing, and transforming the entire value chain with the life cycle of products through three types of effective integration: horizontal, vertical, and end-to-end engineering integration, resulting in increased productivity and flexibility, the

industry 4.0 leads to cost optimization and reduction [11]. The Cyber-Physical Systems (CPS), Internet of Things (IoT), artificial intelligence (AI), additive manufacturing, cloud computing, and other technologies are then combined to construct dynamic, real-time optimized, and self-organizing cross-company value networks. All of these components are necessary and integral to the futuristic Industry 4.0 concept.

3. Components of industry 4.0 and the key enabling technologies

Industry 4.0 is a complicated technical pattern characterized primarily by connection, integration, and industrial digitalization, highlighting the possibilities for integrating all components in a value-adding system. Digital manufacturing technology, network communication technology, computer technology, and automation technology are all included in this approach. Industry 4.0 technology breakthroughs are blurring the lines between the digital and physical worlds by merging human and machine agents, materials, products, production systems, and processes [20]. Industry 4.0 enables rapid technological advancements in a variety of areas; however, the emerging fourth industrial revolution is being shaped largely by the technical integration of Cyber-Physical Systems into manufacturing processes, as well as the use of the Internet of Things and Services in industrial processes [1]. As a result, this section gives a brief overview of each significant technology driver for Industry 4.0. It also is providing information on the basic components of Industry 4.0 or key technologies enablers for Industry 4.0, which consists of 10 components.

3.1 Cyber-physical system (CPS)

Cyber-Physical Systems (CPS) is the combination of computational and physical processes, which are essential components of Industry 4.0 implementations. They integrate imaging and control capabilities into the relevant systems. The ability of these systems to respond to any input generated is a key feature. They provide rapid control and verification of process feedback in order to generate predicted outputs. Berger et al. (2016) defined cyber-physical sensor systems as part of cyberspace, special types of embedded systems, based on powerful software systems, enable integration in digital networks, and generate whole new system features [21]. Generally speaking, the evolution of a CPS is characterized by three phases. Identification technologies are included in first-generation CPS. Second-generation CPS is equipped with some sensors and actuators with a limited number of functions. In the third-generation CPS, data is kept and analyzed in addition to setting up the equipment. The CPS has many sensors and actuators and is meant to be network compatible. CPSs offer various features [19].

The CPS has several sensors and actuators and is meant to operate with a network. CPSs have features including quicker information access, preventative maintenance, pre-defined decision-making, and optimization processes. Also, CPS can boost consumers awareness and consciousness. Conversely, the CPS has certain security issues, which means that further usage will definitely result in increased dangers. It was pointed out that CPS equipment might cause disruptive societal changes since intelligent assistive or autonomous environments can cause mental illnesses, which can lead to bias toward new technology adoption and usage [21]. Cyber-Physical Systems have consisted of two key components: i) A virtual environment built through computer

simulation of items and actions in the actual world, and ii) a network of objects and systems interacting with each other over the internet with a designated address [4].

3.2 Cloud systems (CS)

The term “cloud” is utilized for applications, for instance, remote services, color management, and performance benchmarking applications. It has taken remarkable attention from the IT community, and its role in other business areas will continue to grow. Machines, data management, and functionality will continue to transition away from traditional ways and toward cloud-based solutions as technology improves. The cloud enables significantly faster distribution than standalone systems, as well as quick upgrades, current performance models, and other delivery possibilities [19].

The industry has found a significant shift toward cloud solutions, which will continue to develop and represent a substantial challenge to traditional data storage methods. Cloud technology is the most basic online storage service that gives operational comfort with web-based apps that do not require any installation. Cloud computing refers to the process of storing all applications, programs, and data on a virtual server. It improves efficiency by guaranteeing those input suppliers, employees, and consumers have access to the same information at the same time [22]. Cloud Systems lower costs, simplify infrastructure, expand work areas, safeguards data, and allow for instant access to information. There are four types of the system, mainly: i) Public Cloud; ii) Private Cloud; iii) Hybrid Cloud (combination of public and private cloud); 4) Community Cloud (this refers to the co-operation of any service on the cloud with a few companies) [9].

Cloud systems are an excellent source of Big Data (which might be organized or unstructured) management solutions. Because traditional computers may not be capable of managing large amounts of data, using a cloud system to do the necessary analysis, would be much easier and more efficient. As a result, data analysis and cloud systems should be inescapable components of Industry 4.0. The integration of cloud-connected robots into everyday life, as well as their impact, is considerable [4].

3.3 Machine to machine (M2M) communication

Machine to machine (M2M), refers to the technology that allows direct communication between devices using any channel, wired or wireless. Machine-to-machine communication can include industrial instrumentation and personal communications [23]. M2M is also considered to be an essential component of Industry 4.0. Machine to machine (M2M) is a technology that allows devices to communicate directly with one another over any channel, wired or wireless. Machine-to-Machine Communication can include industrial instrumentation and personal networks. M2M is also considered to be an essential component of Industry 4.0. The apps are geared toward adding value to the enterprises by introducing alternative revenue streams and reducing operational costs [24].

Ackermann (2013) clearly states that M2M operations have to enable aspects with different networked organizations including i) Remote Service and Asset Information Management delivering, which provide information federation and lifecycle support. ii) Connected Vehicles, which creates relationships and interactions. iii) Smart Vending, which includes retail, supply chain, and associated sub-elements [4]. The M2M vision has raised a number of issues, including establishing smart settings, smart architecture, and a smart grid with wireless sensors, as well

as developing a communication language between machines and humans, as well as between humans in different locations [23].

3.4 Internet of things and internet of services

The Internet of Things (IoT) is an emerging concept that combines various technologies and techniques, based on the interaction between physical things and the Internet. The advancement of technology in recent decades has enabled the Internet to be expanded into a new level known as “smart objects,” which is the foundation of an IoT vision, for this, the novel pattern consists in awarding ordinary things with intelligence, permitting them not only to accumulate information and cooperate with their surroundings, but also to be interrelated with other items, communicating information, and conducted a preliminary via the Internet. The growing interest in this field, which is widely regarded as one of the primary drivers of Industry 4.0, has produced the development of a number of visions and definitions for (IoT) [1].

The Internet of Things (IoT) refers to the interconnection of physical devices, cars, buildings, and other entities that are equipped with electronics, software, sensors, actuators, and network connections to gather and share data to create a smart manufacturing environment, also known as a smart factory [25]. Additionally, the concept of “The Internet of Services (IoS)” takes a similar approach to IoT but applies it to services rather than physical assets. The Internet of Services (IoS) idea will open up new prospects for the service sector by providing a commercial and technological foundation for the construction of business networks between service providers and clients [4].

The expansion of IoT in industrial contexts and value chains will give several opportunities for users, manufacturers, and businesses, having a significant influence in a variety of industries. The Internet of Things is breaking new ground, with a slew of new applications emerging around three key pillars: i) process optimization; ii) resource optimization, and iii) the building of sophisticated autonomous systems. IoT technology will continue to evolve and spread, allowing objects to become smarter, more dependable, and autonomous, allowing for the supply of higher-value products and services [1]. On the other hand, the effectiveness of Industry 4.0 depends upon existing network infrastructure, the intelligence, and human knowledge embedded into the system [22].

3.5 Smart factories or smart manufacturing

Smart factories or Smart manufacturing is a type of manufacturing that aims to improve concept creation, production, and product interactions by moving away from traditional methods toward automated and digitized systems. It aims to take advantage of advanced information and manufacturing technologies in order to operate and produce fully flexible production at the highest speed required [6].

“Dark factories,” “lights off factories,” and “unmanned factories” are all terms used to describe smart factories, this system is integrated with the small intervention of human beings. The individual is entering into these systems mainly in the problem-solving stages. The concept known as Lights out (dark) or unmanned factories nowadays is an automation and autonomy enhanced methodologies including equipment used in factories that actively operate the production [4, 26]. The most famous characteristic of dark factories is that they do need no human power. In unmanned factories, there is not enough time to enter the plant from the raw material

to the exit from the factory. That is to say that in these factories, production is carried out entirely with robotic systems [18]. It is self-evident that smart factories will have the characteristics and procedures required by the Fourth Industrial Revolution. And these processes, which are of great importance to our future of production. Furthermore, the essential activity for generating a smart factory running under Industry 4.0 is integrating different other components together, such as big data, CPS, cloud, IoT, M2M, etc. [4].

There are many challenges that determine the formation of smart factories, such as the availability of energy and its supply, the efficiency of the labor, and the availability of the technological infrastructure necessary to shift toward smart factories. On the other hand, these factories will have a negative impact on existing employment and increase unemployment rates [7].

3.6 Big data and data mining

Big data is being generated continuously by everything in environments. Every digital process and social media exchange produce data. Systems, sensors, and mobile devices transmit those. Big data is arriving from multiple sources at an alarming velocity, volume, and variety. To extract meaningful value from big data, there is a need for optimal processing power, analytics capabilities, in addition to information management skills [4]. An abundance of heterogeneous data abounds in the world around us. Without properly applying data mining technology, it appears impossible to make this atmosphere keenly intelligent. With today's automation, data mining can be supervised, unsupervised, or reinforcement learning. When executed in numerous layers in a hierarchical way, computer-assisted learning becomes more exact. Machine Learning is the process of automatically extracting features through supervised or unsupervised learning in a hierarchical fashion (ML) [27].

3.7 Intelligent robotics

Every day, new goods and systems emerge as a result of technological advancements. Flying automobiles, holographic television, and hundreds of electrical devices to be implanted into the human body are all possibilities [26]. Humanoid robots will be a part of everyday life in the not-too-distant future. Recent innovations have brought about skills that empower robots to control their environment. Artificial intelligence will contribute to the development of having robot teams cooperating and collaborating in achieving certain tasks defined for a specific purpose [28].

Implementing a collaborative robot in a factory will provide several benefits for the company, including i) preventing humans from performing repetitive, non-ergonomic, and dangerous work; ii) producing high-quality products with favorable cost-benefit ratios while also increasing productivity; and iii) increasing competitiveness in comparison to countries with cheap labor [29]. When a robot is used in a productive process, the benefits of the robot utilization are combined with the effort of an operator. There is no teamwork between the man and the robot on the first level. The workplace is totally shared between the man and the robot at the final level [30].

3.8 Augmented reality and simulation

Simulation, the data obtained and processed from big data and cloud systems can be used as a feed to a virtual model to evaluate all possible scenarios related to the

product design, development, and production. Simulation is used broadly in business models to leverage the available real-time data and simulate the actual working world in a virtual ecosystem. Process testing and optimization through simulation permit people to decrease business changeover, risk, setup time, and enhance quality control for future processes and services, even before the implementation of adjustments in the actual physical world [22].

Simulation and augmented reality (AR) is a type of enhanced reality in which live direct or indirect views of physical real-world environments are augmented with computer-generated visuals projected on top of them. Industry 4.0 applications rely heavily on this technology. This innovative technology, which is critical to the industrial revolution, was created by combining real operations and simulation industries [4]. These strategies have a lot of advantages, especially when it comes to creating products and manufacturing processes. One of the cutting-edge technologies included in the Industry 4.0 trend is augmented reality, which is particularly useful in producing smart manufacturing functions [28].

3.9 Enterprise resource planning (ERP) and business intelligence

Enterprise resource planning (ERP) refers to information systems that are designed to integrate and efficiently employ all of an organization's resources. An ERP software is a system that supports an organization in bringing together processes and data that are executed all over the processes (suppliers, production, stock, sales). ERP systems are able to provide an integrated approach to information use, to start forecasting and extracting information, which can use in various departments [4]. There is a connection between big data and Industry 4.0, Manufacturing Executive Systems (MES), cloud systems, and ERP are integrated. It is critical that all procedures in the design stage as well as the customer journey are compatible with the Industry 4.0 approach. The ERP process is also a vital component in this framework [28].

The idea of Industry 4.0 necessitates connection and collaboration criteria. End-user feedback is critical, as is providing immediate additional value to all interested parties. In order for personalization to be possible, network systems must be intelligent [22]. A telecom operator may be able to analyze network performance during fluctuations and use preventive scenarios to reduce client dissatisfaction. A well-structured ERP system can enable these characteristic features. ERP systems can help with Industry 4.0 implementations, especially as a result of the following advantages: i) Real-time data may be evaluated and allow for early detection; ii) ERP systems can provide sales and purchasing transparency; iii) ERP data may be used by mobile applications to communicate; iv) Optimum resource utilization may be achieved under varying job descriptions; v) Clients may be able to track their orders online and receive the necessary information quickly [4].

3.10 Smart virtual product development system (SVPD)

The Smart Virtual Product Development (SVPD) system is a product development decision support technology that saves, uses, and shares the experiential knowledge of previous decisional events in the form of SOEs. It was created to address the requirement for digital knowledge captured in smart manufacturing product design, production planning, and inspection planning. As a result, product quality and development time will be improved, as required by Industry 4.0 concepts [31].

4. Industry 4.0 characteristics

The core progress from traditional manufacturing toward Industry 4.0 concluded into four key features and characteristics [32]: (1) vertical networking of smart manufacture schemes; (2) horizontal integration through a new generation of global value chain networks; (3) through-life engineering across the entire value chain; and (4) the impact of exponential technologies.

4.1 Vertical networking of smart production

Industry 4.0's first main characteristic is the vertical networking of smart manufacturing systems. Vertical integration in Industry 4.0 establishes a connection between the many levels of the industry, from the manufacturing floor up, via production monitoring, control, and supervision, quality management, operations, product management, processing, and so on. This interconnectedness across all corporate levels provides for a fluid, transparent data flow, allowing for data-driven strategic and tactical choices [20]. Hence, the main objective behind vertical networking is to utilize Cyber-Physical Production Systems (CPPSs), to enable industries to quickly respond to unexpected order changes resulting from demand fluctuations, equipment failure or stock shortage. Vertical networking improves an organization's capacity to adequately adapt to changes in market requirements and benefit from new possibilities [22].

Furthermore, it makes it easier to link resources to goods and find supplies and parts at any time. Similarly, processing data, anomalies, and defects from various processing stages of the manufacturing line are automatically captured and registered, allowing for quick responses to order changes, quality variations, and even machinery breakdowns. As a consequence, waste is decreased, and resource efficiency, notably in terms of material usage, energy consumption, and human resources is improved [28].

4.2 Horizontal integration through a new generation of global value chain networks

In the Industry 4.0 concept, horizontal integration refers to the network of diverse processes, companies, and services that make up a product's global value chain. This can be viewed at the production level as a total consolidation of all associated manufacturing processes. Vertical integration, on the other hand, refers to a high level of coordination between production and top management layers such as quality management, product management, and production control [33].

The horizontal integration in an Industry 4.0 enterprise occurs at different levels: production floor, multiple production facilities, and entire value chain. Each connected machine or production unit becomes a node with well-defined properties within the production network. These nodes continuously communicate their status to respond autonomously to dynamic production requirements cost-effectively and reduce system downtime through predictive maintenance. If an enterprise owns several production sites, the horizontal integration enables to share inventory levels and unexpected delays, and possibly redistribute work among owned facilities to respond to market demand fluctuations rapidly or increase the efficiency and speed of the production process. However, the most critical and global horizontal integration remains the integration across the entire value chain [12].

Industry 4.0 offers a highly automated and transparent collaboration across the complete value chain, using CPPSs, from the inbound assembly, packaging, storing, production, quality control, marketing, and sales, to outbound distribution, logistics, and retail services. The horizontal integration across all these activities creates a transparent value chain that is updated in real-time. Hence, this feature provides a high level of flexibility to respond more rapidly to changing market demands, shortcomings, and problems, facilitates the optimization of the production process, increases its efficiency, and reduces the generated waste [17]. Additionally, the fact that any part or product's history is logged and can be accessed at any time ensures constant traceability, also known as "product memory" [19].

4.3 Through-life engineering across the entire value chain

Among the characteristics of the Fourth Industrial Revolution is also the impact of the ten components of the 4th Industrial Revolution "*ten types of innovation*," Efficient management of innovation, and finally, Efficient life cycle management. These are shown below.

The "ten types of innovation" (Components of Industry 4.0). Industry 4.0 will enable integrated and cross-disciplinary engineering throughout the value chain, as well as throughout product and customer life cycles. Industry 4.0 applications are intended to ensure the traditional domain of product innovation. Innovation is not limited, innovation has traditionally been related mainly to product offerings, but it also has significant potential in areas such as company structures, processes, networks, and profit models, as well as customer-facing functions [5].

Efficient management of innovation. The digital transformation to industry 4.0 will make it possible to improve further the efficiency of innovation management in all the Components of Industry 4.0. Interactive and designed curricula make individualized learning achievable, thereby, speeding up strategic implementation and organizational development [34]. Industry 4.0 solutions in project portfolio management make it easier to track not only the return on investment (ROI) in innovation, but also to identify risks by utilizing global comparative project data for monitoring and remediation. Information technology can be utilized to speed up R&D in the field of product development [5].

Efficient life cycle management. The digital transformation industry 4.0 will allow essential data for life cycle management to be provided at any time and from any location. These data will include not just information and reports, but also the outcomes of big data processing, which will be used to develop appropriate early indicators using artificial intelligence (AI). AI will employ global cross-checking to determine the plausibility of developing suitable bases for data-driven decision-making. It will allow businesses to better understand and address the needs of their customers, as well as customize product cycles [5].

4.4 The impact of exponential technologies

Exponential technologies solutions. Corporate venture capital firms have a strong chance of profiting from disruptive innovation and exponential technology by investing in new trends early on. Corporate venture capital Investing in start-ups allows businesses to participate in the development of new products and services while also ensuring their long-term competitiveness. This type of investment allows for early and convenient access to new technologies. Companies must be given more leeway

to “see around the next corner.” Only then can a new business region be formed, which will eventually become the company’s new heart. Companies’ survival may be jeopardized if such possibilities are neglected [2].

The learning organization. If companies are to fully use the promise of exponential technologies in making the digital transformation to industry 4.0, they must change into learning organizations. Exponential technology adoption and integration must be slow but continuous. Learning is essential for long-term organizational development. It is time to make a change that is not so counterproductive. New ideas, processes, and business sectors are most successful when they begin as a learning niche and eventually migrate to the center of the organization, establishing themselves as a new leading segment [5].

5. Effects of industry 4.0

Innovation and scientific advancements perform an essential role in businesses, sectors, and countries. However, the digital improvements and the increasing interconnectivity will bring additional challenges and upgrades to societies, since, Industry 4.0 (Ir 4.0) will significantly change the manufacturing systems in terms of design, processes, operations, and services. Industry 4.0 will lead to potential deep changes in a variety of fields outside of the industrial sector. Its influence and effect may be divided into six categories: (1) Industry sector, (2) Products and services, (3) Business models, entrepreneurship, and market competition, (4) Economies of nations, (5) Work environment, and (6) Skills development.

5.1 The impact of industry 4.0 on the industrial sector

The industry sector will be the first to feel the effects of Industry 4.0. This new industrial paradigm will usher in a vision of manufacturing that is decentralized and digitalized, with production elements that can autonomously govern themselves, trigger operations, and adapt to changes in their surroundings. Furthermore, the developing paradigm recommends fully integrating products and processes, altering industrial vision from mass production to mass customization, resulting in increased complexity [35]. Consequently, advanced technologies and the building of smart factories will have a significant impact on production processes and operations, providing for greater operational flexibility, and more efficient utilization of resources. Industry 4.0 will have a considerable effect on the production systems, supply chains, and industrial activities. This new paradigm is changing the current industrial landscape in three ways: (1) production digitization, (2) automation, and (3) integrating the manufacturing site to a larger supply chain. Industry 4.0, in this sense, entails complete network integration and real-time data sharing [1]. Productivity growth is at the core of each industrial revolution. The 4th industrial revolution, on the other hand, will influence the entire supply chain, from product creation and manufacturing to outbound logistics, in addition to enhancing productivity [36].

ROJKO, et al. (2020) used the vector autoregression model forecast for data from the manufacturing sector in the United States over the period (2008–2018) and concluded that, the share of manufacturing output and employment has declined, and that the manufacturing sector has reached a turning point, after which robotization can increase employment and labor productivity of workers while also stimulating further growth of their education levels. They concluded that the shift to Industry 4.0

has a significant impact on the growing demand for new knowledge and skills in order to boost productivity. As a result, anticipated growths of assessed manufacturing indicators imply that the negative effects of robotization in the recent past were only transient, as the Industry 4.0 age has begun. Nonetheless, further policies are needed to enable long-term industry development [37].

5.2 The impact of industry 4.0 on products and services

This new industrial paradigm has a significant impact on products and services. Rapid changes in the economic landscape and dynamic market demands have resulted in an increased demand for the development of more complicated and intelligent products in recent years [36]. Products will become increasingly modular and configurable, allowing for mass customization to match individual consumer needs [35]. As a result, Industry 4.0 is defined by the emergence of new products and services as embedded systems that can become attentive and interactive, be managed, and tracked in real-time, optimize the entire value chain, and provide pertinent information about their status throughout their lifecycle [37].

5.3 The impact of industry 4.0 on business models and market

In the previous few years, company models and markets have swiftly altered, and new inventive business models will emerge. In the context of Industry 4.0, the introduction of new disruptive technologies has altered the way products and services are sold and delivered, disrupting established enterprises, and introducing new business prospects and models [33]. As a result, value chains are becoming more responsive, as Industry 4.0 encourages integration between manufacturers and customers, allowing for closer customer connection and business model adaption to market demands. The rising digitalization of industrial production, combined with system integration and complexity, will result in the establishment of increasingly sophisticated and digital market models, boosting competitiveness by removing barriers between information and physical structures [1].

5.4 The impact of industry 4.0 on the work environment

Because of technological advancements, the workplace environment is changing fast, and Industrial revolution 4.0 is redefining jobs and key competencies. The most significant transition is the human-machine connection, which includes employee contact and a set of new collaborative work approaches [18]. The number of robots and intelligent technologies is growing, the real and virtual environments are merging, implying the existing work environment is undergoing a considerable transition [13].

The rising importance of human-machine interfaces will encourage interaction between production elements as well as the necessary communication between smart machines, smart products, and employees, which will be aided by CPS' vision of IoT and IoS. As a result, ergonomic concerns should be considered in the context of Industry 4.0, and future systems should emphasize the relevance of workers. Job profiles, as well as work management, organization, and planning will be affected by the integration of Industry 4.0 in industrial systems and the rising deployment of new technologies [12]. In this scenario, the major task is to avoid technological unemployment by reframing present jobs and taking steps to adapt the workforce to the new jobs that will be generated [28].

5.5 The impact of industry 4.0 on skills development

One of the most significant fundamental factors for a successful acceptance and implementation of the Industry 4.0 framework is skill development, which will lead to demographic and societal changes. New competencies will be required in the future work vision, and it will be vital to provide opportunities for the acquisition of these abilities through high-quality training. This new industrial paradigm will have a significant impact on the labor market and professional roles, and it will be critical to ensure that more jobs are generated than are lost [26].

Interdisciplinary thinking will be vital, and outstanding abilities in social and technological domains will be desired. The new required competency sectors must be included in schooling. As a result of Industry 4.0's rising automation of jobs, workers must be prepared to take on new responsibilities [28]. The same can be said for engineering education, which has a lot of promise in terms of training future professionals and informing them about new technical trends and opportunities, as well as managers who need to adapt their management strategies to meet changing market demands. Furthermore, in order to address Industry 4.0, more qualified personnel will be required in technological sectors [1].

In summary, Industry 4.0 has enormous potential in many areas, and its implementation will have an impact across the entire value chain, improving production and engineering processes, improving product and service quality, optimizing customer-organization relationships, bringing new business opportunities and economic benefits, changing educational requirements, and transforming the current work environment.

5.6 The impact of industry 4.0 on the economy

An economy can be inspired by the introduction of new models and emerging technological improvements. Digitization involves the convergence between physical and virtual worlds and will have a widespread impact in every economic sector [15]. This will be the primary driving force behind innovation, which will be crucial to productivity and costs of production, which is reflected in the competitiveness (companies, sectors, and nations) [17].

Industry 4.0 also, can transform existing relationships in the manufacturing process, allowing the manufacturing sector to join the information age by allowing communication at all stages of the manufacturing process. Some academics anticipate that Industry 4.0 would lead to new economic forms in the industry, agriculture, and services [3]. The majority of businesses expect a two-year payback on their Industry 4.0 investments, which leads to a considerable rise in investment in this area is likely, it's reflected in economic growth [37].

On the other hand, some experts believe that Industry 4.0 will result in increased inequality due to its threat of disrupting labor markets. It is argued that the continuous growth in automation, robots, and computers will take the jobs of workers in many industries with the most worrying factor being the increased danger of the disappearance of low-skill/low-pay jobs which will cause a lot of challenges for the poor, which will lead to a rise in social tensions [37]. The most concerning fact in Industry 4.0 is that it is not only the transfer of labor from one sector of the economy to another but also the availability of technology that will replace human capital, in other words, taking people's jobs. The technological revolution will also have an impact on topics such as material or ideological changes brought about by the

introduction of new gadgets or systems, all of which will have an impact on redefining humanity's culture [3].

In general, digitization and interconnection of industrial processes, lead to potentials in all three dimensions of sustainability. However, achieving long-term benefits of sustainability is accompanied by several challenges respectively, especially in the implementation phase of Industry 4.0 [38].

Referring to the economic perspective of Industry 4.0, transparency and interconnection of processes enable process optimization, resulting in increased efficiency, flexibility, quality, and customization. Industry 4.0 allows load balancing between smart manufacturing technologies, innovative value propositions, and increasing demand orientation. All these are enabling smart products, which boost a company's competitiveness [39]. In the same regard, increasing process openness in intra- and inter-firm logistics can also be accomplished, lowering logistics costs. On the other hand, such procedures, as well as the adoption of Industry 4.0 in general, represent risks in terms of high investments and uncertain profitability [38]. Furthermore, manufacturers consider the transition to Industry 4.0 of their current business models to be difficult. Furthermore, Industry 4.0 necessitates the standardization of processes both within and between businesses. Due to their low degree of process standardization, more flexible but less automated manufacturing equipment, and resource limits, among other things, both undertakings, i.e., business model change and standardization, can become particularly problematic for SMEs [40].

Regarding the ecological dimension of sustainability, Industry 4.0 offers a number of advantages: transparency in demand and process enables for an intelligent task and process scheduling, resulting in lower energy use [38]. Furthermore, direct data linkage from product consumption back to design can improve manufacturing design, resulting in improved product lifecycle management, including recycling, as a result, Industry 4.0 aids in the identification and reduction of greenhouse gas emissions [40]. As a result, waste reduction and resource consumption can be improved. Reduced transportation operations and superfluous material flows can also be realized in logistics [25]. Furthermore, data openness across the entire supply chain can reduce the frequency of incorrect deliveries, wasteful waiting time, and damaged items. Decentralized production close to the point of consumption minimizes both logistics costs and environmental concerns [41]. Similarly, emerging manufacturing technologies such as additive manufacturing can aid in the reduction of waste in manufacturing and logistics processes, such as replacement parts [42].

Regarding the social dimension of Industry 4.0, several benefits for employees are named, such as improved human learning through intelligent assistance systems as well as human-machine interfaces that lead to increased employee satisfaction in industrial workplaces [8, 22]. However, current literature cannot provide a unified perspective on whether Industry 4.0 will cause an increase or decrease in employee numbers in the industry. In this regard, concrete numbers named differ to a large extent [3, 15]. In general, a further replacement of simple tasks is expected, whereas tasks such as monitoring, collaboration, and training will still be required [3]. Hereby, new job profiles with novel requirements for training and education are expected to emerge, mostly referring to decreasing importance of manual labor in contrast to IT skills. On the other hand, tasks that include planning and monitoring, as well as decision-making, could fall to autonomous systems, therefore, possibly replacing jobs in this area.

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and human-machine interfaces that lead to increased employee satisfaction in industrial environments [38]. However, the present research cannot agree on whether Industry 4.0 would result in an increase or decrease in the number of employees in the industry [25]. In general, easy jobs will be replaced further, while monitoring, collaboration, and training will continue to be required. It is possible that occupations in this field will be replaced [38]. As a result, implementing Industry 4.0 in an organization necessitates deliberate transformation activities, sometimes known as “digital transformation.” It necessitates new attitudes for dealing with digital transformation difficulties as well as a unified approach for staff qualification and acceptance [43].

5.7 The impact of industry 4.0 on value chains and supply chains (SC)

The fourth industrial revolution has a significant impact on supply chain interactions, which is mainly due to the exponential growth of sensible data and the widespread of digitalized processes [40]. To understand the impact of the adoption and exploitation of Industry 4.0 technologies on the value chains and supply chains (SC). Based on the review, the effect of Industry 4.0 implementation on the supply chains (SC) are identified as follows:

Agility and Customization. Industry 4.0 implementation enables real-time planning and control, permitting organizations to be flexible and agile in responding to rapidly changing conditions; for example, by faster reacting to changes in demand, supply, and prices, companies can reduce planning cycles and frozen periods [34]. Future events and trends, such as consumer behavior, delivery time, and industrial output, can be predicted using business analytics techniques. Real-time delivery routing and tracking also allow logistics operations to be more flexible, efficient, and agile [44].

Accuracy and Efficiency. Industry 4.0 technologies provide better decision-making by providing real-time, consistent, and accurate data. As a result, next-generation performance management systems will improve end-to-end visibility across the value chain. The data includes everything from key top-level performance metrics like customer service and order fulfillment to detailed process data like a truck position in the logistics network. The automation of physical tasks, planning, control, and information exchange processes improves supply chain (SC) efficiency. Automated technologies are used by a large number of businesses, particularly in their logistics operations [44]. Companies choose cross-company transportation optimization to optimize truck utilization and boost transport flexibility by cooperating and sharing facilities. The entire SC network design is constantly optimized to ensure that it is a perfect fit for business needs [34].

6. Key drivers and obstacles or barriers of industry 4.0

6.1 Key drivers of industry 4.0

Despite the rapid rise of Industry 4.0, research related to the identification of potential drivers and hurdles to its implementation are scarce. To better understand the motivations and challenges to the adoption and use of Industry 4.0 technologies, a literature review was conducted. The following are the primary drivers for Industry 4.0 implementation, as determined by the review:

Agility and Customization. Industry 4.0 implementation enables real-time planning and control, permitting organizations to be flexible and agile in responding to rapidly changing conditions; for example, by faster reacting to changes in demand, supply, and prices, companies can reduce planning cycles and frozen periods [34]. Future events and trends, such as consumer behavior, delivery time, and industrial output, can be predicted using business analytics techniques. Real-time delivery routing and tracking also allow logistics operations to be more flexible, efficient, and agile [44].

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6.2 Applications of fourth industrial revolution

In this section, we introduce an overview of some applications of the Fourth Industrial Revolution. Also, we provide a case study for these applications by *KUKA Group* in many fields. KUKA is an international automation corporation based in Augsburg, Germany. As a world-class provider of intelligent automation solutions. In areas such as automotive, electronics, metal & plastic, consumer products, e-commerce/retail, and healthcare, KUKA provides everything from a single source: from robots and cells to completely automated systems and their networking [45].

The “*Smart Factories*” are automation solutions from KUKA, which is able to transport aircraft components around the production hangar with millimeter precision. The employees at the Airbus production plant move enormous A380 fuselage sections, weighing 90 tons and measuring 15 meters in length around a building the size of a football stadium. This is made possible by the KUKA omniMove mobile transport platform, a transport vehicle for heavy loads that is equipped with omnidirectional Mecanum wheels [46].

Similarly, using techniques such as *Machine-to-Machine* (M-2-M) and *intelligent robots* as applications from the KUKA company. Robot-based KUKA system technology for machine tool automation is used, among other things, for the loading and unloading of machines and supports elements of Industries 4.0 [47]. In the KUKA's site in Augsburg, work 7 robots, which is a typical production environment at an international machine manufacturer [48].

Another application of industry 4.0 in the *medical sector*, automation solutions for greater efficiency in hospitals, in areas of diagnosis and surgery to therapy, KUKA robots meet the stringent requirements of the medical sector and are well-suited to a wide range of medical technology applications. For this, KUKA offers a wide range of medical high-tech products, ranging from robot-based help systems for surgery to assistive components for diagnosis or rehabilitation [45].

There are several applications for industry 4.0, for example, the KUKA corporation which works in the areas, for instance, smart factories, M-2-M, computing cloud, intelligent robots, e-commerce, and so on.

6.3 Key obstacles or barriers of industry 4.0

There are also some intimidating resisting forces, barriers, for implementing Industry 4.0 practices. These obstacles may be classified under the following business dimensions: *Firstly, Financial constraints*. Financial constraints are a fundamental issue in implementing Industry 4.0 in terms of developing sophisticated contemporary infrastructure and sustainable process improvements [28]. *Secondly, the technical competency* of the focal organization is the key focus that influences the scale of investment. The economic perspective, on the other hand, is still in its infancy; a lack of clarity about cost–benefit analysis and monetary rewards on digital investments is a critical issue for deploying Industry 4.0 [40].

Thirdly, Organizational nature. Other obstacles that businesses aiming to integrate Industry 4.0 technologies confront include insufficient research and development procedures, a lack of infrastructure, poor data quality, a lack of digital culture, and a lack of trust among partners [17]. Poor infrastructure and internet connectivity are significant impediments to any digital transformation or adoption [22]. As well as *fourthly, Lack of management support and Resistance to change*. Industry 4.0 transformative changes are fast-paced and necessitate proper skill development and training, which is difficult to do without a high degree of management support, which is the most important requirement for launching Industry 4.0. Industries are unsure and unfamiliar with the term Industry 4.0 and are ignorant of the benefits of digital transformation due to which there is reluctance in adopting it [22].

Additionally, *Legal Issues*. The big data transaction brings cybersecurity risk; therefore, privacy and security concerns must be considered when implementing Industry 4.0 [44]. Finally, *Lack of policies and support from the government*. In most nations, governments supply the infrastructure for the digital world (such as the internet and communication networks). However, there is a lack of a roadmap for transforming industrial infrastructure, owing to a lack of clarity (for example, the development of the 5G network and its benefits for Industry 4) about the implications of Industry 4.0 [22].

7. Conclusion

This study contributes to bridging the critical gap, by discussing the key components, characteristics, effects on many dimensions, drivers, barriers, and other implementation challenges of Industry 4.0, the fourth industrial revolution describes a future production system's vision. Industry 4.0 is an inevitable revolution covering a wide range of innovative technologies, such as cyber-physical systems, RFID technologies, IoT, cloud computing, big data analytics, advanced robotics, smart factories, etc. The Industry 4.0 paradigm is transforming business in many industries, e.g., automotive, logistics, aerospace, and energy sectors, etc. Industry 4.0 realizes the development and integration of information and communication technologies into business processes. The capabilities or components of Industry 4.0 bring significant advantages to organizations, including customization of products, real-time data analysis, increased visibility, autonomous monitoring and control, dynamic product design and development, enhanced productivity, and competitiveness.

The key characteristic features of Industry 4.0 are collaboration and integration of schemes, both horizontal and vertical. In vertical integration, Information and Communication Technology (ICT) is integrated into various hierarchical levels of

the organization, from floor-level control to production, operations, and management levels. This vertical integration networking empowers the use of components of Industry 4.0 for production to respond to demand disparity or the fluctuations in stock levels. In horizontal integration, ICT is used to exchange information between many players. Integration of these systems for a flawless collaboration, integration, and exchange of data with all the stakeholders is a complicated scenario. Implementation of Industry 4.0 apps support to reduce costs, improves productivity, efficiency, and flexibility, and enhance product customization.

Innovation and technological advancements perform an essential role in organizations, sectors, countries. However, the digital transformation improvements and the rising interconnectivity will bring new challenges to societies, since Industry 4.0 will significantly change the products and manufacturing systems regarding design, processes, operations, and services. Industry 4.0 uses several advanced tools and technologies, thus helping to redefine conventional industrial processes. Industry 4.0 has enormous potential effect in many areas, and its application will have an impact across the entire value chain, improving production and engineering processes, improving product and service quality, optimizing customer-organization relationships, bringing new business opportunities and economic benefits, changing educational requirements, and transforming the current work environment. Digitization and interconnection of industrial processes (Industry 4.0), leading to potentials in all three dimensions of sustainability.

There are several applications for industry 4.0, applied by the KUKA corporation which works in the areas, for instance, smart factories, M-2-M, computing cloud, intelligent robots, e-commerce, etc., these technologies or applications help the industry 4.0 to separate rapidly. On the other hand, there are also some barriers, for implementing Industry 4.0 practices. These obstacles may be classified into many business dimensions: financial constraints, technical competency of the focal, organizational nature, lack of management support and resistance to change, legal issues, lack of policies and support from the government.

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