Challenges in Implementation of Industry 4.0 in Manufacturing Sector

Nikita Sinha and Amaresh Kumar

1 Introduction

With the rapidly evolving technologies in the past few decades, remarkable transformations have taken place in the manufacturing sector that continues to play a critical role for both developing and developed nations. It is anticipated that the ongoing of Fourth Industrial Revolution will increase the share of manufacturing sector in Gross Domestic Product (GDP) wherein it currently accounts for nearly 16% of the global GDP. The Fourth Industrial Revolution, also termed as Industry 4.0 (I4) and first declared by the German government in 2011, heralds the new era of manufacturing that will unfold over the twenty-first century [1]. In essence, Industry 4.0 also known as “smart factory” is the convergence of physical and digital technologies which is expected to increase the flexibility, scalability, agility and productivity. The transformation is reinforced by key technological areas that include the Internet of things (IoT), artificial intelligence (AI), cognitive computing, the cloud, big data, simulation, additive manufacturing (3D printing), augmented reality, big data and analytics, advanced robotics, simulation and horizontal and vertical system integration [2].

The worldwide industrial environment has enormously varied as a result of successive technological development and innovation brought on by the inception of Industry 4.0. It has led to advanced globalization of industries, and in order to gain competitive advantage, the companies are propelled to adopt this new change. Industry 4.0 gave rise to the integration of production facilities, supply chains and service systems through cyber-physical system (CPS) technology that leads to the

N. Sinha (✉) · A. Kumar
Department of Production and Industrial Engineering, National Institute of Technology, Jamshedpur, Jamshedpur, India
e-mail: 2018ugpi040@nitjsr.ac.in

A. Kumar
e-mail: akumar.prod@nitjsr.ac.in

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development of global value-creation network [3]. The application of CPS, that is, interaction between physical processes and computation networking, when applying it in manufacturing is characterized as cyber-physical production system (CPPS) [4]. The new approach to manufacturing has various benefits like smart and efficient production, reduced supply chain complexity and sustainable growth that can meet changing demands, without human intervention, which is the foremost objective of Industry 4.0. It has also been stated that technologies which initially have linear growth will follow the path of exponential growth trajectory instigating large-scale creative destruction [5].

However, opportunities come with their own set of challenges. Despite of I4 offering myriad of benefits that are crucial for an industry, there are roadblocks to its implementation which is the reason behind lack of manufacturing industries leveraging I4 technologies. The revolution is bound to cause disruption, affecting the ways of manufacturing and its business models as it was seen during the previous revolutionary phases. Today, with range of facilities available in context of accessibility, it might seem easy to adopt I4 technologies, but still there are significant barriers owing to which the SMEs as well as large enterprises are unable to make use of advanced technologies.

In order to identify the challenges, research papers have been analysed through extensive literature review. This paper is structured as follows. Section 2 throws light on the background and concept of I4 in manufacturing sector. Section 3 presents the methodology used to select research papers. Section 4 elaborates the challenges faced by manufacturing sector in implementation of I4. Lastly, Sect. 5 concludes the paper along with future research scopes of exploiting I4.

2 Industry 4.0 Concept

Industrial sector has witnessed four phases in the process of revolution. The use of steam-powered engines was marked as the First Industrial Revolution. The Second Industrial Revolution came with the introduction of concept of mass production along with the use of electricity. The Third Industrial Revolution is characterized by information technology (IT) system and the change from electronic to digital technology.

Today, the industries are in the midst of Fourth Industrial Revolution that was set off by the emergence of CPS and advanced interconnectivity. The Industry 4.0 concept first appeared in 2011 in high-tech strategy project by Germany's government whose final report was then presented at Hannover Fair on 8 April 2013.

The basic idea of Industry 4.0 is to exploit the potential of emerging technologies such as big data, cloud computing and manufacturing, additive manufacturing, IoT and robotics for the purpose of attaining transparency, decentralization, agility, flexibility, scalability and real-time functioning. These are the characteristics that enhance the competitiveness and ability to resist the fluctuations in global market [6]. Since the onset of I4, it has substantially changed the industrial outlook wherein companies adopting these technologies will be able to produce high quality and customized products with improved efficiency. The introduction of intelligent manufacturing system has optimized the production, logistics and supply chain management and reduced the need of human involvement which consequently lowers the production cost. It will also strengthen the customer relationship due to increase in transparency and faster response [7].

Many countries have taken initiative to promote Industry 4.0 in pursuit to digitalize manufacturing, such as Industrie 4.0 by Germany, Advanced Manufacturing Partnership (AMP) by USA, Industrial 4.1J by Japan, Make in India by India and Made in China 2025 by China. However, only few companies, mostly large enterprises have transitioned into smart factory. In further section, the literature explicates the causes for limited implementation and impact of new-age technology.

3 Methodology

The proposed extensive literature review is based on qualitative analysis of previous research work. The main aim is to assess the challenges in implementation of I4 in manufacturing sector and hence provide future scope of I4. This extensive literature review was carried out in the following order (Fig. 1).

The planning phase is the initial step to determine the database that will be utilized. To get access of wide range of authentic and peer-reviewed articles, ScienceDirect (www.sciencedirect.com) and Google Scholar (www.scholar.google.com) were selected as electronic database platform.

After planning, the objective was defined as to identify the underlying factors that have obstructed the companies, under manufacturing sector, from adopting I4 and analyse the social impact of industrial transformation. Eventually, the research question was formulated as challenges in implementation of I4.

The search was performed over the period of 2015 to June 2020 for the most recent research articles published only in journals and conference proceedings. The keywords were carefully selected in combination of words such as "Industry 4.0", "challenges", "manufacturing", "workforce", "automation", "robotics", "security", "augmented reality", "Internet of Things" and "proactive maintenance".

The methodology enabled us to find research articles that were close to the objective of this paper. As a result, 41 articles were comprehensively analysed

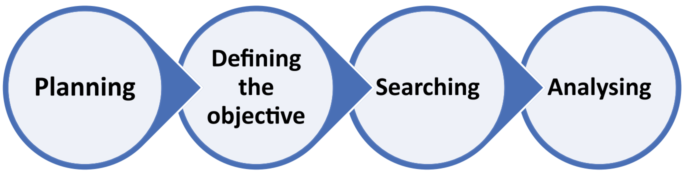

Fig. 1 Methodology of the literature review

under six major categories, that are, security, finance, human resources, operations management, education and training and government policies. The overview of selected literature is shown in Table 1.

4 Discussion

Industry 4.0 is on the verge of transforming traditional manufacturing process, proposing abundance of opportunities to progress. However, for successful implementation resulting into collaboration of human and intelligent machine to work in tandem, it is crucial to analyse the potential barriers. The primary reasons for some of the barriers are considered to be lack of awareness about I4 and lack of proper guidance for its implementation. In order to get deeper understanding of challenges, they have been categorized under six major segments influencing the manufacturing sector.

4.1 Security and Privacy

The increase in IoT and CPS-enabled manufacturing has improved the efficiency of production, but at the same time, a widely distributed network has made the industries extremely prone to cyber-attacks. A survey conducted in 2016 stated that 39% of the manufacturing industries faced security threats within twelve-month period [8]. Data privacy, data security, malware attack and identity theft are some of the major concerns in a data-driven manufacturing, and as it reaches the maturing stage, severity is increased, leading to disruption at larger scale [9–12]. Shift to the cloud storage poses security risk which can compromise the intellectual property rights of an organization and personal information of employees and customers [13, 14]. As the supply chain gets highly outsourced, communicating with two or more parties makes the server more vulnerable to hackers. In some cases, such as, additive manufacturing or robots employed in production, their systems can be attacked resulting into breakdown or data manipulation [15, 16]. If the operator is unable to identify these threats in the initial stage, it remains undetected until defective products have been manufactured. The carelessness of workers and lack of standard security software also create loopholes for cybercriminals [17, 18]. Cybersecurity is not only limited to technical domain; it has become a managerial problem too since the concerned managers remain passive in taking any serious measures towards security threat [19]. Manufacturing industries tend to give secondary preference to cybersecurity. These issues are not new, and it is probable that challenges will increase in order to secure the system from cyber-attacks.

Table 1 Overview of the reviewed literature

Sr. No.	Authors	Source of data	Qualitative analysis	Quantitative analysis
1	Abdur et al. [9]	Secondary data	✓	
2	Gonçalves et al. [10]	Case study	✓	
3	Khan and Turowski [11]	Survey/interviews	✓	
4	Raj et al. [12]	Case study		✓
5	Roman et al. [13]	Secondary data	✓	
6	Tupa et al. [14]	Secondary data	✓	
7	Rokka et al. [15]	Secondary data	✓	
8	Sturm et al. [16]	Case study	✓	
9	Zarreh et al. [17]	Secondary data	✓	
10	Ghadge et al. [18]	Secondary data	✓	
11	Culot et al. [19]	Secondary data/ interviews	✓	
12	Hamzeh et al. [21]	Case study		✓
13	Glass et al. [22]	Survey		✓
14	Kamble et al. [23]	Interview		✓
15	Kurt [24]	Secondary data	✓	
16	Centea et al. [25]	Secondary data	✓	
17	Fareri et al. [26]	Survey	✓	
18	Lee and Lee [27]	Secondary data	✓	
19	Luthra and Mangla [28]	Survey		✓
20	Ingaldi and Ulewicz [29]	Survey/interview		✓
21	Dora and Roland [30]	Secondary data/ interview	✓	
22	Sevinç et al. [31]	Survey		✓
23	Abu-bakr et al. [32]	Secondary data	✓	
24	Lynch et al. [33]	Secondary data	✓	
25	Baboli et al. [34]	Secondary data	✓	
26	Haddud et al. [36]	Survey	✓	
27	Kache and Seuring [37]	Case study	✓	
28	Fisher et al. [38]	Survey	✓	
29	Lee et al. [39]	Survey	✓	
30	Chen et al. [41]	Secondary data	✓	
31	Zhong et al. [42]	Secondary data	✓	
32	Andersen et al. [43]	Secondary data	✓	
33	Mourtzis et al. [44]	Case study	✓	
34	Suárez et al. [45]	Secondary data	✓	

(continued)

Table 1 (continued)

Sr. No.	Authors	Source of data	Qualitative analysis	Quantitative analysis
35	Seamus et al. [46]	Case study	✓	
36	Benešová and Tupa [47]	Secondary data	✓	
37	Motyl et al. [48]	Survey		✓
38	Manda and Ben [50]	Secondary data	✓	
39	Iyer [51]	Case study	✓	
40	Fatorachian and Kazemi [52]	Secondary data	✓	

4.2 Human Resources

The automation in industries will reduce the manual workload which can create alarming impact on the workforce, especially the unskilled laborers [9–11, 14]. McKinsey estimates that by 2030, 400–800 million workers globally can be displaced by automation and will need to find new jobs [20]. It is evident that as the number of smart factories will increase, there will be shortage of skilled labourers and the workers will be left unemployed, though for a shorter term, owing to the lack of training facility in technology-centred skills in addition to population boom in many countries [21–23]. Although there are a greater number of qualified people in large enterprises, training concept which is necessary to get familiar with new technologies lacks in both large enterprises and SMEs. Moreover, SMEs have significantly high number of unskilled labourers. Thus, retaining workforce and aligning the labour market in the right direction will be a challenge in near future [24]. It is found that lasers and hazardous materials used in additive manufacturing and other such technologies can endanger the user's safety, and therefore, Centea et al. [25] emphasizes on the importance of giving proper guidance to the workers which will require more time and effort. The future will also see a major shift in job profiles inclined towards IT skill set [26]. For example, big data will raise the demand for data scientists and self-driving vehicles and predictive maintenance will reduce the need for logistic personnel and traditional technicians, respectively. The challenge is to revise the prerequisites of the existing job profiles without impeding the development of workforce or giving rise to unemployment.

4.3 Finance

Financial aspect is one of the significant challenges hindering the adoption of Industry 4.0 which is greatly influential for the developing and under-developed countries [12, 27]. Initially, a large capital investment is required in appropriate equipment like sensors, actuators, control system and remodelling the existing infrastructure to incorporate better networking system [21]. Further, investment is also needed for security of the system from cyberthreats and research and development activities, but companies are not ready to bear the cost since they lack in technical knowledge and experts. Training and reskilling of employees to handle big data, cloud computing and other complex technologies which add on to the implementation cost of I4 [23, 28–30]. Moreover, the companies use advanced technologies with lack of clarity in goals; in such situation, the risk of failure is high with uncertainty of return as compared to companies using traditional methods [31]. Therefore, due to unstable global economic condition, investment in I4 is highly afflicting.

4.4 Operations Management

As the transition from centralized to decentralized manufacturing becomes prevalent, new outlook is necessary to improve the production and supply chain management [11, 32]. The use of IoT, cloud computing, robotics, etc., requires high Internet connectivity which has pushed the industries in adopting wireless systems. Therefore, sustainable restructuring of business operation is the need of the hour to accommodate new equipment by replacing the old infrastructure. The other most common problem that companies deal with is incompatibility between the existing system and I4 technologies which arises due to lack of infrastructure, planning and preparedness [10, 12, 30]. Consequently, transforming a company into a “smart factory” by using advanced technologies, for example, AGV and ASRS, will make the production efficient only when accurate and optimized navigation planning is done [33, 34]. A survey conducted by NewVantage Partners shows that data-driven companies have declined in the past three years from 37.1% in 2017 to 31% in 2019 [35]. The cause for decline in data-driven model, which is used for predictive analysis and other manufacturing processes, is that they require large volume of data where extraction and organizing the data can be time consuming [36, 37]. Also, non-availability and variability in data can pose challenges in meeting the required standard of product [38–41]. While looking from the managerial perspective, particularly SMEs, they are unable to assess the environmental turbulence due to lack of awareness and ignorance towards changing trends [29]. Also, the study has found that investing in research and development has had significant impact on the growth of organization which is important for sustainable growth, yet it is deemed less important by majority of the companies that can cease further progress [31].

4.5 Education and Training

During the implementation phase of Fourth Industrial Revolution, field of education will play an important role, as any other sector, in seamless transition into I4. The study suggests that future unemployment due to automation can be avoided by revising the course curriculum focusing on more practical knowledge rather than theoretical and inculcating necessary skills to make students capable of tackling new challenges [42, 43]. According to the current scenario, universities lack in interdisciplinary courses and the existing ones greatly differ from actual job requirements [22, 44]. Until engineering courses are upgraded, that are efficient in bridging the gap between academic and industries lack of awareness would persist among future industrialists. Accordingly, Raj et al. [12] has confirmed the fact that unawareness among majority of industrialists or having low knowledge regarding I4 is the key barrier. The rapid increase of artificial intelligence and machine learning in industries has raised the demand for experts who are equipped in mechanics as well as IT skill set, and therefore, Suarez et al. [45] conclude that it has now become necessary for students of mechanical engineering to master their core subjects along with IT. Not only universities but also vocational high schools should impart knowledge on coding, software, robotics, etc., so as to provide high-quality workforce [46, 47]. If proper measures are not taken, there can be shortage of workers skilled in IT required for emerging jobs in the near future. With rapidly advancing technologies, the challenge lies in keeping pace with the advancement, and it can be overcome by introducing the concept of lifelong learning [48].

4.6 Government Policies

The government plays an important role in the development of a business which consequently assists in economic growth of a country. Since I4 is the future of manufacturing sector, which is one of the highest contributors in GDP of a country, it is essential for the government to rethink its policies in favour of I4. A survey conducted by Glass et al. [22] found that SMEs as well as large enterprises require external support from the government, and in order to so, Kuo et al. [49] discuss how the government of some countries (China, Germany and USA) has come up with policies from the supply, demand and environmental sides to combat implementation challenges. Although it is observed that some political institutions have come to realize the importance of I4 and many developing countries have made progress in leveraging advanced technologies, nevertheless it still needs to travel a long distance to keep pace with other developed nations. For instance, in South Africa, National E Strategy focuses on expanding the reach of ICTs for developing digital industries; however, due to poor implementation of strategy and lack of coordination between industrialists and governments, policy reforms fail to take off as planned [50]. The "Make in India" and other similar initiatives will suffer a similar set back due to lack of research and development facility and lack of financial aid from the government, and above all, there is lack of clarity in providing standard procedure to integrate I4 with the existing infrastructure [51, 52]. The challenge lies not merely in initiating change in the existing policies and making long term plans to cultivate Industry 4.0 readiness, but also in implementing them while ensuring inclusive economic and social growth.

5 Conclusion and Future Research Prospects

This literature highlights the major challenges from technological, social and financial aspects that need to be focused on while advancing into new technological era. The discussed challenges seem to be interlinked, and each of them demands equal attention from managerial as well as employee's perspective. The lack of planning and preparation from the management side can defeat the purpose of implementing I4, whereas workers need to quickly adapt to the abruptly changing environment and grasp the skills in domains, wherein the technologies cannot replace the intelligence and ability of humans. Also, to bring extensive transformation and a long-term solution to the challenges, it is crucial to adopt change in education system to meet the requirements of a technology-driven society.

From the analysis, it can be determined that greater extent of challenges is mostly faced by SMEs, which constitutes 90% of the business population [53] and accounting for major part of global economy. Readiness to avoid these challenges can be consequential in shaping the future of manufacturing sector.

Most of the reviewed papers identified lack of knowledge as one of the major barriers which attributes to unwillingness of adopting I4 by the manufactures. Also, some surveys conducted by authors of reviewed papers are subjective in nature and limited to only few companies which tends to produce bias results. There are technological limitations too since many technologies are in their primary stage of development, and their compatibility and competence need to be tested before integration. For example, 3D printers require advancement before they can be used for large-scale production.

The future research scopes of Industry 4.0 are discussed below.

- More empirical study is needed in the context of integration of new technological paradigm to determine its practicality and feasibility.
- The study can be done to gain insight into the extent of sustainability benefits and drawbacks of I4 enablers since sustainable growth is an important factor that company strives to achieve.

- The inception of advanced technologies in manufacturing is expected to change the ways of working and managing. Examining the organizational structure in context of smart factory can help in seamless transformation.
- An in-depth analysis to identify the prerequisites of adopting I4 and model-based approach for reconfiguration of production system can greatly assist the industrialists.

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