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INDUSTRY 4.0: CHALLENGES, OPPORTUNITIES, AND STRATEGIC SOLUTIONS FOR BANGLADESH

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ABSTRACT

In the recent decade, the term Industry 4.0 or Fourth Industrial Revolution is a common buzzword represents the adoption of disruptive digital technologies (Internet of things, Big Data, 3D printing, Cloud computing, Autonomous robots, Virtual reality, Augmented reality, Self-driving car, Cyber-physical system, Artificial intelligence, Smart sensors, Nanotechnology, Drones, and Biotechnology, etc.) in the production process which is transforming the manufacturing units into smart factories and experiencing a great change in the global value chain. Moreover, these revolutionary digital technologies have a profound impact on the economy, growth, globalization, governments, international trade, global supply chain, and human capital transformation, etc. The present review study aims to explore the impact, challenges, and opportunities of the fourth industrial revolution based on empirical findings specially and extensively in the context of Bangladesh. The study finds regardless of having enormous potentiality, the application of the fourth industrial revolution is far lagging for some challenges i.e. lack awareness, insufficient capital, lack of infrastructure, lack of skilled human capital, and some socio-economic challenges. This review paper will also develop conceptual

links with the relevant aspect of strategic planning and application of key industry 4.0 technologies and help to formulate future policy guidelines regarding opportunities, application, and strategic decision making for the fourth industrial revolution in Bangladesh.

Keywords: Industry 4.0, Challenges and Opportunities, Strategic Solutions & Bangladesh.

INTRODUCTION

During the last few decades, technology is evolving with profound pace, velocity and impact (Petrillo, De Felice, Cioffi, & Zomparelli, 2018) and that swift digital technological advancement have bought forth the Fourth Industrial Revolution or Industry 4.0 in front of us (Global, 2017; K Schwab, 2016). The Industry 4.0, an umbrella term primarily coined in Germany at Hannover Fair in 2011, is a tectonic shift in the global value chain and transforming manufacturing units into smart factories virtually and customizing products or introducing new operation models (Acton, 2018; Cheng, Liu, Qiang, & Liu, 2016; Petrillo et al., 2018; K Schwab, 2016; Stankovic, Gupta, Figueroa, Authried, & Rueth, 2017). The world is amid revolutionary digital technology that transforming societies and global production and economy in a sophisticated and integrated approach (Brynjolfsson & McAfee, 2014; Culot, Nassimbeni, Orzes, & Sartor, 2020). The fourth industrial revolution introduced the adoption and integration of disruptive technological tools and cyber-physical system, in a break with the third industrial revolution (artificial intelligence (AI), robotics, the internet of things (IoT), autonomous vehicles, 3D printing, nanotechnology, biotechnology, materials science, energy storage, and quantum computing, etc.) that contain and transmit digital information (Petrillo et al., 2018; Klaus Schwab & Davis, 2018; Wyrwicka & Mrugalska, 2017; Yue, Cai, Yan, Zou, & Zhou, 2015). Adoption of Industry 4.0 leverages the value chain of businesses that enhances the connectivity and horizontal & vertical integration of businesses and transforming into smart factories with the help of the Cyber-Physical System(Hazen, Skipper, Ezell, & Boone, 2016; Trade, 2014). The profound advancement of digital technologies embedded with higher-level manufacturing process automatically administered by cognitive information systems in smart factories in the form of intelligent sourcing, self-optimization, and self-customization (Cezarino, Liboni, Stefanelli, Oliveira, & Stocco, 2019; Hazen et al., 2016; Stankovic et al., 2017). The invention of flexible automation systems help to produce customized goods and services according to the preferences and needs of different customers with a higher degree of efficiency in large quantities (Accorsi, Bortolini, Baruffaldi, Pilati, & Ferrari, 2017; Gokalp, Kayabay, Akyol, Eren, & Koçyiğit, 2016; Huckle, Bhattacharya, White, & Beloff, 2016). The interconnected data integration, the innovation of smart technologies, Internet of Things (IoT), innovative customer demands are among few factors driving industry 4.0 (Cheng et al., 2016; Cooper, 2017; Gokalp et al., 2016; Gorecky, Schmitt, Loskyll, & Zühlke, 2014; Horváth & Szabó, 2019). In particularly, Industry 4.0, now, affects all sectors and disciplines, and have an enormous impact disproportionately on developed and developing nations (Anderl, 2015; Becker & Stern, 2016; Faller & Feldmüller, 2015; Gokalp et al., 2016; Gorecky et al., 2014; Ji, Ganchev, O'Droma, Zhao, & Zhang, 2014; Klaus Schwab & Davis, 2018; Stankovic et al., 2017). This fourth industrial revolution shortens periods for launching new products around the globe, more flexible product lines, increased productivity, more efficient use of resources, integrating the virtual global factory in global value chains (Ângelo, Barata, da Cunha, & Almeida, 2017; Huckle et al., 2016). Though the impact of Industry 4.0 might not be abrupt, it will convey a paradigm shift that will greatly transform the present production, job, business, livelihood, and interaction indiscriminately in the developing

and developed economies (Dagli, 2016; Fettig, Gačić, Köskal, Kühn, & Stuber, 2018; Huckle et al., 2016; Rüßmann et al., 2015; Klaus Schwab & Davis, 2018; Stankovic et al., 2017).

So far the world has witnessed various technologies such as mechanical, electrical, and information technology used improving industrial mechanism and productivity in the first three industrial revolutions (Stearns, 2012; Zhou, Liu, & Zhou, 2015). The industry 1.0 developed efficiency of hydropower and improved production of machine tools; the second industrial revolution was on the widespread use of the electric engine and mass production; and the third industrial revolution on electronics and information technologies that resulting automation in manufacturing industries (Floud, Humphries, & Johnson, 2014; K Schwab, 2016; Stankovic et al., 2017; Stearns, 2012; Zhou et al., 2015). Finally, the fourth industrial revolution, a brainchild of Germany, has started integration of traditional manufacturing processes with cyber-physical production systems (Aulbur, CJ, & Bigghe, 2016; Du et al., 2017; Hofmann & Rüsch, 2017). Due to technological enabling this revolution are connecting with the Internet, big data, cloud computing, advanced robotics, artificial intelligence, new materials, new additive manufacturing technologies (Anderl, 2015; Becker & Stern, 2016; Dener & Bostancıoğlu, 2015; Faller & Feldmüller, 2015; Gokalp et al., 2016; Gorecky et al., 2014; Ji et al., 2014). Moreover, the Big data technologies adopted in industry 4.0 for collecting, processing and analyzing large, unstructured data using smart algorithms for effective real-time competitive business decisions (Anderl, 2015; Faller & Feldmüller, 2015; Gokalp et al., 2016; Hazen et al., 2016; Hofmann & Rüsch, 2017). The sphere of industry 4.0 is not only confined into smart & connected machines and systems but in biological domains such as from gene sequencing to nanotechnology and from renewables to quantum computing(K Schwab, 2016; Wyrwicka & Mrugalska, 2017). Moreover, it will bring immense and multidimensional influence on the global macro-economic variables such as GDP, investment, consumption, employment, trade, inflation, etc. (Klaus Schwab & Davis, 2018; Sozinova, 2019). In these times, we are evolving in a nascent paradigm shift where the fourth industrial revolution exponentially revolutionizing manufacturing process through disruptive technologies but it has also powerful impact on the economy, international trade, globalization, governments and countries, society and, individuals, access to information, global supply chain, bio-research, and human capital transformation, etc. (Bongomin, Gilibrays Ocen, Oyondi Nganyi, Musinguzi, & Omara, 2020; Ivanov, 2020; Kergroach, 2017; K Schwab, 2016; Szalavetz, 2017)

Bangladesh, a country of the Asia-Pacific region, is one of the fastest-growing economies and its GDP is hovering around 6% to 8% during the last two decades. Bangladesh's export earnings are growing at a substantial rate around 10% percent with some fluctuations which are projected to be the twenty-eighth biggest economy in the world by 2030 (Bhattacharya, Rahman, & Raihan, 2002; Griffin & Robinson, 2016; Humphrey, 2019). In the Bangladesh economy, sector-wise Gross Domestic Product (GDP) is contributed by agriculture 13.32%, Industry 31.15% and services 55.53% respectively in the year 2018-19 and around 85 percent of the country’s export earnings come through the RMG sector (Hussain, Failler, Karim, & Alam, 2018; Manni & Afzal, 2012). Due to Prudent macroeconomic policies and structural reforms the growth has been robust, inflation eased, foreign exchange reserves have risen to a comfortable position and stable GDP has facilitated navigating Bangladesh's economy in a good direction having some domestic and global challenges (Humphrey, 2019). However, to gain maximum benefits from Industry 4.0, it is time for the Bangladesh Government and the decision-makers of private organizations to take action so that Industry 4.0 can be adapted and implemented in the manufacturing and service industry(M. A. Islam, Jantan, Hashim, Chong, & Abdullah, 2018).

Presently, the IT industry is playing the central role of digital transformation and ongoing economic growth of Bangladesh and currently exporting about $1.00 billion of technology products every year and projected $5.00 billion by 2025. To facilitate this transition, Bangladesh has developed more than 8 000 digital centers across the country to help provide its citizens with a variety of digital services (Hossain & Khan, 2016; Humphrey, 2019; M. A. Islam et al., 2018). The application of industry 4.0 mechanisms offer tremendous opportunities for companies with large investments not only to speed up production, but also to promote economic growth (Moktadir, Ali, Rajesh, & Paul, 2018; Siddik, Alam, Kabiraj, & Joghee, 2017).

However, despite having a huge prospect of adoption of industry 4.0 in Bangladesh, it has lots of challenges i.e. lack of awareness, labor skills, factory infrastructure, lack of enough investment, technology applications in production, etc. (Jabbour, de Sousa Jabbour, Sarkis, & Godinho Filho, 2017; Sarkar, Anjum, & Khan, 2017). Finally, this is an enormous opportunity offered by the smart revolution, and this opportunity not to be lost, so the government and private agency need to act together to mitigate the challenges reaping the maximum benefits of industry 4.0 for the prosperity of Bangladesh.

BACKGROUND OF THE STUDY

Evolution of Industrial Revolution in the world

Industry 1.0 or the Industrial Revolution, also known as the first industrial revolution, is one of the most significant turning points in the modern history of mankind (Ashton, 1997; Mohajan, 2019a). It was characterized by the transition from manual production methods to machines through the use of steam and hydropower. The introduction of new technologies has taken a long time so that the period to which this refers is between 1760 and 1820 or 1840 in Europe and the United States (Agarwal & Agarwal, 2017; Allen, 2009; Berlanstein, 2003; Mohajan, 2019a). The First Industrial Revolution transformed the world of production mechanism dominantly in the textile industrial sector along with the development of iron and steel industries, development of chemical industries, agricultural and mining, improvement of transportation, and development of the social and economic structures, etc. (Ashton, 1997; Broadberry & Gupta, 2005; Mohajan, 2019a; Wrigley, 2018). In the mid of the 18th century, England was the world's leading trading nation, controlling a global trading empire with colonies in North America and the Caribbean, and with political influence on the Indian subcontinent, especially in Bengal, through a company (Agarwal & Agarwal, 2017; Gillen & Ghosh, 2007; Mokyr, 2008; Ray, 2011). The First Industrial Revolution is always marked as an important turning point in world socio-economic history and almost every aspect of life was influenced in some way in the particularly opened frontier of further improvement (Crafts, 1985; Mohajan, 2019a). Moreover, the First Industrial Revolution contributed significant impacts on global economic growth, increase in production, population growth and consumption of common people along with some negative impacts such as child and women labor, sixteen hours working, unhygienic working environment and created a wide gap between the rich and poor (Mohajan, 2019a; Voth, 2003).

Industry 2.0, also termed as the Second Industrial Revolution, Technological Revolution or the American Technological Revolution, which began at the final third phase of the nineteenth century to the beginning of the twentieth century, generally dated between 1870 and 1914 up to the start of World War I (Mohajan, 2019b; Klaus Schwab & Davis, 2018; Smil, 2005). The Second Industrial Revolution is a revolution of widespread inventions and the adoption of technological advancements in the manufacturing and production process. The major inventions and advancements in manufacturing and production process of the Second Industrial Revolution

are electricity, telegraph, medicine, combustion engine, airplane, marine ship, paper, rubber, automobiles, large scale chemical & petroleum industries, medical instruments, advanced iron, and steel industries, improvement of railway transportation, educational transformation, and scientific management of manufacturing industries (Freeman, 2018; Mohajan, 2019b; Smil, 2005). The massive electrification of factories steered substantial industrial development in the United States, Great Britain, Germany, France, Japan, China, and Italy. The Second Industrial Revolution transformed the global economy and livelihood of the population of the world in many ways than any other period of human history; mainly it sketched a rough draft of today's globalized world (Atkeson & Kehoe, 2001; Freeman, 2018).

Industry 3.0 or third industrial revolution began in the 1960s after two major wars- which made stuck up industrialization and technological progress from the prior two revolutions. It is also known as the computer, information technology revolution, or digital revolution (Baygin, Yetis, Karakose, & Akin, 2016; K Schwab, 2016). The third industrial revolution refers to the combined powers of information technology such as internet and renewables such as solar and wind, computing technologies i.e. mainframe & personal computer, microprocessor or integrated circuit, energy storage technologies, and new digital manufacturing technologies such as 3D printing (Jänicke & Jacob, 2009; Smith, 2001). This revolution mainly revolved counties across the world such as European Union nations, the United States, Japan, and China. Third Industrial Revolution is not only a broad wave of innovation and production but truly it has made the world globalized (Jänicke & Jacob, 2009; Rifkin, 2011; K Schwab, 2016).

Industry 4.0 or the fourth industrial revolution came into light in 2011 as a high-tech strategy of the German government aimed at computerizing production and simultaneously in the same year the Hannover Bureau of Industry Exhibitions introduced the word "Industry 4.0" to the public (Keibek, 2017; Tong, 2016; Wrigley, 2018). Industry 4.0 introduced the adoption and integration of disruptive technological tools and cyber-physical system, in a break with the third industrial revolution (artificial intelligence (AI), advanced robotics, the internet of things (IoT), autonomous vehicles, 3D printing, nanotechnology, biotechnology, big data analytics, materials science, energy storage and quantum computing, new materials like graphene, and Fintech, etc.) that contain and transmit digital information (Petrillo et al., 2018; Klaus Schwab & Davis, 2018; Wyrwicka & Mrugalska, 2017; Yue et al., 2015). The Industry 4.0 revolution process reviled integrated physical and cyber-physical systems automatized mass manufacturing of customized products and services for modern-day clients (Cheng et al., 2016; Cooper, 2017; Faller & Feldmüller, 2015; Gokalp et al., 2016; Hofmann & Rüsch, 2017). Industry 4.0 connects digital and physical technologies predominantly focus on the integrated man-machine approach through the smart factory production process (Baygin et al., 2016; Cheng et al., 2016; Gokalp et al., 2016; Hofmann & Rüsch, 2017). Picturesque view of all industrial revolutions can be drawn as;

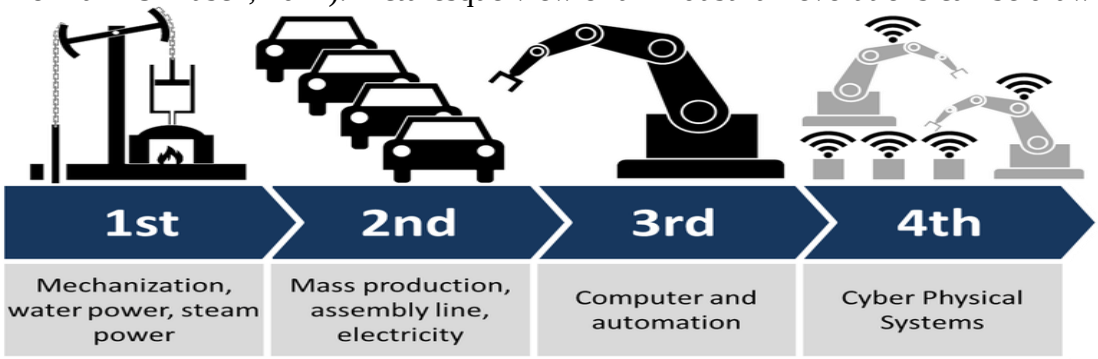

Figure 1. Diagram by Christoph Roser at AllAboutLean.com (CC BY-SA 4.0)

Concept and Robustness of Industry 4.0

The Fourth Industry Revolution is focused on the model of smart factories, where the cyber-physical production systems (CPPS) are used as a way of integration between men and machinery. In other words, Industry 4.0 is the adoption of disruptive technologies in the organization that manages and controls the business or production value chain of customized products to satisfy customer needs (Keibek, 2017; Petrillo et al., 2018; Tong, 2016; Varghese & Tandur, 2014; Wrigley, 2018). Industry 4.0 covers three fundamental aspects of the modern-day manufacturing process a) Digitization and increased integration of vertical and horizontal value chains, b). Digitization of product and service offerings through intelligent networks,c). Introduction of innovative digital business models across the enterprise (Keibek, 2017; Petrillo et al., 2018; Tong, 2016; Wrigley, 2018). In particularly, Industry 4.0, now, affects all sectors and disciplines, and have an enormous impact disproportionately on developed and developing nations (Anderl, 2015; Becker & Stern, 2016; Faller & Feldmüller, 2015; Gokalp et al., 2016; Gorecky et al., 2014; Ji et al., 2014; Klaus Schwab & Davis, 2018; Stankovic et al., 2017). This fourth industrial revolution shortens periods for launching new products around the globe, more flexible product lines, increased productivity, more efficient use of resources, integrating the virtual global factory in global value chains (Ângelo et al., 2017; Huckle et al., 2016). Though the impact of Industry 4.0 might not be abrupt, it will convey a paradigm shift that will greatly transform the present production, job, business, livelihood, and interaction indiscriminately in the developing and developed economies (Dagli, 2016; Fettig et al., 2018; Huckle et al., 2016; Rüßmann et al., 2015; Klaus Schwab & Davis, 2018; Stankovic et al., 2017). In addition to decentralized decisions on the ability of cyber-physical systems to make decisions on their own and perform their functions as independently as possible and also it envisages environmentally sustainable construction through green production processes, green supply chain management and green products (Hazen, Boone, Ezell, & Jones-Farmer, 2014; Huckle et al., 2016; Jeng, Tzeng, Tseng, Xu, & Liu, 2016; Lee, Bagheri, & Kao, 2014). Industry 4.0 is allowing transparency of large amounts of data and information from all parts of the manufacturing process, human support systems, and visualizing information to make informed decisions, to solve urgent problems or to avoid any unpleasant (Accorsi et al., 2017; Backhaus & Reinhart, 2017; Bui, Yoon, Huh, Jun, & Lee, 2017; Dener & Bostancıoğlu, 2015). The fourth industrial revolution might be more powerful, impactful, robust, and historically important than the previous three, is affecting our economic, environmental, social, and political systems tremendously. Moreover, it offers new opportunities to gain deeper insights into simplified process simulations, efficiency optimizations, early warnings, predictive analytics, and access to information on the organizational value chain (Giannetti, 2017; Petrillo et al., 2018; K Schwab, 2016).

Enablers and Drivers of Industry 4.0 Revolution

The main disruptive technology driving the fourth industrial revolution are the internet, big data, cloud computing, advanced robotics, artificial intelligence, autonomous vehicle, new materials, new additive manufacturing technologies especially 3D printing, hybrid manufacturing, machines, and generic and synthetic microbiology (Hofmann & Rüsch, 2017; Klaus Schwab & Davis, 2018). In these "smart industries", machinery and consumables integrate "together" during industrial processes to add scope and personalization to the manufacturing process, which is done in a relatively digital and integrated way (Ângelo et al., 2017). However, the concept of Industry 4.0 goes beyond integrating production and distribution processes rather it includes all

the different spheres of the value chain, and new product development processes (Gokalp et al., 2016; Hazen et al., 2016). Big data is one of the major technologies adopted in industry 4.0. It is for collecting, processing, and analyzing large, unstructured data using smart algorithms for decision making (Anderl, 2015; Faller & Feldmüller, 2015; Gokalp et al., 2016; Hazen et al., 2016; Hofmann & Rüsch, 2017). Another important disruptive technology is cloud computing, which manages huge volumes of data on open systems and provides a real-time connection to the production system. It helps access to information from anywhere in the world at any time, increasing flexibility (Anderl, 2015; Atanasov, Nikolov, Pencheva, Dimova, & Ivanov, 2015; Faller & Feldmüller, 2015). In a smart factory, data is digitally transmitted, so cybersecurity plays a key role in the new industrial data protection. Computer security systems are important for the full potential of other technologies (Du et al., 2017; Hofmann & Rüsch, 2017; Kusiak, 2017).

Industry 4.0 involves the use of automated advanced robotics that are directly managed by the smart factory and connected to the corporate system (Hazen et al., 2016). The development of disruptive technological systems and the increased personal demands of customers have led to the development of additive manufacturing and 3D printing technologies (Gokalp et al., 2016). With horizontal and vertical integration technology, it is possible to cross-group corporate data integration according to data transfer standards (Cheng et al., 2016; Cooper, 2017; Gokalp et al., 2016; Gorecky et al., 2014). This new industrial revolution will include shorter periods for launching new products, more flexible product lines, increased productivity, more efficient use of resources, and even the ability of companies to integrate into global value chains (Ângelo et al., 2017; Huckle et al., 2016). Flexible Customization of the production chain and direct communication between the various links in the production chain with the help of flexible automation systems help to enhance the degree of efficiency and production of large quantities (Dagli, 2016; Huckle et al., 2016).

Global Impact of the Industry 4.0

The fourth industrial revolution is a new episode of the development history of human civilization which is empowered by disrupting technological development including with those of the first, second and third industrial revolutions (Brunet-Thornton & Martinez, 2018; Morrar, Arman, & Mousa, 2017; Klaus Schwab & Davis, 2018). In these times, we are evolving in a nascent paradigm shift where the fourth industrial revolution exponentially revolutionizing manufacturing process through disruptive technologies but it has also powerful impact on the economy, international trade, globalization, governments and countries, society and, individuals, access to information, global supply chain, bio-research, and human capital transformation, etc. (Bongomin et al., 2020; Ivanov, 2020; Kergroach, 2017; K Schwab, 2016; Szalavetz, 2017). The Industry 4.0, however, is a tectonic shift from the analog and mechanical technologies into smart and digital manufacturing factories virtually and customizing products or introducing new operation models (Acton, 2018; Cheng et al., 2016; Petrillo et al., 2018; K Schwab, 2016; Stankovic et al., 2017). Furthermore, revolutionary digital technology has great influences in reshaping societies and global production and economy in a sophisticated and integrated approach (Brynjolfsson & McAfee, 2014; Culot et al., 2020). The fourth industrial revolution will have a massive and multifaceted impact on productivity, growth and economic development through disruptive and innovative smart technologies that unleashing surge in productivity and higher economic growth (Aghion, Bacchetta, Ranciere, & Rogoff, 2009; Rüßmann et al., 2015; K Schwab, 2016). The industry will have a great impact on the global labor market, conditions

and skills of employees and it is thought that many traditional jobs will be replaced by new skills and forms of jobs and lots tiresome and repetitive task are going to transform from manual labor to automation (Benešová & Tupa, 2017; Kergroach, 2017; Rajnai & Kocsis, 2017; K Schwab, 2016). The fourth industrial revolution driving forces Internet of things, Big Data, 3D printing, Cloud computing, Autonomous robots, Virtual reality, Augmented reality, Cyber-physical system, Artificial intelligence, Smart sensors, Fintech, Simulation, Nanotechnology, Drones, and Biotechnology, etc. has a substantial impact on how we live, act and communicate in our everyday life and it is remodeling governments and countries, individuals, education and research, healthcare, international trade, and finally almost every aspect of modern life (Li, Hou, & Wu, 2017; Park, 2016; Philbeck & Davis, 2018; Klaus Schwab & Davis, 2018). So that *Klaus Schwab* In his book "*The Fourth Industrial Revolution,''* has narrated that *''The Fourth Industrial Revolution, finally, will change not only what we do but also who we are. It will affect our identity and all the issues associated with it: our sense of privacy, our notions of ownership, our consumption patterns, the time we devote to work and leisure, and how we develop our careers, cultivate our skills, meet people, and nurture relationships."*

Industry 4.0 in Bangladesh Perspective

Bangladesh, a country of the Asia-Pacific region, is one of the fastest-growing economies and its GDP is hovering around 6% to 8% during the last two decades. Bangladesh's export earnings are growing at a substantial rate around 10% percent with some fluctuations which are projected to be the twenty-eighth biggest economy in the world by 2030 (Bhattacharya et al., 2002; Griffin & Robinson, 2016; Humphrey, 2019). Agriculture is one of the important sectors in Bangladesh's economy in terms of GDP and employment generation, which contributes about 13.32% and 43% respectively in FY 2018-19 (M. S. Islam, 2014). Agriculture, here a means of food security and reducing poverty, is mostly in conventional form and more prone to Climate victim, limited diversity, degrading land, water resources, and harmful agro-chemical but in recent decades using the core technology in a narrow range of the industry 4.0, digital pieces of machinery, big data, IoT Devices i.e.(Soil Moisture, Solar Irradiation, Air temperature & moisture, Leaf Wetness), Data Model i.e. Irrigation data model, Crop Management and Soil properties), AI in farm machinery, seeding the soil, farm management, production forecasting, data, and Software module such as Mobile App and irrigation are created a new era of prospect for food security of 170 millions of people in Bangladesh (Rezvi, 2018; Salim & Rahman, 2018). In recent times, the Fourth Industrial Revolution is graceful to release extensive industrial automation and disrupting nearly every industry i.e. Readymade Garments (RMG) and Textile, Furniture, Agro-processing, Leather and Footwear, Tourism and Hospitality sectors of Bangladesh. Readymade Garments (RMG) and Textile industries contribute significantly in GDP by 14.07%, in export income by about 82% and employ 4 million workforces. To cope with the productivity, growth, and competition, the Readymade Garments (RMG) sector in Bangladesh adapting automation technologies gradually despite having huge threats of losing low wages jobs and workers. The industries such as light engineering, furniture manufacturing, shipbuilding and breaking, Agro-processing, Leather and Footwear, Tourism and Hospitality sectors of Bangladesh are spending more on automated capital machinery, robotics, sensors, software programming, IoT and big data in the repetitive business process for efficient manufacturing and business management. Alarmingly, the fourth industrial revolution is looming as a massive job threat for unskilled, lower-skilled, and semi-skilled workers. A recent study by McKinsey shows that 5.7 million workers mostly unskilled will lost their jobs due to the automation of manufacturing industries in

recent decades. Furthermore, about 90 percent of total industrial units are comprised of SMEs which are still lagging in the adoption of revolutionary technology and mostly using first, second, and third industrial revolution technologies. Despite having a huge prospect of adoption of industry 4.0 in Bangladesh, it has lots of challenges i.e. lack of awareness, labor skills, factory infrastructure, lack of enough investment, technology applications in production, etc. (Jabbour et al., 2017; Sarkar et al., 2017). As a developing nation, the country has been criticized for its lack of production, labor skills, factory infrastructure, technology applications, and low-level adjustments based on industry development and availability (Jabbour et al., 2017; Sarkar et al., 2017). There are key issues found that lack of awareness and knowledge regarding Industry 4.0, poor infrastructure, lack of government support, the availability of cheap labor and human dependency in the manufacturing, expensive technological installations, health, and safety issue are the main barriers for many countries (Ahmad, 1990; Humphrey, 2019; Jabbour et al., 2017; Moktadir et al., 2018; Sarkar et al., 2017). However, to accelerate economic development and gain maximum benefits from Industry 4.0, the public and private organizations are taking immediate actions of policy & investment support, infrastructural support, education & training, and upgrading & upskilling, etc. so that Industry 4.0 can be adapted and implemented in the manufacturing and service industry(M. A. Islam et al., 2018). The application of industry 4.0 mechanisms offer tremendous opportunities for manufacturing units with large investments not only to speed up production but also to promote economic growth (Moktadir et al., 2018; Siddik et al., 2017).

ISSUES, CHALLENGES, OPPORTUNITIES AND STRATEGIC SOLUTIONS

As the disruptive technologies of the fourth Industrial revolution continue changing every sphere of our life i.e. production, economy, business, governments and countries, society and cultural interactions in the world around us, so the new challenges arise. As an emerging developing nation, Bangladesh is adopting revolutionary technologies gradually in every sector for socio-economic development despite having lots of challenges such as lack of awareness, insufficient funding, and availability of cheaper labor, lack of digital infrastructure, skill laggings, and socio-economic challenges. But in recent years, public and private authorities taking endeavors in the development of infrastructure and human, technical, and financial capacity to upgrade the education and training systems to reap the benefits from 4IR. Thus, the study reviews the practical results of identifying the challenges and opportunities and prescribed strategic solutions, presented by the Industry 4.0 revolution, especially in Bangladesh.

Awareness building

The fourth industrial revolution is a very new concept so building awareness is the first and foremost among the authorities, policymakers, businesses and industries, academicians, employees, and consumers. Well awareness among the authorities and policymakers lead the economic growth and development; businesses and industries lead the productivity and production flexibility and control, efficiency and competitiveness; academia and employees lead the growth in high-skilled and well- paid jobs; finally, consumer awareness leads the improved customer satisfaction and product customization. The present state of consciousness regarding revolutionized disruptive technologies of industry 4.0 has not been popular in Bangladesh yet, but it is crucial to accelerate its present economic progress and meet with international standards (M. A. Islam et al., 2018). Workers, SMEs, industries, and national economies are lacking the awareness and/or means to adapt to Industry 4.0 and obviously will subsequently fall behind. So

the policymakers and the promoters should take awareness-building programs i.e. seminar, trade fair, overseas training programs for its stakeholders.

Capital formation

The financial allocation is required more than anything else because such digital technological development, transformation, and implementation will be required a huge investment in the all prescribed sectors. As Industry 4.0 needs high- huge capital for the implementations of smart economic infrastructure, smart business model adaptation, economic benefits, competitors, the banking industry has not focused on financing high-tech industries because the industry is relatively new with high risks. Moreover, cheap labor prices also making Bangladeshi entrepreneurs reluctant to go for automation as it requires a large amount of investment. In the case of Bangladesh, more than 90% of businesses are MSMEs, so arranging a large amount of capital for innovative technology for them is a big constraint. The government should give incentives to attract the banking industries to provide enough loans to high-technology industries in Bangladesh.

Socioeconomics Challenges

The fourth industrial revolution is characterized by the merger of digitization and automation to make the machines intelligent, interactive, and easy to use. These new technologies will have a huge impact on working patterns. There will be new types of robots that can interact with humans. This technology will complement human activity, in particular cognition, combined with other emerging technologies to give us completely new computer models. Thus, following issues are needed to address to make a bridge the gap between engineering and computer science, automatic learning, and artificial intelligence, privacy concerns, surveillance, and distrust, general reluctance to change by stakeholders, the threat of redundancy, and loss of many jobs to automatic processes and it-controlled processes, etc. Moreover, there are also issues for lack of regulation, standards and forms of certifications, legal issues and data security and need to address all relevant changes, innovations, transformations and new dimensions and will be produced necessary rules and acts to ensure of effective implementations of the fourth industrial revolution in Bangladesh.

Training and Skill Development

Numerous types of jobs, predominantly which involve repetitive in nature and physical labor will be replaced by disruptive technologies such as robots, IoT, and intelligence machinery, etc. A recent study by McKinsey shows that 5.7 million workers mostly unskilled will lost their jobs due to the automation of manufacturing industries in recent decades. Besides, it will open horizons of new dimensional jobs of cognitive abilities, technically skilled, complex problem solving, resource management skills, content, process, and social skills, etc. Remarkably, the computing power continues to flourish exponentially, and Sooner than most anticipated, the work of professions as different as lawyers, financial analysts, doctors, journalists, accountants, insurance underwriters, or librarians may be partly or completely automated. So the government policymakers, academia, and training institutes should act immediately to increase investment in human capital and skills to boast industrial transformation for up-skilling, re-skilling, and long-term training and capacity-building to meet the demand of fourth industrial revolution and to bridge the gap between education and industry.

Infrastructural Development

The most difficult aspect of applying industry 4.0 technologies is security and risk issues (Backhaus & Reinhart, 2017; Davali, Belli, Cilfone, & Ferrari, 2016; Hazen et al., 2016). This online integration will provide room for security breaches and data leaks (Du et al., 2017; Hofmann & Rüsch, 2017; Kusiak, 2017). There are issues of internet hacking, as a result, critical its security problems are exacerbated by the data interconnectedness and weak digital infrastructure (Becker & Stern, 2016; Cheng et al., 2016; Gokalp et al., 2016; Hazen et al., 2016). Moreover, the poor infrastructure of the country, such as poor road and transportation, more prone to natural disaster, technological device markets, and productions are still creating the barriers for the Bangladeshi key planners to think regarding industry 4.0. Besides, the introduction of industry 4.0 technologies require more investment and research in several areas, such as Internet broadband disbursement, IT security, cybersecurity, cyber lay and will affect education in particular as a new industry that requires new skills (Anderl, 2015; Becker & Stern, 2016; Cheng et al., 2016; Faller & Feldmüller, 2015; Gokalp et al., 2016; Gorecky et al., 2014; Ji et al., 2014).

CONCLUSION AND RECOMMENDATIONS

As the aim of this study review is an empirical finding of identification of challenges and opportunities due to the Industry 4.0 revolution, especially in the context of Bangladesh. The review findings revealed that the revolution of industry 4.0 has contributed wave of using disruptive technologies in manufacturing units and affects socio-economic changes in Bangladesh. Moreover, the study also revealed that Industry 4.0 revolution can be enabled to increase productivity, (resource) efficiency, (global) competitiveness, revenue growth in high-skilled with customer satisfaction, access and develop new markets for products and services counteracting to participate in new markets, links to new supply chains in Bangladesh. However, the present study also identified huge task to implement of Industry 4.0 revolution in Bangladesh especially for high dependence on the resilience of technology and networks, coherent framework, development and ensure of human resources supply with appropriate skills, allocation of sufficient required investment and cost of the setting of a lab for research and development (R&D) accordingly. In the same way, the study observed that there are potential threats through the process of implementation of Industry 4.0 revolution in Bangladesh for managing of and controlling of Cybersecurity, intellectual property, data privacy workers, SMEs, industries, vulnerability to and volatility of global value chains adoption of Industry 4.0 by competitors in the world. The findings of the study will be developed conceptual links with relevant aspects of the revolution 4.0 especially for strategic planning, key technologies applications as well as expensive installation of technologies, opportunities, and challenges including poor infrastructure, availability and skill development of the labor, and government supports and lack of knowledge respectively. This review article will provide future policy guidelines about opportunities, scenarios, and applications how can be enabled by introducing new tools and technologies for industry 4.0 in Bangladesh.

REFERENCES

Accorsi, R., Bortolini, M., Baruffaldi, G., Pilati, F., & Ferrari, E. (2017). Internet-of-things paradigm in food supply chains control and management. *Procedia Manufacturing, 11*, 889-895.

Acton, A. (2018). Industry 4.0: opportunities and challenges for the developing world.

Agarwal, H., & Agarwal, R. (2017). First Industrial Revolution and Second Industrial Revolution: Technological differences and the differences in banking and financing of the firms. *Saudi Journal of Humanities and Social Sciences, 2*(11), 1062-1066.

Aghion, P., Bacchetta, P., Ranciere, R., & Rogoff, K. (2009). Exchange rate volatility and productivity growth: The role of financial development. *Journal of monetary economics, 56*(4), 494-513.

Ahmad, S. (1990). Foreign capital inflow and economic growth: A two gap model for the Bangladesh economy. *The Bangladesh Development Studies*, 55-79.

Allen, R. C. (2009). *The British industrial revolution in global perspective*: Cambridge University Press.

Anderl, R. (2015). *Industrie 4.0 - Advanced Engineering of Smart Products and Smart Production 09 October 2014*.

Ângelo, A., Barata, J., da Cunha, P. R., & Almeida, V. (2017). *Digital transformation in the pharmaceutical compounds supply chain: Design of a service ecosystem with e-labeling.* Paper presented at the European, Mediterranean, and Middle Eastern conference on information systems.

Ashton, T. S. (1997). The industrial revolution 1760-1830. *OUP Catalogue*.

Atanasov, I., Nikolov, A., Pencheva, E., Dimova, R., & Ivanov, M. (2015). An approach to data annotation for internet of things. *International Journal of Information Technology and Web Engineering (IJITWE), 10*(4), 1-19.

Atkeson, A., & Kehoe, P. J. (2001). *The transition to a new economy after the second industrial revolution* (0898-2937).

Aulbur, W., CJ, A., & Bigghe, R. (2016). Skill development for Industry 4.0. *Roland Berger GMBH, Munique*.

Backhaus, J., & Reinhart, G. (2017). Digital description of products, processes and resources for task-oriented programming of assembly systems. *Journal of Intelligent Manufacturing, 28*(8), 1787-1800.

Baygin, M., Yetis, H., Karakose, M., & Akin, E. (2016). *An effect analysis of industry 4.0 to higher education.* Paper presented at the 2016 15th international conference on information technology based higher education and training (ITHET).

Becker, T., & Stern, H. (2016). Future trends in human work area design for cyber-physical production systems. *Procedia CIRP, 57*, 404-409.

Benešová, A., & Tupa, J. (2017). Requirements for education and qualification of people in Industry 4.0. *Procedia Manufacturing, 11*, 2195-2202.

Berlanstein, L. R. (2003). *The Industrial Revolution and Work in Nineteenth Century Europe*: Routledge.

Bhattacharya, D., Rahman, M., & Raihan, A. (2002). Contribution of the RMG Sector to the Bangladesh Economy. *CPD Occasional Paper Series, 50*(6), 1-26.

Bongomin, O., Gilibrays Ocen, G., Oyondi Nganyi, E., Musinguzi, A., & Omara, T. (2020). Exponential disruptive technologies and the required skills of industry 4.0. *Journal of Engineering, 2020*.

Broadberry, S. N., & Gupta, B. (2005). Cotton textiles and the great divergence: Lancashire, India and shifting competitive advantage, 1600-1850.

Brunet-Thornton, R., & Martinez, F. (2018). *Analyzing the impacts of industry 4.0 in modern business environments*: IGI Global.

Brynjolfsson, E., & McAfee, A. (2014). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*: WW Norton & Company.

Bui, D.-M., Yoon, Y., Huh, E.-N., Jun, S., & Lee, S. (2017). Energy efficiency for cloud computing system based on predictive optimization. *Journal of Parallel and Distributed Computing, 102*, 103-114.

Cezarino, L. O., Liboni, L. B., Stefanelli, N. O., Oliveira, B. G., & Stocco, L. C. (2019). Diving into emerging economies bottleneck: Industry 4.0 and implications for circular economy. *Management Decision*.

Cheng, G.-J., Liu, L.-T., Qiang, X.-J., & Liu, Y. (2016). *Industry 4.0 development and application of intelligent manufacturing.* Paper presented at the 2016 international conference on information system and artificial intelligence (ISAI).

Cooper, S. (2017). Designing a UK industrial strategy for the age of industry 4.0. *Rethink Manufacturing*, 1-27.

Crafts, N. F. (1985). *British economic growth during the industrial revolution*: Oxford University Press, USA.

Culot, G., Nassimbeni, G., Orzes, G., & Sartor, M. (2020). Behind the definition of industry 4.0: Analysis and open questions. *International Journal of Production Economics*, 107617.

Dagli, C. H. (2016). Engineering Cyber Physical Systems: Applying Theory to Practice Preface.

Davali, I., Belli, L., Cilfone, A., & Ferrari, G. (2016). Integration of Wifi mobile nodes in a web of things tested. *ICT Express, 2*(3), 96-99.

Dener, M., & Bostancıoğlu, C. (2015). Smart technologies with wireless sensor networks. *Procedia-Social and Behavioral Sciences, 195*, 1915-1921.

Du, Z., He, L., Chen, Y., Xiao, Y., Gao, P., & Wang, T. (2017). Robot cloud: Bridging the power of robotics and cloud computing. *Future Generation Computer Systems, 74*, 337-348.

Faller, C., & Feldmüller, D. (2015). Industry 4.0 learning factory for regional SMEs. *Procedia CIRP, 32*, 88-91.

Fettig, K., Gačić, T., Köskal, A., Kühn, A., & Stuber, F. (2018). *Impact of industry 4.0 on organizational structures.* Paper presented at the 2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC).

Floud, R., Humphries, J., & Johnson, P. (2014). *The Cambridge economic history of modern Britain* (Vol. 1): Cambridge University Press.

Freeman, J. B. (2018). *Behemoth: A History of the Factory and the Making of the Modern World*: WW Norton & Company.

Giannetti, C. (2017). *A framework for improving process robustness with quantification of uncertainties in Industry 4.0.* Paper presented at the 2017 IEEE International Conference on INnovations in Intelligent SysTems and Applications (INISTA).

Gillen, P., & Ghosh, D. (2007). *Colonialism & modernity*: UNSW Press.

Global, C. (2017). Industry 4.0 Making your business more competitive: CGI Global, Montreal, Canada.

Gokalp, M. O., Kayabay, K., Akyol, M. A., Eren, P. E., & Koçyiğit, A. (2016). *Big data for industry 4.0: A conceptual framework.* Paper presented at the 2016 International Conference on Computational Science and Computational Intelligence (CSCI).

Gorecky, D., Schmitt, M., Loskyll, M., & Zühlke, D. (2014). *Human-machine-interaction in the industry 4.0 era.* Paper presented at the 2014 12th IEEE international conference on industrial informatics (INDIN).

Griffin, K., & Robinson, E. A. G. (2016). *The Economic Development of Bangladesh within a Socialist Framework*: Springer.

Hazen, B. T., Boone, C. A., Ezell, J. D., & Jones-Farmer, L. A. (2014). Data quality for data science, predictive analytics, and big data in supply chain management: An introduction to the problem and suggestions for research and applications. *International Journal of Production Economics, 154*, 72-80.

Hazen, B. T., Skipper, J. B., Ezell, J. D., & Boone, C. A. (2016). Big Data and predictive analytics for supply chain sustainability: A theory-driven research agenda. *Computers & Industrial Engineering, 101*, 592-598.

Hofmann, E., & Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry, 89*, 23-34.

Horváth, D., & Szabó, R. Z. (2019). Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting and Social Change, 146*, 119-132.

Hossain, M. S., & Khan, M. A. (2016). Financial sustainability of microfinance institutions (MFIs) of Bangladesh. *Developing Country Studies, 6*(6), 69-78.

Huckle, S., Bhattacharya, R., White, M., & Beloff, N. (2016). Internet of things, blockchain and shared economy applications. *Procedia Computer Science, 98*, 461-466.

Humphrey, C. E. (2019). *Privatization in Bangladesh: economic transition in a poor country*: Routledge.

Hussain, M. G., Failler, P., Karim, A. A., & Alam, M. K. (2018). Major opportunities of blue economy development in Bangladesh. *Journal of the Indian Ocean Region, 14*(1), 88-99.

Islam, M. A., Jantan, A. H., Hashim, H., Chong, C. W., & Abdullah, M. M. (2018). Fourth Industrial Revolution in Developing Countries: A Case on Bangladesh. *Journal of Management Information and Decision Sciences (JMIDS), 21*(1).

Islam, M. S. (2014). Development of Agriculture Sectorin Bangladesh: A Comparative Analysis. *Al-Barkaat Journal of Finance & Management, 6*(2), 1-11.

Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. *Transportation Research Part E: Logistics and Transportation Review, 136*, 101922.

Jabbour, C. J. C., de Sousa Jabbour, A. B. L., Sarkis, J., & Godinho Filho, M. (2017). Unlocking the circular economy through new business models based on large-scale data: an integrative framework and research agenda. *Technological Forecasting and Social Change*.

Jänicke, M., & Jacob, K. (2009). A Third Industrial Revolution? Solutions to the crisis of resource-intensive growth. *Solutions to the Crisis of Resource-Intensive Growth*.

Jeng, T.-M., Tzeng, S.-C., Tseng, C.-W., Xu, G.-W., & Liu, Y.-C. (2016). The design and fabrication of a temperature diagnosis system for the intelligent rotating spindle of industry 4.0. *Smart Science, 4*(1), 38-43.

Ji, Z., Ganchev, I., O'Droma, M., Zhao, L., & Zhang, X. (2014). A cloud-based car parking middleware for IoT-based smart cities: Design and implementation. *Sensors, 14*(12), 22372-22393.

Keibek, S. A. J. (2017). *The male occupational structure of England and Wales, 1600-1850*. University of Cambridge.

Kergroach, S. (2017). Industry 4.0: New challenges and opportunities for the labour market. *Форсайт, 11*(4 (eng)).

Kusiak, A. (2017). Smart manufacturing must embrace big data. *Nature, 544*(7648), 23-25.

Lee, J., Bagheri, B., & Kao, H.-A. (2014). *Recent advances and trends of cyber-physical systems and big data analytics in industrial informatics*. Paper presented at the International proceeding of int conference on industrial informatics (INDIN).

Li, G., Hou, Y., & Wu, A. (2017). Fourth Industrial Revolution: technological drivers, impacts and coping methods. *Chinese Geographical Science, 27*(4), 626-637.

Manni, U. H., & Afzal, M. N. I. (2012). Effect of trade liberalization on economic growth of developing countries: A case of Bangladesh economy. *Journal of Business, Economics, 1*(2), 1989-2004.

Mohajan, H. (2019a). The first industrial revolution: creation of a new global human era.

Mohajan, H. (2019b). The second industrial revolution has brought modern social and economic developments.

Moktadir, M. A., Ali, S. M., Rajesh, R., & Paul, S. K. (2018). Modeling the interrelationships among barriers to sustainable supply chain management in leather industry. *Journal of Cleaner Production, 181*, 631-651.

Mokyr, J. (2008). The institutional origins of the industrial revolution. *Institutions and economic performance*, 64-119.

Morrar, R., Arman, H., & Mousa, S. (2017). The fourth industrial revolution (Industry 4.0): A social innovation perspective. *Technology Innovation Management Review, 7*(11), 12-20.

Park, H.-A. (2016). Are we ready for the fourth industrial revolution? *Yearbook of medical informatics, 25*(01), 1-3.

Petrillo, A., De Felice, F., Cioffi, R., & Zomparelli, F. (2018). Fourth industrial revolution: Current practices, challenges, and opportunities. *Digital Transformation in Smart Manufacturing*, 1-20.

Philbeck, T., & Davis, N. (2018). The Fourth Industrial Revolution. *Journal of International Affairs, 72*(1), 17-22.

Rajnai, Z., & Kocsis, I. (2017). *Labor market risks of industry 4.0, digitization, robots and AI*. Paper presented at the 2017 IEEE 15th International Symposium on Intelligent Systems and Informatics (SISY).

Ray, I. (2011). *Bengal industries and the British industrial revolution (1757-1857)*: Routledge.

Rezvi, M. R. (2018). The Factors of Declining Agricultural Growth in Bangladesh and Its Impact on Food Security. *South Asian Journal of Social Studies and Economics*, 1-9.

Rifkin, J. (2011). *The third industrial revolution: how lateral power is transforming energy, the economy, and the world*: Macmillan.

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). Industry 4.0: The future of productivity and growth in manufacturing industries. *Boston Consulting Group, 9*(1), 54-89.

Salim, R., & Rahman, S. (2018). Bangladesh agricultural sustainability: economic, environmental and social issues *Bangladesh: Economic, Political and Social Issues* (pp. 1-24).

Sarkar, P., Anjum, A., & Khan, E. A. (2017). Overview of major industries in Bangladesh. *Journal of Chemical Engineering, 30*(1), 51-58.

Schwab, K. (2016). The fourth industrial revolution by Klaus Schwab. *Translated by KJ Song, Mega-study Corporation, Seoul*.

Schwab, K., & Davis, N. (2018). *Shaping the future of the fourth industrial revolution*: Currency.

Siddik, M., Alam, N., Kabiraj, S., & Joghee, S. (2017). Impacts of capital structure on performance of banks in a developing economy: Evidence from Bangladesh. *International journal of financial studies, 5*(2), 13.

Smil, V. (2005). *Creating the twentieth century: Technical innovations of 1867-1914 and their lasting impact*: Oxford University Press.

Smith, B. L. (2001). The third industrial revolution: Policymaking for the Internet. *Colum. Sci. & Tech. L. Rev., 3*, 1.

Sozinova, A. A. (2019). Causal connections of formation of industry 4.0 from the positions of the global economy *Industry 4.0: Industrial Revolution of the 21st Century* (pp. 131-143): Springer.

Stankovic, M., Gupta, R., Figueroa, J., Authried, O., & Rueth, T. (2017). *Industry 4.0: Opportunities behind the challenge.* Paper presented at the Background Paper for UNIDO General Conference.

Stearns, P. N. (2012). *The industrial revolution in world history*: Westview press.

Szalavetz, A. (2017). Industry 4.0 in 'factory economies'.

Tong, J. T. (2016). *Finance and society in 21st century China: Chinese culture versus western markets*: Routledge.

Trade, G. (2014). Invest (2014) INDUSTRIE 4.0: SMART MANUFACTURING FOR THE FUTURE. *Germany Trade & Invest, Berlin*, 1-40.

Varghese, A., & Tandur, D. (2014). *Wireless requirements and challenges in Industry 4.0.* Paper presented at the 2014 International Conference on Contemporary Computing and Informatics (IC3I).

Voth, H.-J. (2003). Living standards during the industrial revolution: An economist's guide. *American Economic Review, 93*(2), 221-226.

Wrigley, E. A. (2018). Reconsidering the industrial revolution: England and Wales. *Journal of Interdisciplinary History, 49*(01), 9-42.

Wyrwicka, M., & Mrugalska, B. (2017). "Industry 4.0"—towards opportunities and challenges of implementation. *DEStech Transactions on Engineering and Technology Research*(icpr).

Yue, X., Cai, H., Yan, H., Zou, C., & Zhou, K. (2015). Cloud-assisted industrial cyber-physical systems: An insight. *Microprocessors and Microsystems, 39*(8), 1262-1270.

Zhou, K., Liu, T., & Zhou, L. (2015). *Industry 4.0: Towards future industrial opportunities and challenges.* Paper presented at the 2015 12th International conference on fuzzy systems and knowledge discovery (FSKD).