Industry 4.0: A Systematic Literature Review of Analyzing the On-Trend and Future Perception in the Industry

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Abstract: Industry 4.0 is a broad domain that includes production processes, efficiency, data management, relationship with consumers, competitiveness, social challenges, environmental and economic impact of people, profit, and loss and much more. Exploratory analysis carried out based on the latest technologies that have made the Industry 4.0 revolution actuality. At current universal manufacturing, the setting is changeable with increasing worldwide demand for enhanced, more creative, value-added and rewarding products. The manufacturing industry's value creation oriented towards high-efficiency and productivity. Industry 4.0 is tied to recent technologies such as the Industrial Internet of Things and Cloud Computing. The term industrial IoT evolved once integrated with industrial automation and control. The purpose of the literature review is to analyze and classify the main contributions of Industry 4.0 in literature, in the quest to give it a unique definition, find the gaps which remain still in literature and outline future avenues of research.

Index Terms **- Industry 4.0, manufacturing industry, challenges, exploratory, IoT, fourth industrial revolution, literature review**.

I. INTRODUCTION

Industry 4.0 is a term coined as the collaborative initiative of the Hannover fair in 2011, due to the German government initiation called the Fourth Industrial Revolution. The first industrial revolution was marked by the use of steam power and water power, the second by the electric power, the third by electronics and the fourth revolution marks a major turning point is the digitalization of the real world, relating to the productive processes of an industry, by transforming the traditional way towards a totally interconnected world, including suppliers and customers, to obtain an intelligent product [1]. Particularly, Germany has shared the concept of Industry 4.0 and since then many researchers have shared additional information on the role and potential of the Industry 4.0 proposal. This paper will review the works of literature that have been written about Industry 4.0 to review through some key views and examples from different researchers [2]. In recent years a lot of work has been carried out in real-life applications of IoT. Industry 4.0 is a common term for technologies and concepts of value chain organization. Within the modular structured Smart Factories of Industries 4.0, CPS monitors physical processes, develops a virtual copy of the physical world and makes dispersive decisions.

II. LITERATURE REVIEW

2.1 Industry 4.0 (I4.0)

Industry 4.0 (I4.0), also called the Fourth Industrial Revolution that is based on several technologies (i.e. IIoT, Cloud, Additive Manufacturing, Cyber Security, Big Data Analytics, Simulation, Augmented Reality, Horizontal and Vertical Integration) that work simultaneously for the development of organizational performance. Most of the technologies required for the implementation of I4.0 which exists already. Industrial Internet of Things (IIoT) and cloud computing for connecting and sharing all the information, Big Data for decision-making using all information gathered and Cyber Security is protecting the computer system [4]. The purpose of Industry 4.0 is to construct a highly flexible production model of personalized and digital products and services, with real-time interactions between people, products and devices during the production process.

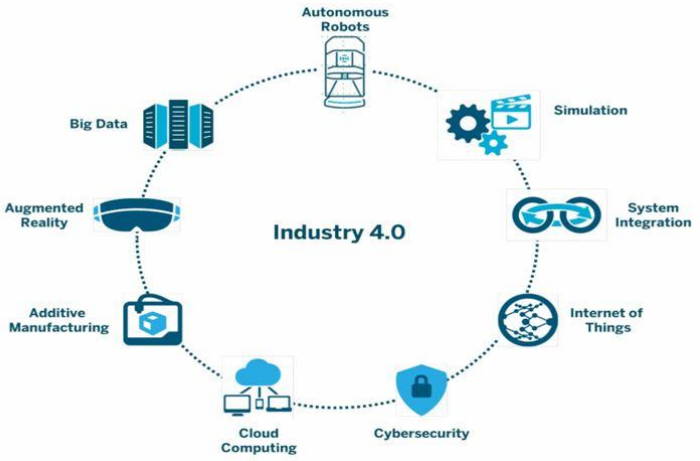

Fig 1: Industry 4.0

2.2. Industrial Revolution

The Industrial Revolution impacted socially, environmentally, and economically in different ways. The people´s lives moved from the agricultural communities and to the factories, moved from the field to the cities; electricity and mass production systems changed the way people used to live and work, and recently the digital revolution caused a digital transformation and experienced vital changes in the way people are living, working and communicating [5]. An industrial revolution is characterized by the emerging of new technologies and new traditions of perceiving the world that drive a significant transformation in the economy and structure of society.

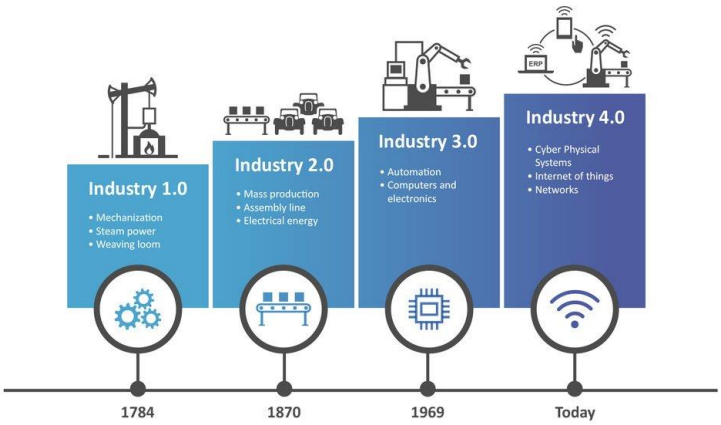

Fig 2. Industrial Revolution

2.2.1 First Industrial Revolution: Steam & Mechanization

The first Industrial Revolution began at the end of the eighteenth century and early nineteenth century, which was represented by the introduction of mechanical manufacturing systems utilizing water and steam power [5]. The revolution opened the way for using steam power and machines, which provided better technologies for railways and ships. The social, environmental, and economic impacts, as a result of this revolution: the factory became the new center of community life in societies, the industrialization created workers, cities and industries grew faster and their economies developed as well [6].

2.2.2 Second Industrial Revolution: Electricity & Line Production

The end of the XIX century started electricity development and mass production. The components that came into view in that period were the gasoline engine, airplanes, chemical fertilizers, discoveries in physics and also with the development of the scientific method (observe, measure, test hypothesis) applied in factories towards mass production lines.

Social, environmental, and economic impacts, as an outcome of this revolution: an enhancement of the population that moved to cities, people started to be informed and communicated to electricity (radio and telephones) which transformed the people´s lives.

2.2.3 Third Industrial Revolution: Computers & Automation

The third industrial revolution also called the digital revolution set in around the 1970s, when advanced electronics and information technology developed further the automation of production processes [7]. Also, the latest devices (laptop, Smartphone, etc.), automation in factories, robots running in assembly lines appeared.

The third industrial revolution also on track to promote the phenomenon of digital conversion, which companies look for to get better operational processes, the creation of new business models and the integration of customer experience through technology.

Social, environmental, and economic impacts, as a result of this revolution: At present people are experiencing the advantages of third revolution such as cloud computing, internet, smart homes, automation, but at the same time the effects such as unemployment, environmental impact by factories, global warming, financial crisis, etc. The third industrial revolution also started the first debates on Artificial Intelligence and its impact on society.

2.2.4 Fourth Industrial Revolution: Digitization

At present, the world is getting the advantage of technologies such as robots, 3D printers, big data, VR, AR, internet, 4G networks, automated assembly lines, smart homes, and even smart cities.

The combination of these technologies with other digital ones shows a technological combinatorial effect that is driving the fourth industrial revolution.

2.3 Manufacturing industry

Manufacturing is an industry that makes goods by hand or by machine which after the business sells to the customer. Manufacturing industry defined as industries in an account for the creation and processing of products and value-added commodities, also proof of the industrial revolution of a developing industry [8].

2.4 Internet of Things (IoT) and Industrial Internet of Things

The Internet of things (IoT) isn't only for connecting most recent gadgets, like voice-activated speaker or a smart thermostat, to an increasingly connected society. Some conditions have led to the eruption in technologies such as cloud computing, artificial intelligence, sensors, big data to power the next industrial generation, as well. This new layer of technology, known to be as Industrial internet of things (IIoT), is transforming enormous industries like manufacturing, energy consumption, mining and transportation, and it will have a huge impact on the economic condition as a whole. The path to creation of IIoT started in 1968 when Dick Marley made the most back through in manufacturing history.

The Industrial Internet of Things (IIoT) as shown in Fig. 3 is presented as that is changing the face of industry in every insightful manner. IIoT is an evolution that has its origins in technologies and functionalities developed by visionary automation. The best outcome from IIoT is that end-users and machine builders can now grasp their existing investment in technology and people while taking advantage of available IIoT technologies. The IIoT vision of the world is one where smart connected assets operate as part of larger systems of systems that formulate the smart manufacturing enterprise [9].

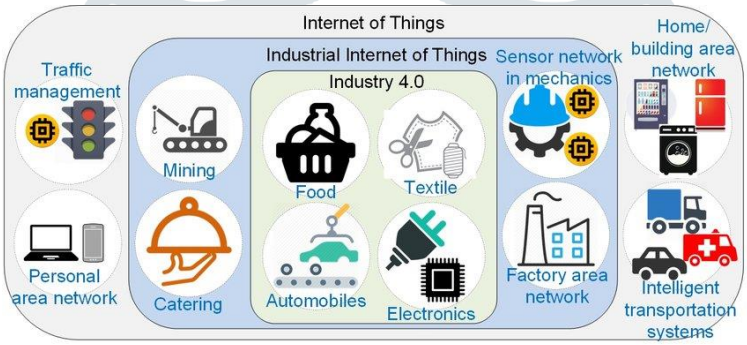

Fig 3. IoT and IIoT

III CHALLENGES AND RISKS

The challenges and risks were identified based on connectivity, vulnerability, employment, education, financial, and time aspects. The analysis was carried out to IoT, base of the IIoT, which are the core components of I4.0.

3.1 Internet of Things (IoT)

The foundation for industrial digitalization is the networking of devices. This is generally known as the Internet of Things (IoT). The term IoT was first referred in 1999 by Kevin Ashton at a presentation for Procter & Gamble (P&G). The main initiative behind the IoT is that over the last few decades IT and telecommunications have evolved [10]. This technology refers to the digital interconnection of on an everyday basis IoT device, in such a way that they become intelligent objects allowing expanding functions, obtaining data for real-time statistics, constant and predictive activities, and more benefits.

Table 1. Challenges and Risks of IoT

IoT Challenges and Risks	**Challenges and Risks**	
	Aspect	**Description**
Challenges	Connectivity	Ability to respond to connectivity in a universally way in the IoT.
	Vulnerability	Companies need to be prepared towards cybercrime, and cybersecurity plans should be on the table to react to possible future attacks
	Employment	New jobs would be needed, but IoT experts are still missing
	Financial	IoT implementations are becoming costly, especially hardware, services, software, and IoT connectivity

	Time	Reduce the time for IoT functionality in every single device
Risk	Connectivity	Everything connected implies everything vulnerable. Things connected are more likely to be attacked or to be controlled.
	Vulnerability	IoT does not only focus on cars but also in factories, since there are many appliances and other devices such as electric meters, controllers, etc. which can also have access to the Internet and be susceptible to some kind of attack.
	Employment	There may be more unemployment due to the "Autonomous Computing" where it involves doing many tasks with less labor
	Financial	That the ROI would not be reached early enough
	Time	That some devices still need some time to be adopted an IoT functionality

3.2 Industrial Internet of Things (IIoT)

The IIoT consists of IoT devices designed for the industry, connected to the Internet and advanced analytics platforms that process the data. The IIoT can be summed up as a large number of industrial systems that communicate several connections and synchronize data and actions. These cyber-physical systems that allow the interface between the digital and the real world are being matched with big analog data which works based on three-tier architecture. They are formed by analog data collection of physical world natural phenomena through an analog-to-digital conversion [12]. The challenges of IIoT adoption are 1. Large investment needs and uncertainty 2. Data security issues 3. Lack of qualified employees 4. The integration with operational technologies and legacy systems [13].

Table 2. Challenges and Risks of IIoT

IIoT Challenges and Risks	**Challenges and Risks**	
	Aspect	**Description**
Challenges	Connectivity	Adaptation to a world in which a greater number of industrial devices are connected through the Internet, increasing the information flow.
	Vulnerability	Security of the transmitted information, maintaining the trustworthiness, integrity, and privacy of the services in the plant.
	Employment	New jobs would be needed. The industrial world would need a bunch of informatics specialists
	Financial	Costly especially for small and medium enterprises (SMEs) in industry. An investment needs to be considered
	Time	Today many companies are already implementing IoT functionality in their shop floors, but others are late.
Risk	Connectivity	One-third of industrial systems are connected to the Internet.
	Vulnerability	Weak authentication, absence of antivirus, unwanted devices, and wireless access, remote Access
	Employment	IIoT is profoundly affecting relationships with suppliers, as it will also reduce human intervention.
	Financial	That the ROI would not be reached early enough, and manufacturing activities could be stopped.
	Time	The implementation of this solution would delay the manufacturing process

3.2 Industrial 4.0 (I4.0)

The term Industry 4.0 was started in Germany as a governmental program even though international technologies are related. Then it changed to Industry 4.0, and even some other countries have different names such as Smart Factory. I4.0 is a major change of mentality, to stop thinking that the purely industrial companies were outside of everything that involves digitization and information systems. The existing Industry 4.0 applications are divided into two parts: (1) the investigation and classification of the mentioned standards, software, and hardware (2) the analysis of laboratory experiments and industrial applications [11].

Table 3. Challenges and Risks of I4.0

4.0 Challenges and Risks	**Challenges and Risks**	
	Aspect	**Description**
Challenges	Connectivity	Implement multi-sensing systems that allow data collection, learning systems, and automatic decision-making processes. Ensure the traceability of the components throughout the value chain, a determining aspect to gather the necessary information from each produced unit.
	Vulnerability	Eliminate variability to ensure the reduction of errors, defects, and failures in the product delivery process.
	Employment	As I4.0 is composed of many technologies, universities and educational institutes must assure the update of study programs, thus enough number of professionals would be available for I4.0 implementation.
	Financial	I4.0 would be a source of competitiveness for industries with labor costs, energy costs and levels of social commitment.
	Time	The implementation of many I4.0 technologies would vary from the type and budget of the company.
Risk	Connectivity	In I4.0, machinery has huge technology dependence. Thus, new specific machinery needs must be identified and fulfilled as soon as possible.
	Vulnerability	Not all companies can adapt themselves to the new methods, for this reason, many industries face the risk of becoming outdated due to fast changes.
	Employment	Labor in the new processes towards Industry 4.0 needs to be more specialized, and it will not be easy to access these profiles, which also require a higher remuneration.
	Financial	There will be technological obsolescence and companies should take into account in any initial project the calculation of ROI (Return-on-Investment), amortization of the investment, among other financial indicators.
	Time	Some companies would face problems and be late for I4.0 implementation.

IV. CONCLUSION

This systematic literature review has reported the current status of the industrial revolution through the analysis of Industry 4. Industry 4.0 proposes the implementation of highly developed ICT to improve manufacturing efficiency and competency. The emergence of interest in Industry 4.0 has improved in recent years and the current Industry 4.0 movement is the most important turning point in history. Industry 4.0 is also of importance to small and medium-sized enterprises (SMEs). Many Industry 4.0 implementations are not currently employing the advanced and new technologies developed under the umbrella of Industry 4.0. Although some technologies and applications introduced in this paper are not being fully utilized in Industry 4.0, they are expected to have enormous potential in playing a major role in the future. Technologies will act as an enabler in Industry 4.0 for tomorrow's more valuable and competitive industrial ecosystems. Increasing the quality of Industry 4.0 can be accomplished with the proper integration of the existing new technologies. There are still a lot of challenges and issues that need to be resolved for Industry 4.0 to develop into more applicable. This paper reviews the recent research on Industry 4.0 from the industrial perspective. We first introduce the background of Industry 4.0 and then discuss the fundamental technologies that might be used in Industry 4.0. Next, we introduce some current research on the industrial applications of Industry 4.0. Afterward, we analyzed the research challenges and future trends associated with Industry 4.0.

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