MASTER THESIS

INDUSTRY 4.0:
ASSESSING THE READINESS, IMPLEMENTATION CHALLENGES AND IMPACT OF COVID-19 IN THE MANUFACTURING INDUSTRIES OF BANGLADESH

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Lastly, we declare that all the works to formulate this report has been conducted by us. This paper will never be submitted or published anywhere else for academic or financial purposes. Also, this paper has not been plagiarized and all the data acquired has been presented with proper references.

Our heartiest gratitude to everyone.

M Nafees Emtiaz Chowdhury

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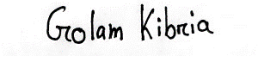

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Abbreviations

AI (Artificial Intelligence)
CAD (Computer Aided Design)
CAE (Computer Aided Engineering)
CBM (Cloud-based Manufacturing)
CIM (Computer Integrated Manufacturing)
CNC (Computer Numerical Control)
COVID-19 (Coronavirus Disease)
CPS (Cyber-Physical System)
EU (European Union)
FDM (Fused Deposition Method)
FMCG (Fast Moving Consumer Goods)
GDP (Gross Domestic Product)
ICT (Information and Communication Technology)
IoT (Internet of Things)
IT (Information Technology)
M2M (Machine to Machine Communication)
ML (Machine Learning)
PLC (Programmable Logic Controller)
RFID (Radio Frequency Identification)
RMG (Readymade Garments)
SARS (Severe Acute Respiratory Syndrome)
SCADA (Supervisory Control and Data Acquisition)
SME (Small and Medium Enterprise)
SLS (Selective Laser Sintering)
TOE (Technology-Organization-Environment)
TQM (Total Quality Management)
UPVC (Unplasticized Poly Vinyl Chloride)
WSN (Wireless Sensor Network)

Abstract

Title: 'Industry 4.0: Assessing the readiness, implementation challenges and impact of COVID-19 in the manufacturing industries of Bangladesh'

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Background: Adaption of Industry 4.0 is the new trend in developing countries mainly to obtain more efficiency and profitability. But to implement industry 4.0, developing countries are facing many challenges that need to be researched. Moreover, due to Covid 19 pandemic and restrictions all around the world, have huge effects on the implementation of industry 4.0. Many companies are forced to implement industry 4.0 in the shortest possible time to sustain themselves in the market. Previous research suggests that pandemic causes a major shift in this regard. Furthermore, the implementation of industry 4.0 will reduce the use of Human labor in industries. This might cause mass unemployment in developing countries where people are less skilled and educated.

Purpose: This thesis identifies the current state of Industry 4.0 in Bangladesh and analyses the challenges that industries faced to successfully implement industry 4.0 in Bangladesh. This thesis also analyses the effects of the COVID-19 pandemic on the implementation of industry 4.0. The purpose of this thesis is to highlight the present scenario regarding industry 4.0 and figure out the strategies of companies regarding the prevention of future obstacles in the manufacturing process due to pandemic and unemployment issues. This research would help decision-makers and researchers to understand the situation easily thus contributing to the development of Bangladesh and academia.

Method: This thesis conducts multiple case studies in which the researcher conducted observation and semi-structured interviews.

Findings & Conclusion: Most of the companies in Bangladesh are in beginner or level 1 in the IMPULS industry 4.0 readiness model. Although they have plans to adopt more industry 4.0 technologies. A majority portion of the sample industry mentioned having some sort of plans to prepare themselves for the future pandemic in post-COVID-19 eras.

Keywords: *Industry 4.0, IMPULS Industry 4.0 Readiness Model, TOE framework, COVID-19, Developing Countries, Bangladesh, etc.*

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Chapter 1: Introduction

1.1 Introduction

Evolution has marked how humans use tools for their welfare, to produce essential goods for daily needs, to build shelter, to convert monuments into wonders, to establish a civilized society for survival and this process of transformation has enabled the gradual enlightenment of civilization (Yin, Stecke, & Li, 2017). Through enlightenment, humankind has learned to revolutionize their fulfillment of needs with machines, instead of mere usage of limbs (Roblek, Meško, & Krapež, 2016).

Ergo, the advancement of the industrial revolution. This industrial revolution can be categorized into four parts: from Industry 1.0 technologies to Industry 4.0 technologies (Oztemel, & Gursev, 2018). The first step towards industrial production was met due to the discovery of water and steam power enabled engines during the eighteenth century (Rejikumar, Sreedharan, Arunprasad, Persis, & Sreeraj, 2019). Before that, kinetic energy from humans and kettles were the only options. Oztemel and Gursev (2018) state that the utilization of steam as Industry 1.0 technology was followed by the invention of electricity and its applications in production. Electricity rendered the process of assembly line production, making manufacturing of goods faster and paved the way towards the second industrial revolution (Rejikumar et al., 2019). Recent research studies by Rumi, Rashid, Makhdum and Nahid (2020) state that during the second industrial revolution in the nineteenth century, entrepreneurs and businessmen utilized the technology of that time to develop steamship, gas turbine, telephone electric lights, railroads and typewriter which fostered the development of technological infrastructure, accuracy of manufacturing and public transportation system worldwide.

According to Oztemel and Gursev (2018) third industrial revolution emerged during the twentieth century which prompted inventions that we call modern sciences today. The latter part of the century enabled humans to use electricity to build semi-automated machines using programmable controls which marked the inception of Industry 3.0 technologies (Yin et al., 2017). Computer and internet technology was introduced during this time and factories were focused on reducing efforts and maximizing production using electronics IT (Rumi et al., 2020). Programmable machines were introduced during this timeline using the programmable logic controller (PLC) technology by Richard Morley and these machines could produce a hefty amount of goods using coded machine language and automated mechanisms (Rejikumar et al., 2019). Back to the present day, what we use now is regarded as Industry 4.0 technologies, an era of cyber-physical systems where machines are so advanced that they can manufacture large scale product lines without human involvement (Lu, 2017). Industry 4.0 enables intelligent and sustainable production process by implementing groundbreaking technologies like Cyber-Physical System or CPS, Internet of Things (IoT), Big Data, Artificial Intelligence, Cloud Computing, Robotics, Additive manufacturing, 3D printing etc. (Oztemel & Gursev, 2018; Ammar, Haleem, Javaid, Walia, & Bahl, 2021).

Industry 4.0 is considered as 'cyber industry' or 'intelligent industry' as it involves collaborative control and optimization of production process due to human-machine interaction, intelligent sensing and processing of information related to production and management and fosters knowledge driven autonomous decision making in the production process by both humans and machines (Jimeno-Morenilla, Azariadis, Molina-Carmona, Kyratzi, & Moulianitis, 2021; Qian, Zhong, & Du, 2017). In addition, Zhang, Wang, Zhu, Cao and Tao (2019) claim that implementation of Industry 4.0 technologies in the manufacturing process increases cost efficiency, resource flexibility, production scalability, customization of products and services. Moreover, industry 4.0 is based on six principles: *'interoperability'* which involves connectivity and co-operation among the various parts of the production process; *'decentralization'* that empowers a manufacturing plant to process the production tasks independently; *'virtualization'* that allows plants to make virtual twins using additive manufacturing technology; *'real time capability'* to monitor production progress and sharing of information in real time; *'service orientation'* which allows companies to provide better services and *'modularity'* that involves plants to make changes in the production process effortlessly (Rejikumar et al., 2019; Enyoghasi, & Badurdeen, 2021).

According to Enyoghasi and Badurdeen (2021) Cyber-Physical Systems (CPS) and Internet of Things (IoT) are the two fundamental concepts of Industry 4.0. Cyber-Physical Systems involve the integration of communication, computing and control in manufacturing systems network (Aceto, Persico, & Pescapé, 2020; Enyoghasi, & Badurdeen, 2021). On the other hand, Internet of Things (IoT) can be considered as an ecosystem of technologies which can be used to monitor the status of physical objects, receiving data and sharing the relevant information by software applications through the web of networks and machines (Anbalagan, & Moreno-Garcia, 2020). When CPS and Internet of Things technology is implemented in a factory it allows the communication, connection and exchange of information between humans, humans to machines and even between the machines themselves (Jiang, 2018). In addition to CPS and IoT there are other disruptive technologies like big data analytics, cloud manufacturing, additive manufacturing and robotics which are essential technologies of Industry 4.0 (Enyoghasi & Badurdeen, 2021). Adoption of these technologies will provide better visibility and control of the interconnected operations, reduce production downtime, increase productivity and ultimately lead towards sustainability of business operations (Roblek et al., 2016). Industry 4.0 technologies are already adopted in the different industries like textile, automobile, chemical, gas production, electronics, pharmaceuticals, logistics, port and maritime industry etc. of developed countries like Germany, United Kingdom, Netherlands, France, Japan, China and Malaysia because of their socio-economic benefits (Masood & Sonntag, 2020; Fromhold-Eisebith, Marschall, Peters, & Thomes, 2021; Lu, 2017).

However, though Industry 4.0 technologies have marked their presence and importance globally, developing countries still struggle to fully implement these technologies due to unstable economy, lack of resources, high infrastructure development cost, technological hindrance and so on (Islam, Jantan, Hashim, Chong, Abdullah, Rahman, & Hamid, 2018). Developing countries in South Asia

like India, Pakistan, Sri Lanka, Bangladesh and Nepal all are trying to shift from traditional manufacturing to Industry 4.0 but due to the aforementioned reasons, these developing countries have been struggling to adopt industry 4.0 technologies yet (Islam et al., 2018; Rumi et al., 2020). Bangladesh is one of the developing countries in South Asia, with her massive population and limited area is the second-largest global exporter of readymade garments (RMG) worldwide and also has the fastest GDP growth rate in Asia (Bhuiyan, Ali, Zulkifli, & Kumarasamy, 2020). This country has a huge population, so the labor cost is cheap and plenty available but full automated production is challenging due to lack of technical knowledge, underdeveloped infrastructure and scarcity of investment.

Moreover, the global pestilence known as COVID-19 which can be indicated as an acute respiratory syndrome coronavirus 2 or SARS-CoV-2 has struck a blunt-force trauma into our lives (Abdel-Basset, Chang, & Nabeeh, 2021). In such a harrowing situation, the world economy has fluctuated enough in the past year and the second wave of the pandemic has again demanded general lockdown (Narayanamurthy & Tortorella, 2021). Where the safety of life is at risk, the economy is sure to suffer and so it did. This scenario is all the grimmer in the context of third world countries where development has met its impediments due to the shutting down of factories and home quarantine (Kumar, Raut, Narwane, & Narkhede, 2020). And the curve of mortality rate has shown no decline, even with vaccination campaigns. So, businesses have to optimize production with what little resources and opportunities they have. In such pandemic circumstances, where there is a shortage of supply of raw materials, lack of human resources to operate factories and maintain production to meet demand, Industry 4.0 technologies shine a glaring prospect of maximizing output with minimum human interaction (Javaid, Haleem, Vaishya, Bahl, Suman, & Vaish, 2020).

The coming decades may show a promising paradigm shift in Bangladeshi industries, yet the question marks still lurk today. Is Bangladesh ready to fully implement Industry 4.0 technologies uniformly? Or will the manufacturing processes of the past century persist in the context of developing countries?

Thus, this research project is carried out to find out the readiness status of Industry 4.0 implementation in the manufacturing industries in Bangladesh, explore the challenges faced regarding the implementation process and understand the impact of the COVID-19 pandemic on the adoption process of Industry 4.0 technologies in the manufacturing industries in Bangladesh.

1.2 Previous Empirical Research on Industry 4.0

Academic researchers and business practitioners have given substantial attention to Industry 4.0 because of its various benefits in manufacturing organizations and so much researches have been conducted on Industry 4.0 in recent years. Researches on key concepts Industry 4.0 is increasing potentially as most of the enabling technologies related to Industry 4.0 are still emerging (Majumdar, Garg, & Jain, 2021).

Industry 4.0 was originated in Germany, so research was conducted to see how implementation of Industry 4.0 technologies could transform the German textile industry as Germany has been a big player in this industry among the other EU countries (Fromhold-Eisebith et al., 2021). The empirical findings showed that the German textile industry has suffered for a long time due to deindustrialization, rationalization and global relocation but in order to meet the challenges of global competition they have kept innovating, new technological tools like Industry 4.0 have been introduced which have turned the fortune of their textile industry (ibid). If they can manage their human resources and labor relations properly by 2030 German textile industry will be a digitized, institutionally supported technical textile production industry (Fromhold-Eisebith et al., 2021).

Similarly, Masood and Sonntag (2020) identified that there have been very few researches regarding adoption challenges and benefits of Industry 4.0 technologies based on the SMEs of United Kingdom. So, they researched on these topics and found out that using Industry 4.0 technologies in the SMEs of the United Kingdom have increased their manufacturing quality of products, manufacturing flexibility, operational efficiency and reduced operation cost significantly (ibid). However, high implementation cost, technology knowledge and implementation time have been the major challenges identified to adopt Industry 4.0 technologies in the SMEs of the United Kingdom (Masood & Sonntag, 2020).

In addition, Kumar, Singh and Dwivedi (2020) also researched on different SMEs (Small Medium Enterprise) of India as they wanted to explore how application of Industry 4.0 technologies can lead to and sustainable production operations and also identify the challenges of implementing Industry 4.0 technologies in India. It was observed that in order to lower the production cost and avoid restrictive legal regulations, many developed countries outsource their services to the different SMEs in developing countries like Bangladesh, India, Cambodia, Vietnam etc. (Kumar et al., 2020). Additionally, the research findings pointed that lack of transparency in operations, lack of IT infrastructure, lack of applications of advanced technologies and poor organizational culture are the predominant barriers to ensure sustainable and ethical business operation in developing countries like India. Adoption of Industry 4.0 technologies in SMEs of India can overcome these challenges and lead towards long term sustainability (ibid).

Moreover, research has been conducted on several SMEs in Thailand to understand how Industry 4.0 technologies can improve the sustainability of business performance in SMEs in Thailand. Result outcome showed that due to lack of human and capital resources, technological infrastructure it was hard for the SMEs in Thailand to cope in competition with big companies in different industries but after adopting different Industry 4.0 technologies in their SMEs in 2017 there was a huge increase in their annual revenue, business savings, production efficiency and decrease in debt (Haseeb, Hussain, Ślusarczyk, & Jermsittiparsert, 2019).

Furthermore, faulty production process and maintenance of machines are crucial concerns in the industrial landscape and thus, previous study has been done on how Industry 4.0 technologies can be helpful in running predictive maintenance of machines (Dalzochio, Kunst, Pignaton, Binotto, Sanyal, Favilla, & Barbosa, 2020). Study findings outlined by Dalzochio et al., (2020) shows that

when Machine Learning (ML) technology is integrated into the machines designed by the CPS and IoT system in the production facility then predictive maintenance of machines can be successfully operated. The application of Machine Learning technology is proficient in accomplishing the task of prognostics and prediction of failures in production process, decrease system faults, minimalize unplanned downtimes, optimize planning of maintenance interventions and sequentially increase productivity (ibid).

However, not only in the manufacturing but Industry 4.0 technologies have also been important in health care service, port and maritime industry as well worldwide. Recent study outlined by de la Peña Zarzuelo, Freire Soeane, and López Bermúdez (2020) showed that six technologies of IoT which are sensors, wireless sensor network (WSN), machine to machine (M2M), network communication technology, handheld mobile terminal and vehicle terminal are used to build an intelligent port. Research result also showed that IoT, big data, cloud computing and blockchain are also used for port equipment condition monitoring, engineering equipment, asset management and international digital trade transactions at ports (ibid). On the other hand, in health care industry, previous study shows that Industry 4.0 technologies like IoT, big data and cloud computing have been successful in monitoring physiological and pathological signals monitoring, telemedicine, telepathology, rehabilitation, cloud-based health information system and personalized health care services (Aceto et al., 2020).

It should be noted that there has been a lack of empirical research in regards to Industry 4.0 in the developing countries of South Asia. Previous study outlined by Bhuiyan et al., (2020) stated that the adoption of Industry 4.0 will convey a paradigm shift which will eventually transform current condition of jobs, production, business, the livelihood of people in the developing countries like Bangladesh. Similarly, Rumi et al., (2020) conducted research related to the adoption of Industry 4.0 technologies in Bangladesh with a focus on the impact on people not the manufacturing process and asserted that adoption of Industry 4.0 technologies in Bangladesh will eventually develop the ICT infrastructure, increase productivity, enhance women empowerment and improve the overall well-being of the citizen. However, Moktadir, Ali, Kusi-Sarpong and Shaikh (2018) conducted research to figure out the implementation challenges of industry 4.0 in the leather industry of Bangladesh and found out that data insecurity, high investment, lack of technology infrastructure and lack of strategy towards implementing Industry 4.0 have been the significant challenges faced during that time.

In the recent times, due to outbreak of COVID-19 pandemic few substantial researches have been conducted regarding Industry 4.0 among which one research was done to discover how through usage of Industry 4.0 technologies affected and recovered patients of COVID-19 can be tracked and how to reduce the massive pressure on hospitals by providing telemedicine digitally (Abdel-Baset et al., 2021). Likewise, recent research has also showed us that aircraft manufacturing, automobile and tourism industry has been affected drastically because of COVID-19 pandemic but the fertilizer, food, FMCG, telecom and pharmaceuticals industries have not affected in regards to the other industries (Belhadi, Kamble, Jabbour, Gunasekaran, Ndubisi, & Venkatesh, 2021).

1.3 Problematization

The transformation of digital industries around the world is still in progress as the technologies of Industry 4.0 are still developing (Roblec et al., 2016; Majumdar et al., 2021). Industry 4.0 technologies will have a significant influence on the transformation of industries as it involves digitization of production, automation of production lines using machines and automatic data transaction across linked manufacturing sites (Roblec et al., 2016). Generally, an industry 4.0 enabled manufacturing plant should be built in such a way where the production environment is equipped with Computer Aided Design (CAD), Computer Aided Engineering (CAE) and Computer Numerical Control (CNC) systems (Anbalagan, & Moreno-Garcia, 2020). Robots, one of the prime technologies of industry 4.0 are considered as part of the Computer Integrated Manufacturing (CIM) environment and are used as material handling systems in the production process (ibid). So, digitization of manufacturing processes adds value by increasing production time efficiency, improving productivity, enhancing product quality, reducing production error and lead time (Ashima, Haleem, Bahl, Javaid, Mahla, & Singh, 2021).

However, all these advantages are not easy to avail because there are several factors that have become impediments in adopting Industry 4.0 technologies. Lack of understanding and commitment of top management, lack of digital culture, difficult organizational process, lack of trained employees, lack of internet coverage and IT facilities, high investment cost, cyber security issues, lack of government support inadequate maintenance support and fear of failure are some of the major impediments in implementing Industry 4.0 technologies in the manufacturing organizations especially in the developing countries in South Asia like India, Bangladesh, Pakistan, Vietnam and Sri Lanka (Majumdar et al., 2021, Rumi et al., 2021; Moktadir et al., 2018).

It is also noticeable that there have been very few researches regarding Industry 4.0 and other concepts related to it in the South Asia region, especially in Bangladesh. After going through previous empirical studies regarding Industry 4.0 implementation in Bangladesh only hand few researches were possible to find. An elaborative study was conducted by Islam et al., (2018) where the researchers mentioned that there have been very few applications of Industry 4.0 in the leather, RMG and tourism industry of Bangladesh. Similarly, another significant research was conducted by Rumi et al., (2020) which was focused on the economic and political impact of Industry 4.0 in Bangladesh context. Apart from this another, research was conducted based only on the leather industry of Bangladesh, as this industry is one of the most polluting industrial sectors of the country (Moktadir et al., 2018). The researchers tried to find out how implementing industry 4.0 technologies in the leather industry of Bangladesh could manage production process safety and ensure environmental protection.

Thus, it is transparent to witness that there has been a clear research gap related to the implementation of Industry 4.0 technologies in Bangladesh. None of the previous researches as of today focused on the readiness status of industry 4.0 in the manufacturing industries of Bangladesh. No research focused on the implementation challenges especially on the manufacturing industries of Bangladesh. And most importantly, as we are going through the

COVID-19 pandemic there has been no research related to the impact of COVID-19 in the adoption process of industry 4.0 in the manufacturing industries of Bangladesh. Therefore, in this research, attempts have been made to fill these lacunae. The research aim, questions and their relevance are described in the subsequent section.

1.4 Research Aim and Questions

The aim of this research is to measure the present readiness status of Industry 4.0 in the manufacturing industries of Bangladesh. We are also focused to identify the challenges that manufacturing companies faced while implementing industry 4.0 in Bangladesh. Finally, we are interested to explore how pandemic COVID-19 has affected the manufacturing industries of Bangladesh and has this pandemic any impact on the adoption process of industry 4.0 technologies in Bangladesh. Therefore, this research will provide social insights into how much advancement manufacturing industries of Bangladesh have achieved so far and which are the areas that they are still facing problems to implement these modern technologies. In addition, this study will give us an idea of how a pandemic like COVID-19 has affected the manufacturing industry and how effective Industry 4.0 technologies can be to face such a crisis in the future. Moreover, this study findings will provide valuable insights regarding the current readiness status of manufacturing industries to the government of Bangladesh and foreign investors so that they can take investment decisions to improve the national economy. Also, the results of this study will provide theoretical contribution as well. The following three questions are studied to fulfill the research aim:

RQ1: What is the current state of Industry 4.0 in the manufacturing sector in Bangladesh?

RQ2: What challenges were faced while implementing Industry 4.0 technologies in the manufacturing industries of Bangladesh?

RQ3: Does the pandemic COVID-19 have any impact on the adoption process of Industry 4.0 technologies in the manufacturing industries of Bangladesh?

1.5 Disposition

This research paper is divided into five chapters. The following chapters of this research paper are structured as follows. In the second chapter, which is the ‘Theoretical Framework’, we are going to provide a review of the studies related to our research topic and we will also provide the adapted concepts and theories which we are going to use to analyze our empirical findings. The third chapter is considered as ‘Methodology’ where we are going to describe the methods of carrying out this research work. In the fourth chapter, namely ‘Analysis of Findings’ we will provide an analysis of our empirical findings. In the fifth chapter which is ‘Discussion’, we will summarize our results and provide answers to our research questions. Finally, in the sixth chapter which will

be our ‘Conclusion’, we will draw conclusion to our research work and reflect on the societal implications and theoretical contribution of this study and give directions for future areas.

1.6 Limitations

As this research was conducted during the COVID-19 pandemic, we faced many restrictions while collecting our empirical data. Some organizations did not allow us to visit their plants due to health risks. Moreover, some potential companies were shut down temporarily due to the lockdown imposed by the government. So, we could not reach them as well. That is why we included 10 cases only in this study. However, some of these companies did not allow us taking photographs inside their factory premises during our observation due to confidentiality issues.

Furthermore, the imposed lockdown and the health risks limited our research & face-to-face interview scopes. So, collecting primary data was a major challenge.

Chapter 2: Theoretical Framework

This chapter is divided into two parts. The first part of this chapter presents the available literature related Industry 4.0. The literature review is divided into four themes which describes Industry 4.0, key concepts of Industry 4.0, implementation challenges of industry 4.0 and the impact of COVID-19 on implementation of Industry 4.0 technologies. The second part of this chapter provides the required theoretical framework to analyze our empirical data. The first theory is the 'IMPULS: Readiness model of Industry 4.0' which is discussed to analyze the readiness status of industry 4.0 in the manufacturing industries of Bangladesh and the second theory is the 'Technology-Organization-Environment' framework which is explained to analyze the challenges of implementing Industry 4.0 in the manufacturing industries of Bangladesh and also to help explain the impact of external environmental factor COVID-19 on the adoption process of the manufacturing industries of Bangladesh.

2.1 Industry 4.0

In the era of digitization in manufacturing, the concept of Industry 4.0 has achieved large acceptance and recognition for improving the production efficiency, reducing production cost and time, minimizing waste, optimizing resource consumption and safeguarding the environment along with improved product quality (Vinodh, Antony, Agrawal, & Douglas, 2020). According to Gerekli, Ziyad Çelik and Bozkurt (2021) the concept of Industry 4.0 can be described as a process in which an advanced level of automation is applied among the machines by creating a network interconnected with sensors and internet, which allows machines to make decisions by communicating with each other, store the information in cloud system and this information can be accessed by all stakeholders incorporated into the system whenever needed.

Traditionally, in the last 20 years manufacturing companies have been following Lean production practices, 'Six sigma', 'Kanban', 'Just in time' production, Kaizen system, and total quality management (TQM) for eliminating errors in manufacturing, producing better quality products in shorter lead time, reducing waste, inventory and streamlining the overall supply chain but they are now shifting towards adoption of Industry 4.0 technologies as it gives better connectivity and sharing of information among the machines and humans, autonomous decision making by machines and ensures predictive maintenance of machines to avoid frequent breakdowns during production process (Vinodh et al., 2020). Besides, Shahin, Chen, Bouzary, and Krishnaiyer (2020) states that integration of industry 4.0 technologies and lean practices would lead towards smart and sustainable manufacturing for next generation manufacturing companies.

Industry 4.0 was first pioneered at the Hannover Fair in November 2011 by the German government as a plan for the advancement of their manufacturing industries (Rejikumar et al.,

2019). According to Majumdar et al., (2021) this new groundbreaking conception was conceptualized by Henning Kagermann, Wolf-Dieter Lukas and Wolfgang Wahlster in order to maintain the competitiveness of the German manufacturing industries with the other nations of the world. For intensive knowledge of the "fourth industrial revolution", it is noteworthy to understand the preceding three industrial revolutions whereby the first industrial revolution offered the foundation for industrialization or mechanical production (Oztemel & Gursev, 2018; Yin et al., 2017). The second revolution presented a base to power and developed the model of 'mass production' and the third revolution gave foundation to computers and with the help of IT and electronics it triggered automated production (Oztemel & Gursev, 2018). Now, the fourth revolution or Industry 4.0 fosters intelligent production which comes with the usage of advanced information and communication technology and is associated with the incorporation of industrial mechanization, interconnected sensors and networks, and latest manufacturing technologies such as cyber physical systems, internet of things (IoT), big data, artificial intelligence, 3D printing robots and smart factories (Lee & Lim, 2021). In the following section the key concepts of Industry 4.0 will be discussed briefly.

2.2 Key Concepts of Industry 4.0

According to Gerekli et al., (2021) the Industry 4.0 era has brought a breakthrough in the manufacturing industries worldwide that allows smart production with the implementation of advanced technologies like the Cyber-Physical Systems (CPS), Internet of Things (IoT), Big data, Artificial Intelligence (AI), Machine to Machine (M2M) communication, 3D printing or additive manufacturing, autonomous robotics, smart products and smart factory. However, Roblec et al., (2016) argues that machine to machine communication and smart products cannot be considered as self-regulating parts where the smart products are subcomponent of Cyber-Physical system and machine to machine communication is just an enabler of the IoT system. So, the key concepts of Industry 4.0 are explained briefly in the followings:

2.2.1 Cyber-Physical System (CPS):

Cyber-Physical System can be described as a complex engineering system which can integrate computation, networking and physical processes (Roblec et al., 2016). Along with it, Lee, Bagheri and Kao (2015) refers that in order to transform today's factories to smart factory CPS can be established to manage a large amount of data, integrate interconnectivity among the machines to make the production process resilient and self-adaptable. In addition, Jiang (2018) stresses that CPS system comes with many benefits as it can engineer better equipment by leveraging operational performance data, control and manage equipment remotely, optimize equipment operations, predict and trigger maintenance activities and share information and data driven services in a manufacturing plant. Moreover, Lu (2017) emphasizes that when CPS is established in the manufacturing system it provides collaborative planning, design modeling, analysis and maintenance reports to the physical system to enhance decision making and productivity.

Apart from that, according to Lee et al., (2015) there is a 5C architecture model for developing CPS in any manufacturing factory and the five levels from bottom to top are 'connection',

‘conversion’, ‘cyber’, ‘cognition’ and ‘configuration’. Firstly, the connection level involves smart connection of sensors and tether free communication among the machines to get accurate and reliable measurement from the production machines (Lee et al., 2015; Jiang 2018). Secondly, the conversion level involves data to information transformation, multi-dimensional data correlation and performance prediction of machines (ibid). Thirdly, the cyber level focuses on connecting more machines in to the machine network to obtain more information regarding the production process (Lee et al., 2015; Jiang 2018). Fourthly, the cognition level involves collaborative diagnostics and decision making that allows humans to make accurate decisions based on the visual and statistics information retrieved from the machines (ibid). Finally, when the cyber physical system of a manufacturing plant reaches the configuration level the machines self-configure for resilience, self-adjust for variation and self-optimize for disturbance and gives feedback to the physical system according to the decision made (Lee et al., 2015; Jiang 2018). So, it is transparent that CPS are required to integrate M2M communication and utilize application platform (Oztemel & Gursev, 2020).

2.2.2 Internet of Things (IoT):

According to Moktadir et al., (2018) Internet of Things technology can be referred as ‘industrial internet’ for which machines and devices gets the capability to communicate with each other over the internet. So this technology is widely used for sharing of information, smart planning and control of machines in the manufacturing industries (Gerekli et al., 2021). Besides, Aceto (2020) states that IoT technology is able to provide connectivity anytime to anyplace through a wide range of Wireless Sensor Networks (WSN), actuators and smart devices with a focus on digital identification and machine to machine communications. Apart from that, Roblec et al., (2016) refers that IoT includes ‘things’ and ‘objects’ like Radio-Frequency-Identification (RFID) sensors which are able to receive, send store, process, and analyze information and smart phones which involves interaction with each other and cooperation with smart components. Subsequently it is important to mention that sensors play a crucial role in establishment of IoT in factories, automation of production process asset monitoring and predictive maintenance whereby significant sensors used in factories are pressure, temperature, proximity, flow, gas, color and light sensors (Javaid et al., 2021). Moreover, The IoT ensures interoperability which allows monitoring of all production process with purpose of maintenance, energy management optimization and product quality management. However, Oztemel and Gursev (2020) emphasized that when CPS and IoT are combined together it can provide more reliable, robust and agile manufacturing system with intelligent production capabilities.

2.2.3 Big Data:

One of the significant technologies of Industry 4.0 is big data which involves processing of large amount of structured, semi-structured and unstructured data generated from the product lifecycle in the manufacturing process (Qi & Tao, 2018). Again, big data can be categorized by 4Vs which are Volume, Variety, Velocity and Veracity (Bousdekis & Mentzas, 2021; Zhang, Ren, Liu, & Si,

2017). Volume is associated with the amount of data generated, variety is related to how many different types of data are generated, velocity involves how fast data is generated and veracity is concerned about how accurate generated data are (Ibid). Recent research outlined by Faheem, Fizza, Ashraf, Butt, Ngadi, and Gungor (2021) states that usage of big data has proved to be efficient in product designing, data visualization, aiding decision making, maintenance, repair and overhaul of machines in the production process. Moreover, Big data provides three types of analytics in manufacturing process: i) descriptive analytics which provides real time information on what is happening, identifies what has happened and examines why it has happened, ii) predictive analytics provides prediction on what will happen and why and iii) prescriptive analytics supports decision making on what should be done and why (Bousdekis & Mentzas 2021). Furthermore, it can be stated that, big data have been very useful in the oil and gas industry for their maintenance and scheduling, safety management, product flow assessment and process risk mitigation (Nguyen, Gosine, & Warrian, 2020).

2.2.4 Cloud-based Manufacturing (CBM):

Another emerging technology of Industry 4.0 is the notion of cloud-based manufacturing systems which can be explained as a cloud based networked manufacturing model used for product development with minimum costs and optimal resource allocation (Thames, & Schaefer, 2016). Along with it can be stated that, cloud manufacturing is a smart manufacturing system which is designed with access to a pool of configurable computing resources which can be operated virtually from distance (Zhang et al., 2019). In addition, Aceto et al., (2020) stresses that cloud-based manufacturing technology involves scalability, ubiquitous access to production information, agility and virtualization of the production process. But, Zhang et al., (2019) argues that there is a difference between cloud computing and cloud manufacturing as cloud computing just requires adoption of computational resources like server, network and software whereas cloud manufacturing involves adoption of cloud computing and other physical systems to produce products. However, cloud-based manufacturing system is customer centric, service oriented and demand driven which eliminates infrastructure complexity, reduces production time and cost, extends work areas, provides access to information real time and protects data (Oztamel & Gursev, 2020; Zhang et al., 2019).

2.2.5 Additive Manufacturing or 3D Printing:

Additive Manufacturing or 3D printing is one of the latest disruptive technologies of Industry 4.0 which includes a set of technologies which are capable of producing virtual prototypes or solid models of products into reality by composing different layers of materials from the bottom to the top according to the shape of the product (Jimeno-Morenilla et al. 2021). According to Yin et al., (2017) 3D printing technology can be used to print many geometric structures, reduce the use of raw materials for production by designing prototypes and shorten product life cycle. In present days, manufacturing organizations in furniture, footwear and toy industries are empowering their customers by responding to their demand for product customization due to additive manufacturing

technologies like 3D printing, augmented reality and virtual reality (Rejikumar et al., 2019). In addition, Moktadir et al., (2018) refers that additive manufacturing related technologies like 3D printing, fused deposition method (FDM), selective laser sintering (SLS) and selective laser melting are used in manufacturing organizations for design optimization and production of customized products in small quantities. Moreover, Zhang et al., (2019) also contends that the additive manufacturing technologies such as reverse engineering, 3D printing and rapid prototyping are very effective for companies to produce small quantity of customized products faster at a comparatively low cost.

2.2.6 Artificial Intelligence (AI) and Robotics:

Artificial Intelligence or AI is one of the vital components of Industry 4.0 which comprises the simulation of human intelligence process into machines by integrating CPS, IoT, machine learning, machine to machine communication technologies (Chatterjee, Rana, Dwivedi, & Baabdullah, 2021). Similarly, Oztamel and Gursev (2018) states that AI allows to adopt smart automation with usage of intelligent robots that can perform manufacturing tasks autonomously, can predict errors in the production process and solve the problem independently and helps human beings to make better decisions related to the production. Additionally, Moktadir et al., (2018) refers that AI contributes to the adoption of autonomous robots which can perform sensitive tasks in the manufacturing process which cannot be performed by humans precisely. There are several industrial robots like 'Baxter' robot used for packaging operation, 'Roberta' robot utilized for efficient automation in manufacturing operation, 'Kuka LBR iiwa' robot engaged to perform sensitive industrial tasks (Moktadir et al., 2018). Moreover, Jimeno-Morenilla et al. (2021) stresses that AI technologies like Artificial Neural Network algorithms, Machine learning, Text mining techniques plays a big role for implementing Robotic Process Automation (RPA) in manufacturing organizations for which they are able to optimize their operational and business performance significantly. However, Zhang et al., (2019) argues that though the use of AI-embedded robotics technology has enabled manufacturing process systems for developing flexible, smart and ecofriendly production ecosystems establishment cost of AI and robotics is very expensive which becomes a challenge for many small and medium sized companies to install them.

2.2.7 Smart Factory:

The term 'Smart Factory' has become a buzzword recently as it is one of the emerging concepts of Industry 4.0. Osterrieder, Budde and Friedli (2020) explains that smart factory can also be termed as 'intelligent' or 'digital' factory as such kind of factory is connected with IT embedded manufacturing system and operated mainly without human interference. In a smart factory, all machines are connected through sensors and actors, which can collect, send, receive and process data automatically and these smart computer-based systems ensures seamless, continuous flow of production operation with increased productivity and ensuring good quality (Wang, Wan, Zhang, Li, & Zhang, 2016). Subsequently, Shao, Liu, Li, Chaudhry and Yue (2021) claims that smart factories are developed in such a way that their technological infrastructures are capable to make

timely decision independently via artificial intelligence, optimize the manufacturing process with autonomous monitoring and ensures predictive maintenance of machines through big data.

2.3 Challenges of Implementing Industry 4.0 technologies

Industry 4.0 is a radical concept that cultivates the growth of self-directed production systems with the combination of AI, IoT, and CPS (Xu, Xu, & Li, 2018). Particularly, while adding value in the manufacturing process, industry 4.0 has achieved popularity as it causes technological amalgamation of CPS and internet-based transmission (Duman & Akdemir, 2021). It has numerous possible benefits but the implementation of industry 4.0 is no easy task to do. As global rivalry on the worldwide manufacturing platforms is expanding, there arises a necessity for examining the challenges of implementing technologies of Industry 4.0 (Mishra, Singh, Johansen, Cheng, & Farooq, 2019). Recent research outlined by Kumar, Singh and Dwivedi (2020) refers that there are potential barriers of implementing various industry 4.0 technologies in developing countries which are weak value-chain integration, poor infrastructure, high charged investment, cyber security risks, uncertainty regarding financial benefits, unskilled labor, poor infrastructure, job disturbances, encounters in data supervision, inadequate data quality, lack of protected values and norms, and lack of changing behavior.

It is important to mention that not many studies gave a strong logic for the implementation of Industry 4.0 and did not offer a roadmap for its implementation process (Zhou et al., 2020). Müller, Buliga, and Voigt (2018) stresses that manufacturing systems and cyber-physical systems could be incorporated by digital learning such as cybernetic classrooms, visualization of data, and adaptive knowledge. Besdies, Luthra and Mangla (2018) has noted that manufacturing SMEs of India are more swayed by the second industrial revolution and thus, falling back to the fourth industrial revolution. Likewise, Morrar and Arman (2017) shed the light upon SMEs and found out that fast-pacing technological interruptions enact many challenges, especially in developing countries. This is further supported by the various researches conducted by Kumar et al, (2014); Moktadir et al. (2018); and Bag et al., (2020) which focuses on the fact that SMEs of emerging nations confront challenges due to weak financial state, paucity of technical competencies, and the excessive price of sustainable practices.

Other than that, generating results corresponding to the environment, society, and culture is also tricky (Shin, Hwang, & Kim, 2019). Rumi et al., (2019) argue that the manufacturing industries around the world may face problems while establishing sustainable development goals due to lack of awareness, the risk unemployment, changes in the market behavior because of the emerging technologies. However, only a hand few of researches have been conducted regarding challenges of implementing Industry 4.0 technologies in Bangladesh among which research done by Rumi et al., (2019) focused on the economic and political impact of adopting industry 4.0 technologies. It was identified that the governance system will change in the coming decade, inequality will increase in the production system, and security concern of national defense system will increase, education and global trade structure will change (Rumi et al., 2019). On the other hand, Islam et al., (2018) stated that lack of awareness, high investment cost, lack of government support are the

main impediments of adopting Industry 4.0 technologies in leather industry of Bangladesh. So, there is a research gap which is why this paper aims to understand at this present year of 2021 what the challenges are that still prevails, especially in the manufacturing industries of Bangladesh.

2.4 Impact of COVID-19 on implementation of Industry 4.0

Due to the severe outbreak of COVID-19 pandemic, the dependency on the technology and intelligent framework have increased worldwide (Abdel-Basset et al., 2021). Using rapid technology, researchers from multiple disciplines are working day to night to offer proper solutions to reduce the disastrous impact of COVID-19 (Kumar et al., 2020). For instance, Abdel-Basset et al., (2021) proposed an intelligent framework for medical industries which contains the combination of disruptive technologies of Industry 4.0, IoT, AI, blockchain, big data, Virtual Reality, Self-directed Robots, Drone technology to offer a solution to government authorities around the world to manage the loss of current situation. On the other hand, Belhadi et al., (2021) provided insight into the supply chain disciplines and found out that one of the best strategies to reduce the devastating impact of COVID-19 is to employ advanced industry 4.0 technologies. Research has also been conducted regarding the impact of COVID-19 pandemic on employee behavior and their daily activities and it is expressed that applying smart technologies of Industry 4.0 can be useful to manage remote working conditions which are significantly helpful to reduce the harmful effects of COVID-19 (Javaid et al, 2020). Moreover, at the time of COVID-19, organizations have experienced different working cultures such as ‘’work from home’’, ‘’virtual meeting’’ and introducing Industry 4.0 technologies have enhanced the employee’s performance reducing the COVID-19’s complications at the same time (Narayanamurthy & Tortorella, 2021). Similarly, Javaid et al (2020) stated the handful of technologies of industry 4.0 can be implemented in the medical and health care sector to manage and mitigate the complications raised due to outbreak of COVID-19 efficiently. However, there have been lack of research related to the impact of COVID-19 especially in the manufacturing industries of Bangladesh. Consequently, a previous research was found by Hossain, Polas, Rahman, Islam, and Jamadar (2020) which was foucsed to explore the consequences of COVID-19 only in the FMCG industry of Bangladesh. So, this research area has still been kept in the gray zone by the researchers around the world.

Thus, the aim of this literature review was to get acquainted with the key concepts of Industry 4.0, identify the crucial challenges which have been faced by different industries globally. Likewise, from all the review of the literature, it can be observed that a limited amount of literature is studied to detect the challenges, implications, and readiness of industry 4.0 in the manufacturing industry of Bangladesh. Let alone, it was hard to find any research that studies the impact of COVID-19 on the adoption process of industry 4.0 in the manufacturing industries of Bangladesh. Therefore, this research contributes to filling in this literature gap.

2.5 Theoretical Frame of Reference

The two theoretical frameworks are IMPULS Industry 4.0 Readiness Model and Technology-Organization-Environment Framework are explained below for empirical data analysis:

2.5.1 IMPULS Industry 4.0 Readiness Model:

The term Industry 4.0 has become very popular phenomena recently as the innovative technologies used in this industrial revolution have proved to be very fruitful in the manufacturing industries around the world (Yin et al., 2017). But still there are many unanswered questions and uncertainties among manufacturing companies globally regarding implementation of Industry 4.0 technologies in manufacturing plants (Hizam-Hanafiah, Soomro, & Abdullah, 2020). Business organizations need to understand in which state they are currently and what changes they need to adopt to shift from traditional manufacturing to smart industry 4.0 manufacturing process (Sony & Naik, 2019).

In order to solve this uncertainty, industry and academia have been trying to develop different models to evaluate the readiness status of implementing Industry 4.0 technologies in manufacturing companies among which models like 'Industry 4.0 Readiness Evaluation for Manufacturing Enterprises' (2018), 'Industry 4.0 Maturity Model' (2018), Industry 4.0 Readiness Model for Tool Management' (2017), 'IMPULS-Industrie 4.0 Readiness Model' (2015), 'The Connected Enterprise Maturity Model (2014) are well known for their theoretical contributions (Sony & Naik, 2019; Hizam-Hanafiah et al., 2020).

Among the different readiness models available, we have chosen the 'IMPULS-Industrie 4.0 Readiness Model' to analyze our empirical data to answer our first research question. Recent research findings outlined by Hizam-Hanafiah et al., (2020) addresses that most of the readiness models were introduced by academia during 2016 to 2018 for which they are relatively new and emerging and have not been used in the industry significantly. On the other hand, Sony and Naik, (2019) claims that 'IMPULS-Industrie 4.0 Readiness Model' is one of the most renowned industry specific readiness model which have six dimensions for assessment and this model is intended to bring the vision of manufacturing companies closer to the business reality.

IMPULS Industrie 4.0 Readiness Model was introduced in 2015 while the study was sponsored by VDMA, the Mechanical Engineering Industry Association of Germany (Lichtblau, Stich, Bertenrath, Blum, Bleider, Millack, Schmitt, Schmitz, & Schröter, 2015). This study examines the willingness and capacity of companies to implement the concepts of Industry 4.0. This model is based on six dimensions: strategy and organization, smart operations, smart product, smart factory, data driven services and employees and 18 fields under the six dimensions (Sony & Naik, 2019; Lichtblau et al., 2015).

Figure 1: Dimensions and associated fields of Industry 4.0 (Source: Lichtblau et al., 2015).

The inner circle of the aforementioned figure shows the basic dimensions and the outer circle shows the fields associated with the six dimensions of industry 4.0. These six dimensions of Industry 4.0 are analyzed to construct a six-level model for measuring Industry 4.0 readiness of a manufacturing company (Lichtblau et al., 2015). In each of the six readiness levels (0 to 5) companies need to meet the minimum requirements of that level in order to complete the level.

The six readiness levels are described briefly in the followings:

Level 0: Outsider

A company will be determined in the 'Outsider' level if it does not meet any of the requirements for Industry 4.0 (Lichtblau et al., 2015). Companies are automatically assigned to Level 0 that expressed Industry 4.0 was either unknown or irrelevant for them (ibid).

Level 1: Beginner

Companies at this level are involved in Industry 4.0 through pilot initiatives in various departments and have initiated investments in a single area (Lichtblau et al., 2015). Besides, merely a few of the production processes are supported by IT systems, and the present machine and equipment infrastructure only partially fulfils future integration and communications requirements (ibid). In addition, Lichtblau et al., (2015) also stated that system integrated inside information sharing of the company is limited to only few areas at this level. The authors also explained that in this level a company just takes first initiative to make products with IT based add on functionalities and the skills needed by the employees of such organization to expand to Industry 4.0 are also low (ibid). Finally, the IT security solutions of the company are considered still in the planning or implementation phase at this level.

Level 2: Intermediate

According to Lichtblau et al., (2015) a company enters the intermediate level when it incorporates Industry 4.0 into its strategic planning and makes investment relevant to implementation of Industry 4.0 technologies in a few areas. At this level a company also should have integrated in-house information sharing into the system to some extent and should try to take first step towards integrating information sharing with its business partners like suppliers, retailers or customers (Ibid). The authors of this readiness model have also emphasized that in the intermediate level a company should have adopted some technology by which some production data is collected automatically and being used to a limited amount (Lichtblau et al., 2015). In addition, a company should have necessary IT security systems installed and start making products with the first IT based add-on functionalities. However, Lichtblau et al., (2015) stresses that in the intermediate level though a company's employees possess the required technical skills to shift towards Industry 4.0 but their machine and equipment infrastructure still does not meet all the requirements for future expansion.

Level 3: Experienced

According to the 'IMPULS- readiness model of Industry 4.0', a company at this level should have already put together Industry 4.0 strategy, invested on Industry 4.0 related technologies in multiple areas and stimulated the introduction of Industry 4.0 in the company through department-oriented innovation management (Lichtblau et al., 2015). Not only the IT systems should have been linked in production through interfaces but it should also support the production processes, with information collected from key areas automatically (ibid). Along with it, Lichtblau et al., (2015) refers that in the 'Experienced' level, a company should have integrated internal and cross enterprise information sharing partially into their system with data driven services option and also strong IT security solutions should have been implemented to protect data.

Moreover, at this level the equipment infrastructure of a company is ready for an upgrade to aid future expansions. As a result, the company produces their products with numerous interconnected IT-based add-on functionalities (ibid). Furthermore, employees of a company are given adequate training to acquire necessary skill sets to adopt upgraded technologies of Industry 4.0 at this level (Lichtblau et al., 2015). However, though data driven services are adopted in a low margin the company might not be connected with its customers yet at this level for which cloud-based information system should be planned to adopt to generate small amount of revenues initially from data driven services (ibid).

Level 4: Expert

A company enters the 'Expert' level of industry 4.0 readiness when it is running its business operation using an Industry 4.0 strategy and monitoring it with appropriate indicators (Lichtblau et al., 2015). Besides, in an expert company investment have been already done in closely all relevant areas, the processes have been reinforced by interdepartmental innovation management (ibid). As a result, the IT systems of the company should support most of the production processes, collect large amounts of data and able to share these information both internally and with other

business partners like supplier, retailer or customer which is used for business process optimization (Lichtblau et al., 2015).

Moreover, Lichtblau et al., (2015) stresses in their industry 4.0 readiness model that a company can be considered as an expert in adopting Industry 4.0 when the company's IT security system is very responsive to protect its confidential data, IT is scalable by cloud-based solutions, IT supports data driven services which features direct integration between the producer and the customers and that generates a small share of revenues. Furthermore, the employees of an expert organization have the necessary skills to run the IT embedded manufacturing system and have the expertise to expand further towards adopting new technologies of Industry 4.0 (ibid). However, it should be noted that the expert level is the beginning of a company to explore autonomously channeled tasks by machines and self-reacting processes. Not only the work process and the finished product feature IT-based add-on functionalities that allow for essential data collection but also it is utilized to run targeted analysis during the usage phase (Lichtblau et al., 2015).

Level 5: Top Performer

According to Lichtblau et al., (2015) a top performer company has already established enterprise-wide innovation management by following detailed Industry 4.0 strategies in different segments of the company and have plans to invest in other projects. Also, a top performer company should have implemented comprehensive IT support system in its production procedure and automatically collects all the significant data. Moreover, the equipment infrastructure of the company should be designed in such a way that allows system-integrated communications both internally and with business partners. Subsequently, an all-inclusive IT security solution should be maintained, cloud-based solutions should be used to provide a flexible IT architecture (Lichtblau et al., 2015).

Furthermore, a top performer company's technological infrastructure permits it to routinely use autonomously guided work process, remote maintenance and independently reacting processes. Undoubtedly, data driven services for customers are integral part of top performer company while they generate a significant share of revenues and last but not the least a top performer company definitely has the in-house expertise it requires in all critical business operation areas and can move forward with Industry 4.0 (Lichtblau et al., 2015).

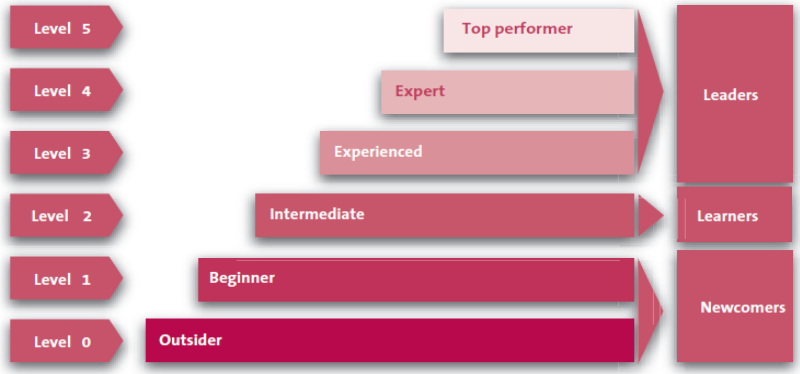

Figure 2: Six Levels of 'IMPULS- Industry 4.0 Readiness Model
(Source: Adopted from Lichtblau et al., 2015)

However, Lichtblau et al., (2015) also proposed that from these six levels of readiness, companies are grouped in three different classes where the first two levels are considered as the "Newcomers", the third level as the "Learners", and the last three levels are deliberated as the "Leaders". This Industry 4.0 readiness model refers to a comprehensive set of impediments that companies need to overcome gradually and also provides guidelines to achieve higher maturity levels (ibid). It is also strongly argued by Lichtblau et al., (2015) that based on the type of business background, companies define their own interim and final goals to implement industry 4.0 technologies.

2.5.2 Technology-Organization-Environment or TOE Framework:

The Technology-Organization-Environment or TOE framework was introduced by Tornatzky and Fleischer (1990) while this theoretical model recognizes three principal contexts which influences the adoption and implementation of a technological innovation within a firm and these contexts are: i) technological context; (ii) organizational context; and (iii) environmental context. We have decided to analyze our empirical data based on this theoretical model and provide answers to research question number 2 and 3 respectively. We have chosen this theoretical model to identify which challenges are faced by organizations on the technological, organizational and environmental context while implementing Industry 4.0 in the manufacturing industries of Bangladesh. Also, we are interested to explore what is the impact of an external environmental factor like COVID-19 on the adoption process of Industry 4.0 technologies in the manufacturing industries of Bangladesh. Thus, this theoretical framework can be comprehended as one of the foundations for the findings and discussion in this research paper.

Previous research outlined by Hoti (2015) stated that there have been an increasing number of studies and theories related to technological innovation and technology adoption among which Theory of Planned Behavior, Unified Theory of Acceptance and Use of technology, Technology Acceptance Model, Diffusion of Innovation and Technology-Organization-Environment framework are noteworthy and have been successfully used for different technology adoption related research purpose over the years. However, Angeles (2014) argues that the Technology Acceptance Model and Unified Theory of Acceptance and Use of technology model are only suitable for predicting adoption factors on an individual level whereas the Diffusion on Innovation model and TOE framework model allows researchers to carry out research related to technology adoption on firm level. Moreover, Alshaikh, Maasher, Bayazed, Saleem, Badri and Fakieh (2021b) refers that the TOE framework can also be used to identify characteristics of innovative concepts affecting their implementation.

As we are interested to conduct research at firm level so we have selected the TOE framework as the basis for our findings and analysis. The purpose to use this theoretical model is twofold, first we are interested to explore the challenges faced to implement innovative Industry 4.0

technologies in the manufacturing industries of Bangladesh and second, we want to identify the impact of COVID-19 on the adoption process of Industry 4.0 technologies in the manufacturing industries of Bangladesh

The technological context comprises the technological boundary which includes both the internal and external technological practices, designs and associated with an organization ((Tornatzky & Fleischer, 1990; Alshaikh et al., 2021b). Again, the organizational context gives concentration on organizational attributes like the organization structure, size and resources that could affect the decision of implementation of innovation, management decisions, and complexity of change, perceived technical capabilities, and employees' attitude towards change and security concerns (Tornatzky & Fleischer, 1990). Lastly, the environmental context includes the surrounding arena of the firm where it runs its business operation, firms' stakeholders such as the competitors, suppliers, government, and customers and how they might drive the firm's need for innovation and new technology implementation (Tornatzky & Fleischer, 1990; Angels 2014). However, the TOE-framework also reflects that the appropriate use of external and internal factors can facilitate an organization's inclination to adopt new technology (Aboelmaged, 2014).

Based on the Technology-Organization-Environment framework developed by (Tornatzky & Fleischer, 1990) we have identified the following challenges that might be faced by a manufacturing firm at organization, technology and environment level while adopting Industry 4.0 technologies.

Challenges	Description
Organizational Context	
Lack of understanding and support from top management (CH1)	The top management of the organization might not understand the benefits of industry 4.0 technologies and be resistant towards the implementation process.
Lack of digital culture (CH2)	The culture of adopting digitization in organization might be a barrier and existing employees might show negative attitude towards change.
High implementation cost (CH3)	Implementing industry 4.0 technologies will require a significant amount of capital investment which might cause financial challenges to an organization.
Lack of trained staff (CH4)	Lack of trained staff is one crucial barrier while adoption of industry 4.0 where an organization might not have the expert employees or get essential training to adapt to new technology.

Complexity of process changes (CH4)	Difficulties can be faced in organizational activities due to changes from traditional process to automation.
Technological Context	
Lack of technological infrastructure (CH5)	Organization might not have the necessary IT facilities, internet connection, machineries and advanced software available to adopt industry 4.0
Lack of technical expertise of employees (CH6)	Existing employees of an organization might not have the technological knowledge of industry 4.0
Time Constraint to adopt new technology (CH7)	The implementation process of industry 4.0 might require time which can cause technical problem in production process.
Cyber security issues (CH8)	Organization can face difficulties in managing confidentiality of necessary information, applications and network due to lacking in cyber security solutions.
Environmental Context	
Lack of support from government (CH9)	Government authority might not have developed any policy to encourage adoption of industry 4.0 technologies for the manufacturing industries. Government authority might not have provided any financial or technological support to the organizations.
Pressure from competitor (CH10)	Pressure from competitor is a very crucial challenge faced by organizations.
Legal uncertainty (CH11)	Legal policy related pressure from government regarding standardization, automation and sustainability can cause difficulties to organizations.
External environmental factors (CH12)	External factors of the environment in which an organization runs its business operation can also incur problems like social and political unrest, industry specific limitations, war, any pandemic crisis situation and employment disruption.

Table 1: Challenges might be faced by organizations while implementing industry 4.0 (Own Illustration based on TOE framework by Tornatzky & Fleischer, 1990).

Chapter 3: Methodology

In this chapter, we have discussed the research philosophy, research approach and research design briefly followed by an elaborative explanation regarding the data collection process, data analysis method, research quality and the ethical considerations adopted. We have also explained all the potential research approaches and methods and provided rationale behind our chosen methods.

3.1 Research Philosophy:

Research philosophy is the term that is related to the development of knowledge, it explains how do we view the social reality and it determines the nature of the knowledge (Saunders, Lewis & Thornhill, 2007). Different authors use different terms like 'ontology and epistemology' (Bryman, 2012), 'objective world and experienced world' (May, 2010) and 'philosophical worldview' (Creswell & Creswell, 2018) for the same purpose which is to explain the philosophy of a research work. According to Saunders, Lewis and Thornhill (2007) any research philosophy that we are interested to follow will contain significant assumptions about the way in which we view the world and these assumptions will eventually become essential factors to determine our research strategy and the methods to conduct the research. Every research study consists of two philosophical considerations; ontological and epistemological considerations (Bryman, 2012). The ontological position is concerned with the nature of reality, the social actors, their actions and perceptions on a certain context and the epistemological position is concerned on how the gathered knowledge in a particular study can be considered as a reliable one (Bryman, 2012).

There are two ontological considerations which are 'Objectivism' and 'Constructionism' according to Bryman (2012) where 'Objectivism' is that ontological position which stresses that social phenomena and their meanings have a presence in social reality which are independent of social actors. So, if we adopt objectivism as an ontological position, it will imply that social phenomena appear to us as external facts which are beyond our hold or influence as it defies the involvement of social actors. On the other hand, 'Constructionism' is that ontological position which opposes the rigid view of objectivism and emphasizes that social phenomena and their meanings are not only being constructed through interactions of the social actors but also are in a spontaneous state of revision (Bryman, 2012). In addition, there are two epistemological considerations, which are 'Positivism' and 'Interpretivism'. Bryman (2012) describes that 'positivism' is an epistemological position which is very scientific in nature, tries to implement the methods of natural sciences to study the different social phenomena and their meanings. On the other hand, 'interpretivism' is another epistemological position which is developed based on the fact that the study of social reality must go beyond empirical and apparently objective evidence and social phenomena and their meanings can be better understandable by interpreting opinions, subjective views, norms, emotions and values of social actors (ibid).

The ontological position of this research study has been determined based on the 'Constructionism' view as the researchers are interested to explore specific social phenomena and their meanings which are simultaneously being constructed and interpreted by social actors. According to Bryman (2012) as social phenomena are continuously constructed by social interactions among the social actors and they are in a persistent state of revision, the researcher following the constructionism research approach will be able to explore different perspectives of the social reality, unlike the definitive one according to the 'objectivism' view. Again, Creswell & Creswell (2018) states that when social constructivist view is followed in a research work it becomes essential to observe the process of social interactions among the participants in specific contexts in which they live and work to understand the cultural and historical settings of the participants. In addition, Creswell & Creswell (2018) also refers that when constructionism approach is adopted in a research work the researchers also become a tool of research where their own background shape their interpretations and they involve themselves in the study in such a way so that they can identify how their interpretations flows from their personal, historical and cultural experiences.

On the other hand, while determining the epistemological position of this study the researchers have adopted the 'Interpretivism' view which is way different from the orthodox positivism view. According to the positivist view research is highly dependent on measurable observations and there should not be any provisions for human interests within the study (Bryman, 2012). That is why when researchers adopt the positivist view their role is restricted to data collection, measurement, and providing interpretations in a very objective way (ibid). But as the researchers are interested to observe social actors, explore their interactions from their perspectives and interpret them to establish knowledge it is necessary to adopt the interpretivism position. According to the interpretivism view knowledge of reality is established spontaneously through an individual's lived experience (Bryman, 2012). Moreover, Creswell & Creswell (2018) states that interpretivism and constructionism are such perspectives that are typically seen as an approach to qualitative research.

3.2 Research Approach:

Based on the ontological and epistemological standpoint mentioned above, a definite research approach has been considered to put light on the methodological process for this research study. There are three research approaches which are deductive, inductive and abductive (Bryman, 2012). According to Bryman (2012) deductive approach is adopted when the researcher is interested to test an existing theory and an inductive approach is adopted when the researcher is interested to develop a new theory. Besides, the deductive approach of research involves deducing a hypothesis based on the existing theory, then the collected data is analyzed, based on the empirical data the hypothesis is either accepted or rejected and if necessary, based on the findings the theory is revised (Saunders et., al. 2007). When there is a need to understand a causal relationship among the variables deductive approach is adopted (Saunders et., al. 2007). Moreover, in order to generalize the results of a deductive approach statistically, there should be sufficient numbers of relevant samples from the total population (ibid).

On the other hand, the inductive approach is more concerned with developing a new theory which starts from finding specific observations to making broad generalizations (Bryman, 2012). Apart from that, inductive approach provides a close understanding of the research issue and involves less concern with the necessity to generalize (Saunders et., al. 2007). However, the third approach is the abductive research approach which has become very popular as it allows to move back and forth between the theory and the empirical data at any given time of the research (Bryman, 2012). Sometimes it becomes hard to follow any specific approach between deductive and inductive as researcher needs to go back and forth between sampling and theoretical reflection to ensure that the research issues are acknowledged properly, empirical data are analyzed accurately on the basis of existing theory to confirm research validity and generalizability and in those situations abductive approach helps to complete the research successfully (ibid).

In this research, we have adopted the abductive approach, as on one hand we have collected the empirical data from the participants through semi-structured interviews and observation but on the other hand we have used some of the existing theories for the analysis of our collected empirical data. In the beginning of the research, we started accumulating the previous literatures related to our research topic 'Industry 4.0', read them thoroughly to explore the relevant topics that emerged from the main topic so that we can relate them for further analysis through existing theories. After the literature review was completed the research gap was clear to us so we developed our research questions with an aim to fulfill the research gap areas. Then we selected existing technology adoption related theories such as 'IMPULS Industry 4.0 Readiness Model' and 'Technology-Organization-Environment' Framework to analyze our empirical data and answer our research questions. We collected empirical data until we reached theoretical saturation. Finally after the analysis of our findings we could answer our research questions and reach the conclusion of our research by generalizing our results. Thus, we actually followed the abductive approach where we merged the process of inductive approach while collecting our empirical data and also adopted the deductive approach to analyze the data using the existing theories to reach conclusions and such process is also referred to as an iterative process by Bryman (2012).

3.3 Research Strategy:

The research strategy gives a general orientation regarding how the overall research will be conducted. The research strategy acts as guideline to a researcher on how to collect and analyze the empirical data either by surveys and experiments or interviews, observations, and document analysis based on the research problem (Bryman, 2012).

There are three types of research strategies which are quantitative, qualitative and mixed method research strategy (Bryman, 2012). According to Creswell & Creswell (2018) a quantitative research strategy involves in testing existing objective theories while scrutinizing the relationship among the variables. In addition, Saunders et., al (2007) states that quantitative research adopts any sort of data collection procedure or data analysis method which uses or generates numerical data. Moreover, Bryman (2012) refers that quantitative research strategy emphasizes quantification while collecting and analyzing the data and generally follows a deductive approach to explain the relationship between theory and the research problem. In a qualitative research

strategy natural scientific research model is followed and the preferred ontological and epistemological considerations are 'objectivism' and 'positivism' accordingly (ibid). Furthermore, survey research and experimental research are the two research designs usually followed while conducting a quantitative research (Creswell & Creswell, 2018).

On the other hand, a qualitative research strategy involves in exploring and understanding the meaning of actions performed by individuals in particular social contexts (Creswell & Creswell, 2018). Again, Saunders et., al (2007) asserts that qualitative research adopts any sort of data collection procedure or data analysis method which uses or generates non-numerical data. In addition, according to Bryman (2012) as qualitative research is involved in generation of theory, inductive approach is adopted while conducting such research. Moreover, the preferred ontological and epistemological considerations are 'constructionism' and 'interpretivism' accordingly in a qualitative research (ibid). Furthermore, narrative research, phenomenological research, ethnography, case study and grounded theory are the different research designs followed commonly while conducting a qualitative research (Creswell & Creswell, 2018).

Subsequently, the third type of research strategy is mixed method strategy which is basically the combination of quantitative and qualitative data collection and analysis techniques (Bryman, 2012). In addition, Creswell & Creswell (2018) state that when quantitative and qualitative research approach is integrated it provides a more comprehensive understanding of the research problem. Consequently, Creswell and Creswell (2018) argue that when quantitative and qualitative database both are adopted then one database can be used to check the validity of the other to enhance research quality.

However, for this research purpose the researchers have adopted the qualitative approach with abductive reasoning as we wanted to understand the current state of implementation of Industry 4.0 technologies in manufacturing industry of Bangladesh, what challenges were faced to implement these technologies and how COVID-19 pandemic has influenced their adoption process. So, a qualitative research approach is adopted as it the most suitable way to answer the research questions of 'what' and 'how'. The research strategy is also aligned with the 'interpretivism' and 'constructionism' research philosophies which have been followed to conduct this research work. The researchers have conducted a qualitative research which involved collecting empirical data through structured observation in different manufacturing plants in Bangladesh and by conducting semi structured interviews with the concerned personnel related to the production process in those manufacturing plants to understand the current scenario of the implementation of Industry 4.0, explore the social opinions of people related to the challenges faced while implementing the technologies and discover the experiences faced during the COVID-19 pandemic.

3.4 Research Design:

Research design illustrates how the research work will be carried out as the research design specifies the research objectives, provides indication on how the researchers are planning to answer the research questions, and clarifies the empirical data collection and analysis methods for

the study (Bryman, 2012). There are different research designs which are experimental design, cross sectional design, longitudinal design, case study and comparative design (ibid).

Firstly, experiments are not very popular as a research design in sociology but sometimes they are used to analyze social psychology or organizational behavior (Bryman, 2012). Secondly, cross sectional designs are also called survey designs which involves structured questionnaires or structured interviews or structured observations to analyze specific social problems at a given period of time (Bryman, 2012). Thirdly, longitudinal studies are just another cross-sectional designs which are conducted for a longer period of time. However, due to the long time frame and the high cost involved with that sort of prolonged research it is not commonly used in social researches (Bryman, 2012). Fourthly, the comparative design involves conducting research with more or less similar methods on two or more distinct cases. It is conducted to make comparison among different cases to get better understanding of similar social phenomena (Bryman, 2012). Finally, in social research different sort of research methods can be found among which case study is one of them. According to Bryman (2012) a case study involves an in-depth research on social concepts regarding a person or a group of people or an organization or a community. We have decided to follow the case study design to conduct this research work.

3.4.1 Case Study Design:

Among the other research design methods, the rationale behind choosing the case study method for this research was to draw broader conclusion from real life social contexts. According to Yin (2009) case studies have been popularly used as a research method in many research fields like sociology, psychology, social work, anthropology, political science, business and economics as it helps to understand complex social phenomena with the benefit from the previous theoretical propositions to guide the process of data collection and analysis. So, we have decided to follow multiple case study method in this research as our aim is to understand the readiness status of industry 4.0 in the manufacturing industries of Bangladesh which is a complex social context, identify the challenges faced while their implementation and the explore the impact of COVID-19 on the adoption process of the industry 4.0 technologies in Bangladesh. Yin (2009) also stresses that the first and most significant condition for choosing the appropriate research design from the different research methods is to classify the type of questions asked for conducting a research and if the research questions start with ‘What’ then it can be considered as an exploratory case study. As our research questions starts with ‘What’ that is why we can state that we have conducted an exploratory case study.

Again, the rationale behind choosing the multiple case study approach was to make the results of this study reliable and generalizable. According to Yin (2009) multiple case studies are often more convincing and for which the overall study can be considered more robust. As we were interested to understand the readiness status of industry 4.0 in the manufacturing industries of Bangladesh, their implementation challenges and also the impact of COVID-19 on the adoption process in the manufacturing industries of Bangladesh it would have been difficult to generalize our results if we would have chosen single case study approach as there are several companies in the manufacturing industry of Bangladesh. Adopting a single case study method was not sufficient to portray the

overall scenario of the manufacturing industries of Bangladesh. However, when multiple case studies are conducted it becomes easier to gather a deeper understanding of the different cases as a unit by comparing similarities and differences of the individual cases which eventually enhances the generalizability of the research findings So in order to ensure validity, generalizability and replicability of the research findings we conducted the multiple case study approach with
Moreover, defining the degree and unit of analysis is also a necessary task while conducting a case study and in regards to that Yin (2009) refers that there are four possible case study designs which are single-case holistic, single-case embedded, multiple-case holistic, and multiple-case embedded, where multiple-case study designs have been recognized as suitable for a variety of social studies. In this regard, Yin (2014) states that the degree of analysis conducted in each case in a research determines whether an embedded or holistic research design should be used.

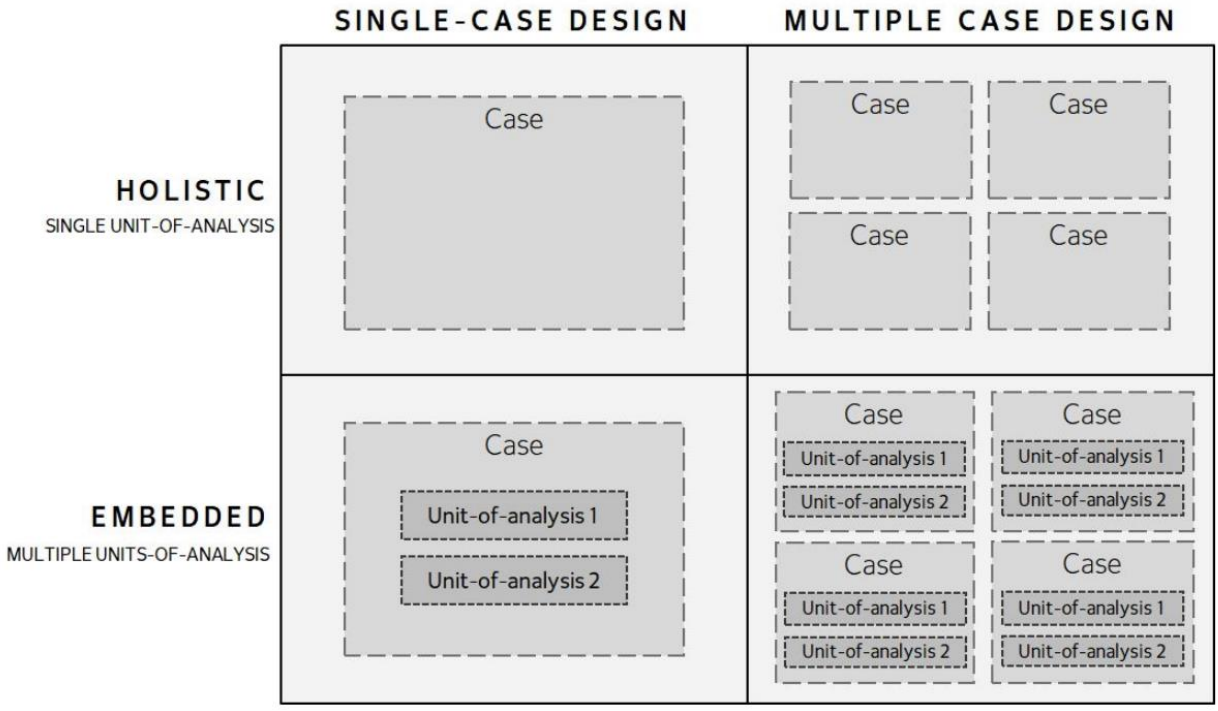

Figure 3: Four different case study designs (Source: Yin, 2009)

From the 2 x 2 matrix figure we can see that there are four types of case designs which are Type 1) single-case (holistic) designs, (Type 2) single-case (embedded) designs, (Type 3) multiple-case (holistic) designs, and (Type 4) multiple-case (embedded) designs (Yin, 2009). As we have multiple units of analysis for each case, we have actually adopted multiple case study with embedded designs. For this research we have selected 15 (fifteen) companies from cement, electrical appliance, food & beverage, automobile, motorcycle, pharmaceuticals, readymade garments, footwear, gas and furniture industries of Bangladesh. Each of the company is considered as single case so total 15 cases will be analyzed for this research in order to give an overall picture

of the manufacturing industries of Bangladesh. The three units of analysis are 1) readiness status of industry 4.0, ii) challenges of implementation of industry 4.0 and iii) impact of COVID-19 on the adoption process in the manufacturing industries of Bangladesh.

Furthermore, Bryman (2012) describes that case study involves triangulation process which includes more than one research methods to collect the empirical data which increases the trustworthiness and ensures credibility of the research findings. Likewise, we also have used semi-structured interviews and factory observation in order to collect our empirical data for each case company. To be precise we have followed a research protocol which was formulated based on the case study protocol criteria by Yin (2009) so that we can maintain a uniform series of tasks which are specially required while conducting multiple case studies. The empirical data collection process will be discussed elaborately in the following section.

3.5 Data Collection:

This research study has taken resort to both primary and secondary data for in depth analysis. We have collected the primary data by conducting a qualitative semi-structured interviews and observation. On the other hand, the secondary data for this research was accumulated through literature review.

3.5.1 Literature Review:

Previous literature related to Industry 4.0 and their relevant topics were sourced to conduct the literature review. The literature review is the basis of secondary data used in this research. The literature review gave us comprehensive knowledge regarding what is currently known regarding Industry 4.0 and its relevant concepts. By conducting the literature review we identified the research gap which helped us to construct our research questions and provided us the theoretical frame of reference for empirical data analysis in the later part of the research.

The literature used in this study was sourced from different data bases which are Lund University's LUBsearch, Springer, Science Direct, EBSCOhost, Elsevier, Emerald Insight and Google Scholar. Several key words and phrases like "Industry 4.0'', "Challenges of Industry 4.0 implementation'', "COVID-19 and Industry 4.0'' and "Industry 4.0 in Bangladesh" were used to search the previous studies in the data bases. Articles which included explicit discussion based on the concepts and methods relating to Industry 4.0 were put in the inclusion criteria. Many articles were seen from which only the articles written in English language were selected primarily. Further refinement was done by reading the abstracts, concepts and methodology and unpublished papers were removed. Besides that, while reading through the articles additional relevant papers were also included. Finally, the literature review provided us the background knowledge of the key concepts of Industry 4.0, the evolution of Industry 4.0, the applications of Industry 4.0 around the world, the barriers of adopting industry 4.0 globally specially in the developing nations and the application of Industry 4.0 during the COVID-19 era.

3.5.2 Sampling Technique:

We have followed generic purposive sampling method while selecting the participants for conducting the semi-structured interviews. According to Bryman (2012), purposive sampling is a

strategic way of non-probability sampling which involves the selection of participant samples who are highly relevant to the research topic and capable of sharing insights leading to answering the research questions. There are three types of purposive sampling which are theoretical sampling, generic purposive sampling and snowball sampling among them we have chosen the generic purposive sampling as this technique involves sampling of participants purposely with relation to the research topic but without having the intention to generate any theory or theoretical categories like the theoretical sampling. On the other hand, snowball sampling is also avoided as it involves selection of a small group relevant to the research questions and these participants of the group propose others to participate due to their characteristics or experience. Rather, based on our each case company decided earlier, we have selected our interview participants in those companies based on their job positions and industry knowledge related to the manufacturing process. As our research topic is a very significant one involving the 'Industry 4.0' technologies in the manufacturing process, we have selected our sample participants who have specific technical knowledge related to their manufacturing process and their relevant industries and could share their insights and experiences which is helpful to provide answers of our research questions.

3.5.3 Designing Semi-Structured Interviews:

There are different interview techniques which are structured interviews, semi-structured interviews, unstructured interviews, group interviews and focus groups.

Structured interviews are also called standardized interview where the interview schedule is fixed by the interviewer and all the interviewees are given the same types of closed end questions so that a similar type of aggregated response regarding a specific social context can be understood (Bryman, 2012). In such interviews the sequence of questions are even fixed and these interviews are conducted in typical survey research (ibid).

According to Bryman (2012) unstructured interviews are very casual way of taking an interview which can be very similar to a mere conversation where the researcher just uses an aide-mémoire as a brief set of key points to carry out the discussion with the interviewee. In unstructured interview the researcher might ask the interviewee a single question and then the interviewee speaks freely about the topic and the interviewer just follows up the conversation and keeps note of the key points of discussion (ibid).

Moreover, Bryman (2012) states that when researchers conduct semi-structured interviews, they generally use an interview guide which includes a series of questions covering all the topics of the study. In semi-structured interviews the interviewer is not bound to follow the sequence while asking the questions from interview guide and the interviewee can also be relaxed while replying. Even questions which are not included in the interview guide can also be asked by the interviewer if the interviewee brings up any such discussion. But even in semi-structured interview the interviewer is supposed to ask all the questions in the interview guide with the similar wording to the interviewee (Bryman, 2012). May (2010) refers that if the interviewer requires both clarification and elaboration of the qualitative information, he or she can record the interview session as well for further analysis.

Furthermore, group interviews and focus groups are also popular research tools which allows researcher to investigate and understand the group norms and dynamics regarding the research topic (May, 2010). The core difference between group interviews and focus groups is that in focus groups participants are more encouraged to participate and share their views explicitly to each other unlike the group interviews (ibid).

The empirical data for this research has been sourced by conducting semi-structured interviews with the concerned personnel related to the manufacturing process of each company and through structured observation made in the official visits in the manufacturing plants of those companies. We developed an interview guide for conducting the semi structured interviews. According to Bryman (2012) an interview guide should be prepared in such way where the order of questions should come as a spontaneous flow related to the topic, the language of questions should be very clear based on the understanding level of the respondent and list those questions in the guide which should provide answers to our research questions and we tried to develop our research questions accordingly. Additionally, we have also run two pilot tests where we pre-tested our interview questions before conducting the semi-structured interviews with the industry experts. Conducting the pilot test proved very useful to us as we realized that some of the terms that we used in our questions were hard to understand, some of the terms created confusions and some question's answers might come based on hypothetical assumptions. Moreover, we tried to identify which questions required additional instructions for better understanding and was there any question which made the respondent uncomfortable. Thus, we made changes to our final interview guide based on the findings that we found from the pilot tests. Lastly, the pilot test provided us confidence which helped us to conduct the semi-structured interviews with the industry experts successfully.

3.5.4 Conducting Semi Structured Interviews:

In order to collect the empirical data for this study we have conducted a total of 10 semi structured interviews. When a semi structured interview is conducted it allows the participants to go beyond the set questions unlike the structured interviews. In a structured interview there are closed ended questions which require specific answers but in semi structured interviews the participants get the flexibility to add more to their answers and can discuss other relevant topics regarding the specific research topic (Bryman, 2012). A set of questions which is also known as interview guide was developed to understand the different aspects of the research questions from the participant's point of view. This interview guide was prepared in an easy language so that interviewees can easily understand the questions and it included all the relevant questions required to answer the research questions. Subsequently, while taking the interview we made sure to ask 'facesheet' information like their name and specific information like the name of the company they worked for and their position in that company in order to contextualizing participant's answers.

Besides, as this research was carried out during the COVID-19 pandemic and everyone is advised to maintain social distances to ensure their safety, we conducted all the interviews digitally using the Zoom platform and mobile phone. In the beginning of the interview, we made rapport with the

participant by stating our research topic and the purpose to carry out this study with them. Then we asked for their consent to record the interview session. Zoom has a built-in recording option which was used to record the interview sessions. When they gave their consent, we started asking the questions from the interview guide. Lastly, after the interview sessions were transcribed successfully, we deleted the recordings in order to ensure safety of the information shared by the participants.

For this research, we have conducted 10 semi-structured interviews with participants mentioned in the following:

Code	Company	Position in the Company	Industry	Interview Date	Duration	Mode
Interviewee 1	Company 'A'	Mechanical Engineer (Production & Maintenance)	Cement	6 April, 2021	57 minutes	Zoom
Interviewee 2	Company 'B'	Senior Additional Director (Project Management)	Electrical & Electronics Appliances	14 April, 2021	66 minutes	Zoom
Interviewee 3	Company 'C'	Chief Technical Officer	Electrical & Electronics Appliances	19 April, 2021	63 minutes	Zoom
Interviewee 4	Company 'D'	Assistant Engineer (Production)	Food & Beverage	27 April, 2021	72 minutes	Zoom
Interviewee 5	Company 'E'	Assistant General Manager (Production)	FMCG	5 May, 2021	59 minutes	Mobile Recorder
Interviewee 6	Company 'F'	Head of Production	Automotive	12 May, 2021	64 minutes	Zoom
Interviewee 7	Company 'G'	Senior Executive (Production)	Pharmaceuticals	3 June, 2021	52 minutes	Zoom
Interviewee 8	Company 'H'	Team Head (Merchandizing)	Readymade Garments	10 June, 2021	58 minutes	Mobile Recorder
Interviewee 9	Company 'I'	Assistant Manager	Footwear	14 June, 2021	76 minutes	Zoom
Interviewee 10	Company 'J'	Assistant Manager (SCM)	Furniture	23 June, 2021	55 minutes	Zoom

Table 2: Semi-structured interviewee particulars

3.5.5 Observation:

We also conducted non-participant observation in the different manufacturing companies from where we took the interviews to validate their information. We went to visit their manufacturing plants with prior permission from them. So, we followed an overt observation technique. We observed their manufacturing process assisted by one of their employees related to the production and quality control process, witnessed which technologies are used in their manufacturing process and tried to understand how COVID-19 has impacted their production process. To be precise, we collected our data as a complete observer while focusing on the central aspects that are relevant to our research questions. According to May (2010) when observation is focused on the core aspects related to the research questions, it can be considered as focused observation technique.

We took field notes while observing the manufacturing process of the different companies and took pictures of the technologies and machines used in the production process with prior permission from the authority. We conducted our observation process until theoretical saturation has been reached which means we conducted until that time after which the observation did not provide any further knowledge (May, 2010). By conducting the non-participant observation in the same companies besides the semi-structured interviews, we could cross-check, match and validate the information collected from the interview sessions which also enhanced the reliability of our study eventually.

3.6 Data Analysis Method:

According to Bryman (2012), the goal of the data analysis phase is to minimize the massive volume of acquired data and make it more relevant and comprehensive. Data analysis is required to seek patterns and draw preliminary conclusions from the categorized findings. We have taken several steps to analyze our data. In order to find the research gap, we have conducted literature review and determined our theoretical framework to analyze our empirical data collected through semi-structured interviews and factory observations. Our aim was to identify the readiness status of Industry 4.0 in the manufacturing industries of Bangladesh, the challenges of implementing these technologies and scrutinize the impacts of COVID-19 on the adoption process.

A case study protocol was prepared where we stated our research purpose, research questions and added the interview questions relevant to the study. Then the interviews were conducted and transcribed. Afterwards, the interviews were coded. We also took field notes and photographs from the factory observations with prior permission. These data from the factory observations were later coded and categorized. Finally, all of these data were recorded into the findings section and analyzed to answer the research questions and draw our conclusion.

3.7 Research Quality:

In order to maintain the quality of the research work and avoid biases, researchers need to ensure the validity, reliability, generalizability and reliability of a research work (Bryman, 2012). In order to construct research validity Yin (2009) has suggested using multiple sources of evidence. In this research work, we have conducted semi-structured interviews with industry experts and

participated in structured observation in those same organizations' factories to construct validity of our empirical data. The data which have been collected from the semi-structured interviews have been cross-checked by conducting observation in the factories. Again, Yin (2009) states that reliability of a research work can be ensured if the results and findings become identical even if the research is conducted again with same procedures at a later time. For this research work we have ensured reliability of our empirical findings as we have designed a case study protocol that includes all the relevant steps taken to collect our empirical data. We have conducted literature review to identify the research gap, then based on that we selected our theories to analyze our empirical data, based on the theories we prepared our interview guide, then when interview was conducted it was recorded with prior permission from the respondent and then the interviews have been transcribed and coded for further analysis. We have also taken field notes and pictures while conducting our observation with necessary permission from the authority. So, we believe that the data we have presented for this research is trustworthy and reliable. If someone wants to carry out the same research by following our protocol then our study can be replicated as well at a later time. Moreover, we have conducted multiple case studies with embedded units which provides replication logic to our empirical findings. As we have conducted multiple case studies on the different manufacturing companies of Bangladesh our research findings can be highly generalizable as it provides overall picture of the manufacturing industries of Bangladesh.
Thus, we can state that the research quality is ensured through constructing validity, reliability, generalizability and replication.

3.8 Ethical Considerations:

To ensure the integrity of research and to protect study participants, ethical considerations are essential (Bryman, 2012). In order to conduct a reliable and valid research work some ethical considerations have been fulfilled. Firstly, proper consent was asked from the participants to conduct the semi structured interviews. The participants were briefed about the research purpose and asked for their permission to record their interviews. Secondly, in order to avoid invasion of privacy the participants were allowed to keep their identity anonymous. Thirdly, to avoid deception the participants were informed that the empirical data collected from their interviews and observations will be solely used for research purpose and not for any other issues and their personal data will be preserved as strictly confidential among the researchers only. Finally, proper assurance was given to the respective participants that after the transcription of the interview was done the recordings were deleted permanently.

Chapter 4: Analysis of Findings

4.1 Case 1: Company 'A'

For over 15 years, Company 'A' has been Bangladesh's most popular cement brand. It is one of Bangladesh's largest group of companies. During the first year of its debut, the brand became the market leader, and it has maintained that position every year thereafter. Most private house builders as well as big construction projects in the country prefer this company's cement.

Company 'A' now owns the world's largest vertical roller mill. The World's Largest Cement Vertical Roller Mill facility was acknowledged by Guinness World Records as the World's Single Largest Cement Vertical Roller Mill facility.

Industry 4.0 readiness status of Company 'A':

Through the semi-structured interview with Interviewee 1, we learned that the company has adopted some of the technologies of the Fourth Industrial Revolution in the production process, including SCADA, automation and recording business intelligence. Models, including strategy and organization, smart operations, smart products, data-driven employees, and services, evaluate their readiness through semi-structured interviews. During our visit to the Company 'A' factory, we also confirmed the information collected in the semi-structured interviews.

According to Lichtblau et al., (2015), the strategy and organization aspect of the readiness model focuses on strategy, investment, and innovation management. This company has made considerable strategic and organizational growth, having effectively adopted industry 4.0 technology adoption strategies into their manufacturing processes, as well as investing in the manufacturing process, infrastructure, and human resources. This company also has its own Research and Development department, which ensures that good innovation management is implemented throughout the business.

The interviewee #1 mentioned their view as below:

Yes, we are currently using SCADA to control and maintain efficiency. We are using Oracle to track our finances, and we are using Record Business Intelligence to track our inventory, forecast our needs, our spare parts, etc. /---/ Our top management always welcomes new technology. They want to keep up with the market and they make contact with a supplier across the world to collect new types of equipment for the plants. /---/ Yeah, our higher management has to invest to acquire these IT technologies for the manufacturing process. (Interviewee #1)

Furthermore, according to Lichtblau et al., (2015), the smart product component of the readiness model focuses on ICT add-on functionalities and data analytics in the consumption phase. We found that Company 'A' records business intelligence to track their inventory and forecast needs. Their plant is connected through internet.

Yes, the entire system is connected with internal internet & grinding system. If I put or change something in one place, the entire system changes according to it. (Interviewee #1)

From the factory observation, we have seen their automated grinding process controlled by SCADA Interface and cloud-based manufacturing.

Figure 4: Cement grinding machine

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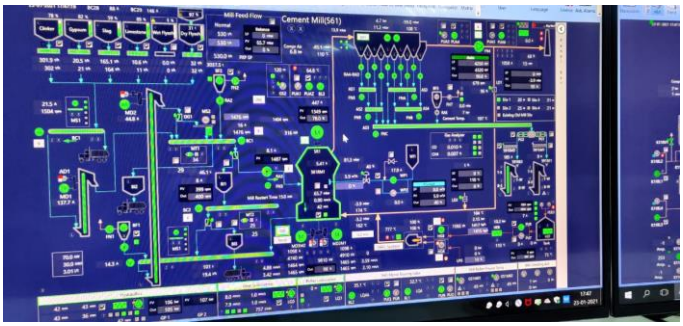

Figure 5: SCADA Interface

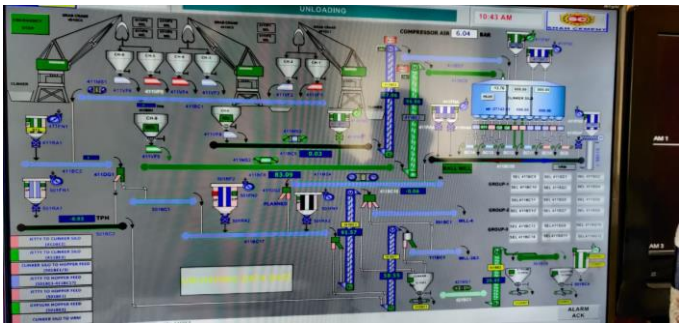

Figure 6: Cloud-based manufacturing

Furthermore, the readiness model's smart operations dimension focuses on the adoption of information sharing, autonomous processes, IT security, and cloud utilization (Lichtblau et al., 2015). This company uses a cloud-based information system to share information across departments, with some machines having autonomous and remote functionality. They have a secured IT system and anti-virus to protect the confidential information about their manufacturing process. The interviewee #1 stated:

Yes, we have several machines that can do this. One might be the packing machine that can pack ready cement autonomously. /---/ Yeah, we can. Our whole system is controlled remotely. We can

change the parameters in the grinding unit from distance. I can say this also about the RPM in machines. Then I can, as I have told you earlier that we have lots of raw materials, these cannot be controlled remotely. /---/ Yes, use the latest anti-virus and security software all over our plant and we update this software very often. (Interviewee 1)

According to Lichtblau et al., the areas that are considered when assessing the ´smart factory' dimension of the readiness model are equipment infrastructure, IT systems, data utilization, and digital modeling (Lichtblau et al., 2015). Keeping this in mind, we discovered that this company has an excellent infrastructure to manufacture quality cement in their plant. Their factory is well-connected via the internet and a cloud-based system and they have a comprehensive website that informs stakeholders about their products and company although they do not sell through the website.

It is also worth mentioning that we discovered a well-organized equipment infrastructure in their manufacturing facility during our visit. During the manufacturing process, various interconnected machines, robotics technology, and multiple layers of conveyers were used to move products from one step to the next.

Furthermore, data-driven services are an important component of Lichtblau et al., (2015)'s readiness model, which focuses on data-driven services, data utilization, and revenue distribution. We discovered during our interview that this company shares a small amount of data about its manufacturing process with his stakeholders.

The final dimension of the readiness model is 'employees,' which is defined by the degree of available employee skill sets as well as the company's skill acquisition timeframe (Lichtblau et al., 2015). According to the interview, almost all of the employees received training to learn how to operate and maintain all of the necessary industry 4.0 tools and mechanisms. Occasionally, they might well hire new employees to fill the vacancy. The interviewee #1 mentioned:

Yes, they have the required expertise to operate all the software and hardware in the facility. /---/ It depends, sometimes we recruit new employees but most of the time we try to give training to our existing employees in the organization for their personal growth and efficiency. /---/ We usually have one month of training for every new technology that we acquire. But for special cases, we increase time to give them the best chance to deal with the changes. (Interviewee #1)

Based on the earlier section, we can conclude that this company has incorporated industry 4.0 into its strategic orientations. In addition, a significant amount of money has been invested in a few areas of the business. Moreover, cloud sharing allows for automated data collection. There are also IT solutions and security available. According to the readiness model proposed by Lichtblau et al., (2015), this company falls into the ‘Intermediate' category.

Challenges of Industry 4.0 implementation in Company ‘A’:

Using Tornatzky and Fleischer's (1990) Technology-Organization-Environment framework, we tried to investigate what obstacles this company encountered at the organizational, technological, and environmental levels when introducing industry 4.0 technology in the production process. It was discovered that they did face some difficulties at the organizational level. According to Tornatzky and Fleischer's (1990) they did not face any challenge regarding support from their top management, lack of trained stuffs or complexity of process changes. But they faced challenge of high implementation cost as the Interviewee #1 mentioned that huge investment cost of the machines was the most difficult challenge faced by them. When asked about the challenges of the financial side of the business, the interviewee #1 stated:

Yeah, we have. These new technologies are often very expensive, management had to spend a lot of money on the system. /--/ Our top management always welcomes new technology. They want to keep up with the market and they make contact with a supplier across the world to collect new types of equipment for the plants. According to our management, the huge investment cost required to importing the latest machines from abroad is the most difficult challenge. (Interviewee #1)

Again, from the semi-structured interview conducted with Interviewee #1 we realized that the existing technological infrastructure is good enough to adopt new technologies of Industry 4.0, they also have well trained employees who have technical expertise to control the IT embedded manufacturing system. But they faced difficulties in establishing this technological infrastructure because their technologies had to be imported from abroad, which is difficult to obtain without good international connections and political power. However, thanks to the initiative of upper management, they were able to overcome this. According to the interviewee, the following technological barrier was expressed:

Yes, we import all of our technologies from abroad. Sometimes the local company helps us to install or repair it. Actually, it was difficult to find a good supplier for the new technology. Sometimes it is difficult for a 3rd world country like us to get the latest technology even though you have enough money to buy it for some bureaucracy or political reason. (Interviewee #1)

Apart from that, they also had to deal with environmental factors like competition, government regulatory organizations, and other external concerns like the COVID-19 pandemic. According to the respondent, they are constantly under pressure from their competitors, but the government has encouraged them to implement new technology. The interviewee #1 responded to the threat of competitors and government, technological, or financial assistance and impact of COVID-19 as follows:

Most of the time we try to adopt new tech as soon as possible before our competitor can manage it. But yes, if we do not have some tech but our competitor has it, we feel pressure. /---/ No, we have not. Our government is very helpful and encourages us to import, adopt new technologies.

/---/ Yes, it was hampered in the beginning but not that much. Now we have taken some action and minimized our loss. (Interviewee #1)

To summarize, significant financial, technological and environmental challenges existed in Company 'A', but they also had tools to address these challenges.

Impact of COVID-19 in the adoption process of Industry 4.0 in Company 'A':
The COVID-19 pandemic, according to Tornatzky and Fleischer's (1990) TOE framework, can be considered as an external environmental factor that has a negative impact on the production process of Company 'A'. The respondent also stated that they did not implement any new Industry 4.0 technology during the pandemic. But they intend to implement more tech in the post-COVID-19 era. When asked about the impact of automation on unemployment, the interviewee #1 stated:
We are already running low on skilled manpower; we would need a lot of people in near future. So, I do not think this would be an issue. /---/ Yes, now we have a signature or fingerprint as attendance in our plant, but management is trying to implement a new system where the employee will be able to sign with their smart ID card. (Interviewee #1)

As a result, we can conclude that COVID-19 has a negative impact on the production of companies such as Company 'A'. This company did not adopt any new technology during the pandemic but they have plan to continue to automate and adapt to Industry 4.0 in order to maximize profits and minimize future losses due to a pandemic.

4.2 Case 2: Company 'B'

Company 'B' is the forerunners in implementing automation among Bangladeshi industries. Based in Gazipur, Bangladesh, they produce freezers, refrigerators, motorcycles, air conditioners and televisions. They also manufacture smartphones in their Digi-Tech subsidiary but the research doesn't include that sector.

Industry 4.0 readiness status of Company 'B':
The semi structured interview was conducted with Interviewee #2 who is an Additional Senior Director of the organization. He has provided significant insights into the company and how they are dealing with Industry 4.0 technologies. They use a wide variety of technologies like Cloud Manufacturing & Robotics along with CNC machines, 3-D scanners etc. Their factories are connected through internet. All 49 departments of their organization use ERP modules to exchange information. The purpose of using these Industry 4.0 technologies was to get more real-time data and better quality control. So, Company 'B' fit into the profiles of Smart Organization.
This company has implemented industry 4.0 technologies in their strategic orientation. They have highly invested in different areas of their production process to produce high quality smart

electrical appliances and they also have their dedicated R&D department to add value not only to their products but also their manufacturing process. Thus, according to Lichtblau et al., (2015) this company has good hold in the strategy and organization dimension of the readiness model. The Interviewee puts this information as the followings:

We are using cloud manufacturing systems and industrial robotics, especially in the hazardous areas. And we use 3-D scanner, also called Coordinate Measuring Machine (CMM). Moreover, we have 7/8 CNC machines in one cell which is Computerized Numerical Control, connected through bus topology system. /---/ We have 21 buildings and all of them are connected internally though optical fibers. /---/ We have 49 departments and each department customizes their own ERP module as per need. All departments can share data from the main database. /---/ Industry 4.0 technologies are a must for quality control. We also use these for data analysis, enterprise resource planning, you know, to get real-time data. (Interviewee #2)

The next dimensions are Smart Operations & Smart Products according to Lichtblau et al., (2015) and we have witnessed from the factory observation that the factories of this organization have their internal cloud-system that is used to control the operation systematically. Besides that, all of the machines respond to digital instructions. They have automated error identifying system and the capability to control machines from distance. Despite not having fully autonomous system, their factory runs automatically with preprogrammed machines. They have ERP systems to track inventory and they have been using Barcode & RFID system in all of their products. The interviewee shares his insights regarding their smart operation and smart products according to the following:

All sets of machines use cloud system to convey information regardless of their dissimilarity. We direct them through control panels. /---/ Our CNC machines are interconnected and if something goes wrong, one machine instructs the other that the machines were unable to do an operation. /---/ Our robotics can perform autonomously but coding is prerequisite, so not fully autonomous in this regard. /---/ We can track them by ERP systems. But we do not have automated inventory control. /---/ We have been using barcodes for 8 years. If any fault occurs in the factory, we use the barcode system to identify which machine is producing the defective product. Now we are using RFID sensors for 2 years. /---/ As we use automated technologies, human involvement has decreased along with chances of error. Consequently, the conversion cost is very low. (Interviewee #2)

Moving on to Data-Driven services, they have a complete IT system as mentioned above. Additionally, they have their own server and bought database from Oracle while the database is protected by a security system. Their IT department monitors ERP modules, cloud-based production, data sharing, product & inventory tracking etc. These employees are given training every month to efficiently handle the IT department.

We now have our very own server and we bought database from Oracle. /---/ We have a security system for our servers and it keeps data safe. /---/ We are continuously developing our IT system

and for that, every month, a training program is held to develop the employees' expertise on using technologies. (Interviewee #2)

Lastly, the have their own website from which customers can view products and buy them online. So, they have also advanced in managing data driven devices and they are earning revenue from that. According to Lichtblau et al., (2015) a company need to adopt data driven services dimension in order to advance in the process of industry 4.0 adoption and this company has performed well in this dimension. Moreover, the top management believes that machines and technologies are very crucial to the manufacturing process. That's why the employees are given 25-26 hours of training every month. They are still expanding their workforce and training them to stay updated. Based on this we can also state that this company has also progressed in the employee dimension of the readiness model stated by Lichtblau et al., (2015). The interviewee #2 shared the following information:

Our top management is very clear about using technology in any opportunity. Because they believe humans might not comply exactly the way they want. But machines technologies will not deviate from their instruction. /---/ It depends on what technology are we introducing and the capabilities of the trainers and learners. We provide training for 25-26 hours per month and that is enough. /---/ We hire employees regularly and train them every month. (Interviewee ##)

Thus, according to the above discussion we have seen that this company has a good strategy to implement Industry 4.0 technologies in various departments of the organization for which they have invested heftily, they are using CNC technology, robotics technology, cloud-based manufacturing for their smart products and good IT solutions to secure data. Moreover, they have implemented data driven services to communicate with their customers and they are earning a good amount of revenue through it. Though they have skilled employees to run their smart production operation still they do not have autonomous process yet. Based on all these advancements, this company fall into the 'Intermediate' level according to the readiness model of Lichtblau et al., (2015).

Challenges of Industry 4.0 implementation in Company 'B':

Among the organizational challenges, Company 'B' regards the financial challenge as the crucial barrier. The investment on these Industry 4.0 technologies that they have implemented are too high but they have gained their return on investment over the years. And with their training programs, the employees adapt to these technologies very easily so they do not have problem regarding lack of trained stuff. Their management have been enthusiast in implementing latest technologies in order to stay ahead of their competitors.

In these IT systems, the initial investment is very high. But we do get the return over time. That's why we are constantly investing in new technologies. /---/ Our top management is very clear about using technology in any opportunity. Because they believe humans might not comply

exactly the way they want. But machines only know 1 and 0. And surely, machines and technologies will not deviate from their instruction. So, our top management inspire and appreciates the implementation of technology. (Interviewee #2)

Apart from that, they did not face any major technological challenge regarding lack of technical expertise, time constraints or cyber security issues in their production process but they feel that they have lacking in technological infrastructure as these technologies are mostly not available locally in Bangladesh. The interviewee quotes as follows:

A decade ago, broadband internet was the prime concern due to its lack of availability. But things have changed now. Implementing a new technology can be challenging in terms of finance and utilization. /---/ Most of the machines and IT systems are imported from Japan and Germany, even India also. (Interviewee #2)

However, regarding the environmental challenges the Interviewee #2 explained that they are the pioneers in using these technologies and they are constantly on top in the market so they do not feel that much pressure from their competitors. Moreover, the government has improved the company's infrastructure and facilities notably with a view to digitizing the country and that has provided remarkable advantage to the organization. But they faced problem in their production process due to the outbreak of COVID-19 which is an important environmental factor explained by (Tornatzky & Fleischer, 1990). The interviewee shares the following information regarding challenges from environmental context:

We did not yet feel any pressure from our competitors because they are not very familiar with these technologies. And we are continuously adopting new technologies so that we stay first in using them. /---/ The government of this term came in power with a commitment to turn Bangladesh into a digital country. So, they have improved a lot of infrastructure and facilities that have proven to be very helpful for us. /---/ Yes. Our production was hampered due to COVID-19 pandemic. (Interviewee #2)

So, it is evident that Company 'B' did not face any major throwback in terms of implementing Industry 4.0 technologies apart from the capital investment on these IT systems and machineries.

Impact of COVID-19 in the adoption process of Industry 4.0 in Company 'B':

Interviewee #2 described the COVID-19 situation as a lesson to be learned. Their production lines, especially the refrigerator sector, had faced a major drop due to lack of human touch. But they quickly adapted due to pre-obtained Industry 4.0 technologies that were not installed in the plants before the pandemic. They have shifted to virtual meetings, digital workspace, less human interaction and installed the automated machines mentioned above.

COVID-19 made us realize the importance of IT systems. /---/ Our main product is refrigerators and they require human touch. In the assembly lines of other products too, lack of human resources has hampered production greatly. /---/ We already had some automated machines that were not installed in the plants. But suddenly came COVID-19 and we deployed them in the manufacturing process. /---/ We have LED screens in every work cell and we use platforms like Zoom & Microsoft Virtual Workspace to communicate with the operators for instruction and supervision. /---/ In the plants, we are heavily dependent on cloud-based machineries due to the lack of human resources. (Interviewee #2)

Furthermore, they have plans to install more technologies in the post COVID-19 scenario with a view to implementing fully autonomous machines. And they will resort to newer ventures if any unemployment issue arises due to the automation process. Interviewee #2 also hinted at the possibility of three new projects under consideration at the moment.

Crisis doesn't come knocking at the door. And we plan to invest more on IT systems and some autonomous machineries. /---/ Our top management says that automation will reduce cost and time, which we will use for newer ventures. These employees, replaced by machines, will be transferred there. /---/ I have seen a lot of human rights activists complaining about the unemployment situation due to automation. /---/ We are actually working on launching 3 new projects and we need employees to run them. (Interviewee #2)

Thus, this company adopted Industry 4.0 technologies during the pandemic and is ready to take on the challenges of future expansion in regard to industry 4.0 in the coming years.

4.3 Case 3: Company 'C'

Company 'C' is one of Bangladesh's major industrial companies and a pioneer in consumer electronics product in Bangladesh.

Industry 4.0 readiness status of Company 'C':

From the semi structured interview conducted with Interviewee# 3 we got the idea that this company has implemented few technologies of the fourth industrial revolution in their production process among which IoT, CPS, cloud-based manufacturing and robotics are significant. According to the semi structure interview conducted with Interviewee #3 we understood that this company assembles refrigerators, televisions, washing machines, air conditioners and other home appliances of international trademarks like Samsung, Sony, Toshiba etc. Starting off with importing parts from Toshiba Corporation, Japan, Company 'C' have significantly improved their business strategy. They have adopted some of the fourth industrial revolutionary technologies to maintain market demand and compete against similar manufacturing companies.

According to the strategy and organization dimension stated by Lichtblau et al., (2015) a company need to have a strategy to adopt industry 4.0 technology, invested in one of the areas and should have innovation management. This company has established strategy to implement several technologies to help them produce large volumes of products in shorter periods. It was possible due to high investment to develop a cyber-physical infrastructure but they still do not have any R&D department for innovation management. The interviewee #3 puts this as follows:

As we produce electronics appliances, we have robotic arms to help make our products and we also use cloud manufacturing technology in the production process. /---/ There are some big companies in this industry who have started to implement latest technologies in their production process. So, to capture the demand in the market our management has decided to introduce some latest technologies of industry 4.0. /---/ No, we do not have any sort of R&D department. *(Interviewee #3)*

From the factory observation, we have seen the robotic arms, COMI machines and automated Thermoforming machines.

Figure 7: Robotic Arm

Figure 8: COMI Machine

Figure 9: Performance Testing Line

Figure 10: Thermoforming Machine

Lichtblau et al., (2015) states that in order to have a smart factory a company should have good IT systems, equipment infrastructure, data usage and digital modeling. We have seen form the factory observation that their manufacturing plants are equipped with internet to connect machines and operations. They have multiple automate machines like COMI Thermoforming machines, CNC bending stations & machines, laser cutting machines etc. that can perform tasks with digital instructions and convey information in the production lines. However, these machines need preprogramming, so they cannot not operate autonomously. For inventory, they use ERP modules to track materials. For product tracking, they use sensors in all of their products

Our manufacturing plant have internet connection and different machines and robotic arms are connected and operated through internet. /---/ Yes, we have COMI Thermoforming machines, bending machines, laser cutting machines, CNC bending station and few robotic arms which are linked with computer programming and communicate information and pass the product from one segment to another segment in the production line. /---/ We can track movement of inventory materials using our ERP system. /---/ As we produce electrical appliances, our products carry sensors by which they are tracked in different stages of production line. (Interviewee #3)

Company 'C' has also performed well to meet the criteria of smart operation as described by Lichtblau et al., (2015) because this company stores production plans and other relevant data in their cloud servers while their cloud manufacturing system helps them forecast production & wastage, conserving time & raw materials. These valuable data and technologies are safeguarded by their File & Mail Tertiary Backup System. Additionally, this system provides cyber-protection to the database, duplicates files in backup cloud storage and prevents virus attacks. They also use SAP-ERP systems to communicate among different departments in the organization. The interviewee shared the following information with regards to smart operation:

We have cloud manufacturing system. We have stored our production plan in cloud and we can see the inventory of raw materials available for production and make changes during production timeline using software to reduce production time and wastage. /---/ Our IT security system had to be very safe as there are lot of information regarding our inventory materials and finished products available in the ERP system and Cloud. So, in order to keep all our data safe, we have automated File & Mail Tertiary Backup system. /---/ We use the SAP- ERP system which is used to share information among the different departments (Interviewee #3)

Furthermore, Interviewee #3 has shared his professional experience with us. Originated from India, he was hired by Company 'C' to supervise the inclusion of latest technologies into the company. He also provided training to the existing employees during their 6 months long probation for technological adaptability. This training periods result in employees capable of operating the new technologies. They have about 460 official personnel altogether and they are all positive regarding the adoption of Industry 4.0 technologies. The board of directors aspire to see Company 'C' as

market leaders in electrical appliance industry here. And they constantly developing to achieve that.

Well, I can talk about myself actually. I am originally from India and I was recruited by the company to manage the latest technologies in the production system. /---/ I along with the existing engineers provided training to the current employees to get them acquainted with the new IT embedded manufacturing system. /---/ There are approximately 460 employees including management and non-management employees. (Interviewee #3)

From the above statement we can realize that their employees have the necessary skill set to perform the tasks related to this IT embedded manufacturing system. However, Company 'C' also have a well-developed website through which customers can view and buy products of their choice which implies that this company has enabled data driven services as well. But and the company does not earn revenue from sharing data with their stakeholders.

Based on the above discussion it can be stated that as this company has met the requirements of strategy and organization, smart product, smart operations, employee, data driven services and smart factory dimensions to a good extent but still it does not have invested in all the relevant areas of production, the company does not have any R&D department for innovation management and also it does not earn any revenue from data driven services. Thus, based on all these facts this company falls into the 'Intermediate' level according to the readiness model developed by Lichtblau et al., (2015).

Challenges of Industry 4.0 implementation in Company 'C':

This company faced few challenges at the organizational context as we realized that they had to make huge investments to purchase new machines, their existing employees did not have that much of technical expertise to run the new IT embedded production process for which they had complexity to shift from their traditional manufacturing operation to semi-automated operation. According to Tornatzky & Fleischer (1990) this company faced problems related to high implementation cost, lack of trained staff and complexity of process changes at the organizational context. Interviewee #3 has expressed that they faced financial challenges initially while adopting Industry 4.0 technologies. But they soon received the return on their investment which is stated as below:

Yes, it required a huge amount of investment to purchase new machines and install them with proper technical expertise in our manufacturing plant. /---/ In the beginning we faced some financial challenges of course, as most our latest machines have been bought from foreign companies and they required a lot of investment but I must say after they have been operational, we were able to recover our ROI a lot sooner. (Interviewee #3)

Not only that, this company also faced problems at the technological level. The employees took some time to adopt to the technologies but reacted positively. Based on the TOE framework by Tornatzky & Fleischer (1990) this company faced challenges related to time constraint to adopt new technology and lack of technical expertise of employees. The interviewee explained us the about their technological challenge as the follows:

Yes, in the beginning it was hard for us as most of our existing employees did not have the expertise to run the new machines. So, it took time to get them acquainted with the new production systems. /---/ Yes, we faced some technical challenges while shifting towards automation. (Interviewee #3)

Moreover, we realized that this company did not get any support from government as their company is free from government interference. They have not received any benefit nor any legal issue from the government. All of their investments were inspired by their own ideas and materialized for their own benefit. On the contrary, their competitors are a major issue as the market for electrical appliance in Bangladesh is very volatile and subject to dominate with huge investments and better technologies. So, the obligation to invest and improve is a constant for the competing companies. According to the TOE framework by Tornatzky & Fleischer (1990) this company has encountered pressure from competitor and lack of government support in the environmental context. And the interviewee acknowledges these impediments by stating the following statements:

We did not get any policy related pressure from any government authority to implement the new technologies. /---/ There was no financial or technological support from the government /---/ The electronics market in Bangladesh is very competitive. There are big companies who are competing in this industry and there is always a pressure from our competitors. In order to cope up with the competition we always have to keep us one step ahead of them and that is why we are trying to implement state of the art technologies in our production system. (Interviewee #3)

Impact of COVID-19 in the adoption process of Industry 4.0 in Company 'C':

The lethal pestilence obstructed flow of raw materials as international borders were sealed. Moreover, the general lockdowns in the country exhibited scarcity of human resources in the factories. So, Company 'C' faced a rapid decline in production. They were saved by their pre-installed automation systems and they continued production with less workers.

Yes, we have faced some problems in our production process in the beginning of the COVID-19 pandemic outbreak. We suffered due to the shortage of raw materials from our suppliers. Then the government initiated several lockdowns and issued circulars to run factories with minimum workers for which our workers could not reach factory properly and in the worst cases few of them got affected by the virus and we had to run the operation with few workers in each

production line. /---/ We survived the initial hit of the Corona virus as we had a good amount of automation in our production line. (Interviewee #3)

After the outbreak of Coronavirus, they issued safety measures like temperature checking and sanitization but did not install any newer technologies for the assembling process. They have realized full automation is what they need after the COVID-19 situation. And once they have achieved that, they will resort to newer ventures to keep the existing employees and hire more if need be.

We did not add any new machine to the production process. We just checked temperature and sanitized them manually before entering the factory premises. /---/ Well, we do not have any plan currently to implement new technology but the COVID-19 pandemic has taught us that we should shift towards full automation in future to avoid the negative impacts of any pandemic in future. /---/ In future, we will open new production lines or introduce new brands under our umbrella where we will shift our extra employees for further production. (Interviewee #3)

As a result, this firm is prepared to face the obstacles of possible upgrades in the context of Industry 4.0 in the near future.

4.4 Case 4: Company 'D'

Company 'D' is one of the largest conglomerates in the Food and Beverages sector in Bangladesh. This company produces drinking water and various local carbonated drinks. They have a fairly modern enterprise with several advanced technologies in use to produce export quality drinking water and cold beverages.

Industry 4.0 readiness status of Company 'D':

Company 'D' established their modern manufacturing plant with a view to produce quality assured products with minimum human interaction. They implemented their strategy into reality by incorporating state of the art modern technologies in their manufacturing plant. While conducting the semi structured interview with Interviewee #4 we got to know that this company has a fully automated manufacturing plant where humans are there just to monitor the process. In their organization, they are using Internet of Things, Cloud Manufacturing & Robotics as part of the implementation of Industry 4.0 technologies. They invested in these technologies to reduce manpower, save production cost, increase efficiency and so on. They also highlighted that these technologies are crucial for improvement of hygiene level of the consumable products. Investment in such systems and machines had been materialized during the inception of their venture.

According to the strategy and organization dimension of the readiness model by Lichtblau et al., (2015) an organization need to have a strategy to implement industry 4.0 technology, invest in a few areas and integrate innovation management into their system. This company have already

strategized industry 4.0 technologies by investing a big amount of capital to build an automated beverage factory and they have specific R&D department for innovation management. The Interviewee #4 shares the following insights with us:

Yes, we are using Industry 4.0 technologies such as Internet of Things (IoT), Cloud manufacturing, Robotics etc. /---/ We made a big investment to implement IT technology in our manufacturing process from very beginning. /---/ Yes, we have a dedicated R&D department to manufacture our products and carry out researches to launch new flavors of cold beverage drinks. (Interviewee #4)

Figure 11: Automated Beverage Manufacturing

Figure 12: Automated Drinking Water Manufacturing

Figure 13: Cloud-Based Manufacturing

Figure 14: Automated Conveyor

Further information of their company portrayed a clearer picture of how much automated their production line is and they have met the requirements of smart factory dimension stated by Lichtblau et al., (2015). Their plants have internet connectivity. They can operate machines from distance and their machines in the production line can communicate among themselves. So, the machines in use are autonomous. The following statements were described by the interviewee #4:

Our factory internally connected through the internet. /---/ our machines in the production line have the capability to communicate an exchange information with other parts of the production line. /---/ Yes, we have such type of machines that can perform a task in the manufacturing process autonomously. Several of our machines have sensors which can screen out faulty products autonomously out of the production line. (Interviewee #4)

Not only that, the company's factory is equipped with smart factory features. For data storage, they use cloud servers and they use their IT system to track inventory materials digitally. They have not introduced RFID, but the products are all marked with barcodes. This helps them track products easily. They have the required expertise to operate IT systems and those employees are responsible for keeping data safe and secure. They can internally share information and data across the whole organization which fulfills the criteria of smart operation dimension described by Lichtblau et al., (2015). The interviewee #4 quotes that:

We have cloud-based information system. /---/ we can track the movement of inventory materials in the production line digitally. /---/ Our products carry barcode sensors by which it can be tracked during the manufacturing process by the machines or personnel. /---/ Our data is safe and responsive due to IT security. /---/ We manage an information sharing system for data sharing across the organization. (Interviewee #4)

Moreover, currently, they have 540 employees and they are trained for three months to adapt to technological or operational challenges. Their top management is concerned and urges the adoption of newer technologies. The initial difficulties were overcome by existing employees and now they can operate IT concerns or machines with no problem which shows that the employees of the company have also performed well in the employee dimension as they have the necessary skill sets to carry out production tasks in such an IT embedded manufacturing system (Lichtblau et al., 2015). The interviewee #4 puts it as the followings:

There are 540 employees in our organization. /---/ After implementing any new technology, they would require about three months training to adopt new IT system though it varies with Technology to Technology. /---/ Our top management and existing employees are very much positive about the implementation of new technologies. (Interviewee #4)

However, we realized that though they have a website of their own but customers can just only see products but cannot purchase them online. Additionally, they do not share their manufacturing

information with their business stakeholders for which they do not earn any revenue from data driven services. Thus, according to Lichtblau et al., (2015) they have a major lacking in the data driven services dimension of the Industry 4.0 readiness model. We got this information as mentioned below:

Yes, we have a website but people can just only see our product variants, they cannot customize or purchase from the website. /---/ No, we do not share our manufacturing information with our customers. Our supplier and retailer get limited information on need-to-know basis. /---/ No, we do not generate revenue through sharing data with our business stakeholders. (Interviewee #4)

Thus, based on the above-mentioned information we can state that this company has initiated strategy to implement industry 4.0 technologies into its production process, invested in a few areas to install state of the art technologies like IoT, cloud-based manufacturing, robotics into their manufacturing infrastructure, their employees have the necessary skill sets to run the automated operations and they have strong IT systems as well. However, the lack in the data driven services dimension of the Industry 4.0 readiness model. So, this company falls into the "Intermediate" level of the readiness model.

Challenges of Industry 4.0 implementation in Company 'D':

From what we have gathered from the answers that respondent of Company 'D' provided us, we could not identify any major challenge. They are financially solvent to afford the technologies they are currently using. They did not face any pressure from their competitors as well. The government does not interfere with their manufacturing process or organizational operations. The management of this company has been very enthusiast about implementing new technologies for the betterment of the company. However, the adaptation of new technologies was an issue for the employees but they learned through regular training programs.

We did not face any financial challenges while investing in the new IT system/machine. /---/ We did not face any legal policy related pressure from government to implement new technology. Nor from our competitors. /---/ Employees' skills were the difficult challenge to implement new IT technologies in our company as most of the employees were not familiar with these new systems. (Interviewee #4)

It is very important to mention that as Company 'D' fall under an Industrial Economic Zone (IEZ), the government organization namely Bangladesh Export Processing Zone Authority (BEPZA) supports them with finance and facilities in times of need. The respondent puts it as the followings:

As this project is inside an Industrial Economic Zone (IEZ) that's why we always get the support from BEPZA. (Interviewee #4)

So, it is evident that Company 'D' did not face any major throwback in terms of implementing Industry 4.0 technologies apart from the lacking of technological expertise of their employees.

Impact of COVID-19 in the adoption process of Industry 4.0 in Company 'D':

The impact of COVID-19 pandemic on the production process of Company 'D' was very insignificant. Their production process was hampered at the beginning of the lockdown caused by the COVID-19 pandemic. But most of the factory workers reside adjacent to the plants. So, manpower was not an issue for long. They have further argued that they did not need any new technology due to COVID-19 as their plants were already under the spell of automation. They do not have plans to implement technologies in a post-COVID situation. Additionally, they are confident that no unemployment issue can arise due to the fact that their plants were already running in automated process from the beginning.

Our manufacturing process been hampered a little bit as all the products are cold items and factories were temporarily shut down. /---/ We did not face any problem as most of them are staying besides the factory. /---/ There is no way to input any technologies in our automated manufacturing process which could help us to fight the pandemic in a better way. /---/ We don't have any plan for unemployment of employees due to automated manufacturing process as it is fully automated from very beginning. (Interviewee #4)

Thus, the case of Company 'D' provides us insight that having automation in the manufacturing process can help an organization to cope up in crisis situation like COVID-19 pandemic in a better way.

4.5 Case 5: Company 'E'

Company 'E' is a privatized FMCG giant in Bangladesh. They started out with oil mills but quickly spread out into other goods due to their rapid success. They have flour mills, rice and lentil mills at present. But for this research we have only focused on one of their automated flour mills.

Industry 4.0 readiness status of Company 'E':

In Bangladesh, flour mills were not automated. Company 'E' introduced automation to monitor the whole process, minimize effort, instruct different operations to the machines and maximize production. Roll Automation System & PLC Controllers were imported from Switzerland along with other machineries and software. Their mill is partially automated. The machines in the factories are controlled by an internal interface. They use Yield Management System (YMS) to calculate machine performance and production rate. They also implemented Error & Downtime Analysis (EDA) to calculate production loss rate. They are the first to revolutionize flour milling with automation & IT systems. This is a clear indicator of the inclusion of industry 4.0 technologies in the company's strategic decision. They also have a laboratory for product quality development.

According to Lichtblau et al., (2015) this company fulfills the requirement of strategy and organization dimension of the readiness model. The respondent shared the following statements:

Now, we monitor everything through our control panels. Our manufacturing equipment are installed by the Switzerland based company. They provide us Roll Automation System, software, PLC panels along with the machineries. So, we didn't have to invest separately. /---/ We have YMS to collect machine performance, production report and market data. We also use EDA to find out production loss rate. These Industry 4.0 technologies help us improve our production process. (Interviewee #5)

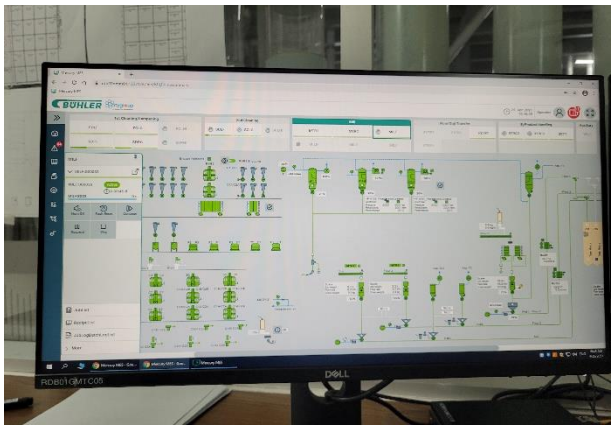

Figure 15: Mercury Interface

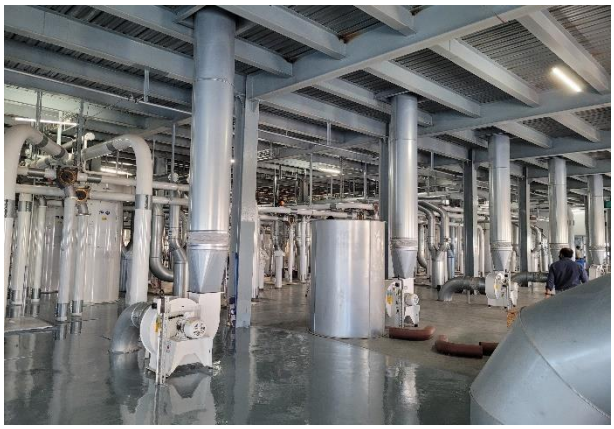

Figure 16: Automated Grain Refinery

On the contrary, even though they use Robotics and Cyber-Physical System but their machines cannot be controlled from distance. So, the machineries are not autonomous, rather requiring factory workers to be operated. Consequently, the machines cannot communicate between themselves on their own. Again, they do not have any digital inventory tracking system. The products are manually marked with Barcodes but there is no RFID inclusion. So, it shows clear picture that they lack in the smart product and smart factory dimensions according to the readiness model of industry 4.0 (Lichtblau et al., 2015). The respondent states the following statements:

We do have CPS and advanced robotics. /---/ No, the machines cannot communicate among themselves, operators are required to control the machines from fixed stations. None of the machines have remote control system. They run on manual controls. Even the robotics we use are not autonomous. They are operated by factory workers. /---/ We have a manual barcoding system, not RFID. (Interviewee #5)

Moreover, they do not have any cloud-based server. Their data is stored in hard drives which are prone to malfunctioning of the devices. That means their data is not backed up. But they have an operating interface named Mercury which is used to store & share data and Mercury has firewall & alarming systems for cases of emergency. Even they do not have implemented any IT security solutions in their system. All these facts give us indication that this company has not progressed well in the smart operations dimensions as well based on the readiness model of industry 4.0 (Lichtblau et al., 2015). The respondent passes the following comments when questions were asked regarding their business operations:

No, we do not use a cloud-based information system. /---/ As we don't have any IT security system, our data is not stored in clouds. /---/ But we have an operating system named Mercury. We have this interface that we use to monitor everything, from machines to operations. We have our firewall structure and alarm systems if any problem arises. (Interviewee #5)

Furthermore, we have gained knowledge from the semi-structured interview that they have a website but people cannot buy products from there. They do not share any data to their supplier, retailer or customer either. Consequently, no revenue is being generated from data driven services. So, this company also fails to meet the requirement of data driven services dimension of the readiness model introduced by (Lichtblau et al., 2015). The respondent answered the following statements while questions were asked regarding data driven services in their organization:

Yes, we have official website but people cannot buy products from there, it is mainly used to display company portfolio. /---/ No, they do not have access to our manufacturing information. /---/No, we do not generate any revenue by sharing data with the stakeholders of our business. (Interviewee #5)

Lastly, they have about 380 employees with no recruitment. They train their employees for a month to handle all operations. Besides, the regular employees are not allowed to operate any IT system. Only the dedicated IT team conducts technological tasks. So, the employees did not have to struggle with technological difficulties. So, it can be stated that they have lacking in skill acquisition and employee skill sets based on the readiness model explained by (Lichtblau et al., 2015). The respondents quote the following phrases:

The organization consists of 380 employees including factory workers. It took them around a month to be trained for the operations. /---/ Only the individuals trained to operate the IT concerns are allowed to conduct such operation. (Interviewee #5)

However, the flour mill of Company 'E' is partially automated. They have many lacking in the technological field. But their board is interested in more automation systems in the future. Even, the employees are delighted with such change from the archaic flour processing methods. The minimal technologies they use, already have yielded a substantial raise in production & efficiency,

giving them the edge against their competitors. The respondent expressed the following proclamations:

Our top management always keen on development and they issued all of the technologies we have currently. Most of our employees had a positive reaction to the changes. /---/ Our production line has improved significantly after implementing the barcode system & robotics. Basically, by implementing robotics technology, our annual production capacity has increased much more than our competitors of same size and volume. (Interviewee #5)

Based on the above-mentioned findings it be stated that this company has taken first few steps towards automation by introducing and investing in some industry 4.0 technologies in their manufacturing process. But they have a low system integrated communication, they lack in IT infrastructure and IT security solutions. They do not have cloud-based manufacturing system and data driven services present in their operation. Lastly, their employees do not have the necessary skills set to operate IT embedded manufacturing process. Thus, based on all these facts this company can be considered as a 'Beginner' level organization according to the readiness model of Industry 4.0 developed by (Lichtblau et al., 2015).

Challenges of Industry 4.0 implementation in Company 'E':

Based on the TOE framework developed by Tornatzky & Fleischer (1990) an organization can face challenges at organization, technology and environment context to adopt any new technology. From the interview conducted with the respondent from Company E we have identified that financial challenge was their biggest challenge at organization level. But once they issued the funds to acquire the current technologies they have, they received substantial profit. The technologies were not too pricey to begin with. So, there was no setback for the company.

Additionally, there was no legal clashes with the government. At the same time, they did not receive any benefit or facilities from the government. All the IT systems and machines were purchased with company's own initiative. As they did not have any complex technological infrastructure so they did not face any technological challenge. Even they did not feel any pressure from their competitor. The following speeches were delivered by the respondent while asked questions related to challenges faced at technological and environmental level:

If we have to name one, it would be the financial challenge but it was not that big of a deal. We didn't face financial draughts while implementing such system or machine. /---/ We did not face any legal issue from the government. We adopted these on our intuition and effort. /---/ No, there was no duty benefit or such benefits from the government. /---/ No, we didn't face any pressure from our competitors. *(Interviewee #5)*

Thus, it can be stated that financial challenge was the only barrier faced by Company 'E' while implementing industry 4.0 technologies in their manufacturing process.

Impact of COVID-19 in the adoption process of Industry 4.0 in Company 'E':

The respondent of Company 'E' admitted to the sufferings caused by the global pestilence COVID-19. Absence of manpower rendered factories obsolete. So, production rate declined along with company morale. But they did not take any further initiatives for newer machines or to minimize the health risks. The respondent further added that as their manufacturing process is not fully automated, they do not forecast a crisis of job positions or downsizing due to automation in future. The following proclamations were stated by the respondent in regards to the impact of COVID-19 pandemic on the adoption process of industry 4.0 in their manufacturing process:

Half of the processes are manual. So, we did suffer greatly due to the absence of manpower and the factories being shut down. /---/ We have not implemented any such initiative to reduce health risks. /---/ Since we have not implemented full automation process, we are not losing employees in the near-future. (Interviewee #5)

Thus, we can state that COVID-19 pandemic has negative impact on the manufacturing process of Company 'E' but they did not adopt any new industry 4.0 technology to mitigate the loss and to take preventive initiative for future.

4.6 Case 6: Company 'F'

Company 'F' is the pioneer in automobile assembly business based in Chittagong, Bangladesh which is administered by a government corporation. It is the country's largest automobile assembly factory, founded in 1966 and has manufactured & marketed over 50,000 vehicles, including cars, SUVs, buses, trucks, pickups, ambulances, and tractors of various types, by importing Completely Knocked Down (CKD) kits from overseas.

Industry 4.0 readiness status of Company 'F':

The semi structured interview was conducted with the Head of Production of the company, working as factory in-charge. He has described 3 types of vehicles that they provide to their customers on Completely Build Up (CBU) basis by importing CKD kits. From the interview we realized that Bangladeshi automobile market is not that much big for which they does not produce a lot of vehicles yearly in comparison to other developed countries. In Bangladesh automobile manufacturing is still conducted based on manual human labor with limited technologies to meet the quality standard. We also understood that no such technologies of Industry 4.0 are available at Company 'F'. They have plan to build new automated assembling plant for the future. In regards to the present condition of the automobile manufacturing industry in Bangladesh, the respondent shared the following information:

We do not use much of these technologies in our plants because the context of Bangladeshi Automobile Assembly Industry is very grim. Though worldwide automobile manufacturing is mostly automated, Industry 4.0 technologies have recently come forth in Bangladesh. We still use human resource over automation for assembling vehicles. /---/ As a developing country, we are not accustomed to terms like Cloud Manufacturing or Cyber-Physical systems in this industry. /---/But our organization is going to establish a modern automated plant in our factory. So, for this purpose, feasibility studies are going on. In that new project, there are lots of scopes for Robotics and Cyber-physical System etc. (Interviewee #6)

Figure 17: Manual Automobile Assembly

The following information gives us the impression that they do not have any industry 4.0 technology present at their company rather they have plan to implement new technologies in future. So according to the readiness model developed by Lichtblau et al., (2015) they have lacking in the strategy and organization dimension of the readiness model.

Now to scrutinize their factory, they have internet connectivity but their machines cannot interact among themselves. They use barcoding system on their vehicles for status check in the Quality Control line. Two of their machines can be operated from distance, they are: Wheel Alignment Machine & Brake-Speed Tester Machine. They have plan to install ERP system which is under planning phase. So as Lichtblau et al., (2015) describes the smart product and smart factory dimensions which should include features like the ICT add on functionalities and data analytics at usage phase, data usage, equipment infrastructure, digital modeling and IT system used for manufacturing, all these are missing in this company. The respondent stated the following speeches:

Yes. The entire plant is connected internally. But internet is not used in production line. /---/ We have the barcode system installed during the production line. Before putting a vehicle on the market, we check vehicle status through barcodes in Quality Control (QC) Line. /---/ No, all the production stations are independent and do not have any way of exchanging data with other stations at this moment. /---/ No. We have not implemented any inventory movement tracking system yet. Our IT team is working on an inventory tracking system, much like ERP and it will be materialized very soon. (Interviewee #6)

Moving forward to checking the requirements of the smart operations dimension we realized that they do not have any cloud-based information system available in their organization. They also do not have any machine in their production line that can perform task autonomously. Moreover, they are still panning to implement any IT system through which integrated information sharing would be possible. While asked regarding their IT security systems, we understood that as they do not use cloud-based systems for manufacturing they just only use internal servers to collect and share data for internal communication via internet and they feel to serve that mere purpose their IT security system is performing well do far. The interview puts these expressions as follows:

We do not use any concrete security system in our assembling process. We use internal servers to communicate and share data. There has been no single error till now. /---/ So, I believe our security system is doing a good job so far by keeping the data safe. /---/ No we do not use a cloud based information system for our manufacturing process. (Interviewee #6)

Moreover, from the semi-structured interview we realized that they have also not included data driven services in their company as they do not share information related to their production process with their retailer or customer. They only share such information with their supplier from whom they import the Complete Knock Down (CKD) parts of the vehicles. However, they have a website from which customers can make bookings of their preferred vehicle but they do not generate any revenue from data driven services. Most importantly, being an automobile manufacturing company, they do not have any specific R&D department present currently. The respondent stated the following speeches:

We only share our information of the production process with our supplier, not with our retailer or customer. /---/ No, we do not have any specific R&D department for innovation management. /---/ Yes, we have a website where potential customers can see our vehicle model, their specification and their prices and place order online. /---/ No, we are not involved in any revenue generation through data sharing. (Interviewee #6)

Lastly, their employees are trained by experts from international conglomerates while Company 'F' imports CKDs and full-built vehicles. They have hired IT specialists for their data security. These specialists have not faced any single IT issue so far. Employees take around two months to

grasp minor changes and month-long intermediate trainings are given before implementing major technologies.

As we import parts or full vehicles from international automobile companies, they send experts to train the newly hired employees here. /---/ We hire IT Engineers and Specialists to safeguard the digital integrity. /---/ Honestly, some senior employees do not prefer change for obvious reasons but newer employees are quick learners and they accept change very positively. I estimate it takes around two months for them to adapt to technological change. Also, we hold training sessions before using a new fully-functional IT system. (Interviewee #6)

So from the above-mentioned analysis of the findings, we can state that the automobile industry is still far away from adopting the industry 4.0 technologies in their manufacturing process. This company has taken some initiatives to adopt new technologies and invested in implementing ERP system and other automated machines. The employees also need to expand their technical skills to adopt the latest technologies in the future. So, this company can be considered as 'Beginner' level company according to the industry 4.0 readiness model by (Lichtblau et al., 2015).

Challenges of Industry 4.0 implementation in Company 'F':

As a government owned organization, Company 'F' faces the lack of independence to proceed implementing initiatives on their own intuition. Their proposals need to be sanctioned by the controlling government authority before they can invest on certain projects. And here comes the financial struggle. The government may or may not issue vast funds due to the capricious economic milieu of Bangladesh. So, time, money and intention – all work as obstacles from the government in terms of adopting newer & better technologies.

As this is a government organization, we need clearance to invest funds in a new system. And sometimes, it gets difficult to make them understand the importance of latest technologies and they don't offer us sufficient finance to attain so-called luxury equipment. Government directs and restricts certain aspects of new technologies adopted by the company because they feel a need to verify the utility of such initiatives. (Interviewee #6)

So, it is evident that this company suffers from lack of support from top management, lack of digital culture, high investment cost and lack of trained staffs at the organizational context according to the TOE framework by (Tornatzky & Fleischer, 1990).

Yet like a cloud with silver lining, the technologies they have implemented in their factory gives them a significant advantage over their competitors in the market. But somehow, they feel the pressure to upgrade their systems lest competitors bridge their market domination. So, the constant need for improvement is always on their top management's minds. Thus, capital and authorization, lack of government support and competitor pressure are the major factors at the environmental context which is thwarting the company's vision for automation. The interviewee puts it as follows:

Indirectly, we do feel the pressure because competitive disadvantage can push us out of the market and that's why we recognize the urge to upgrade whenever a competitor threatens us with a new IT system that we do not have already. For example, our competitors have better Service Center Facilities and we are working on to improve ours. /---/ Seems like permission to invest and the required funds are the biggest challenges. (Interviewee #6)

Lastly, we realized that they also face some challenges at technological level as the existing employees have difficulties to adopt the change specially the old ones and they also lack the knowledge to accept the new advanced technologies. The following proclamations were shared:

Technological change is mandatory but employees do not adapt so quickly. That's why we hold training sessions before using a new fully-functional IT system. /---/ Honestly, some senior employees do not prefer change for obvious reasons but newer employees are quick learners and they accept change very positively. /---/ Yes, we face technical challenges, lack of expertise while shifting from traditional manual manufacturing to automated manufacturing. (Interviewee #6)

Thus, there are many difficulties faced by this company which needs to be fixed by the company in order to progress towards the automation of this industry.

Impact of COVID-19 in the adoption process of Industry 4.0 in Company 'F':

The respondent has shed light on the COVID-19 situation in context of his company. Importing CKDs and fully-built vehicles from international brands turned out to be troublesome. Moreover, the government issued a selling limit that resulted in loss of demand, bulk of unsold products, production uncertainty and so on. The interviewee shared the following statements:

Of course. Government has imposed a bar on purchasing vehicles to the government sector during the pandemic. So, we cannot sell in bulk and consequently, we do not assemble in bulk as there are numerous product lines still in queue in our factory. /---/ Moreover, foreign investments and training agendas have been hampered, not to mention the hassles of importing parts or unassembled vehicles from manufacturers. (Interviewee #6)

Moreover, the reopening of factories with half the manpower issued by the government resulted in further hassles. Then they realized the true values of automation but the cost was too high for implementation. However, they ensure health security by using oximeter and disinfectants in their factory despite not implementing newer automated machineries to reduce human touch.

Government declared the reopening of many industries with 50% or less employees to reduce COVID infection. But production is greatly hampered due to the lack of manpower in the factories. /---/ We use oximeter and disinfectant sprayer gates to ensure a safer workplace. But no extra machineries to facilitate the production procedure. (Interviewee #6)

Furthermore, their plans for the fully automated factory were hindered by the global pandemic. But they are still gaining progress gradually towards materialization in a post-COVID scenario. And they believe that after the automated manufacturing plant, they will require more employees to maintain these machineries and contribute to other sectors.

The new project of ours will ensure more automated machines that will turn out as effective in post COVID scenario. Although this project planning was in motion before the pandemic. /---/ I think we need more staff to maintain the automated machineries and as we are planning an expansion for an upgraded automobile plant, we will reassign them to other sectors beside the automated manufacturing process. (Interviewee #6)

Thus, it is evident that COVID-19 pandemic has also affected Company 'F' which needs to be recovered through proper support from government end. They could not adopt industry 4.0 technology during the COVID-19 pandemic due lack of support from government and lack of technological infrastructure but they plan to implement the latest technologies in their new plant in post COVID-19 situation.

4.7 Case 7: Company 'G'

Company 'G' is one of Bangladesh's most dependable and well-known pharmaceutical firms. Company 'G' began its adventure in 2012 by establishing a joint venture with a large Japanese multinational corporation. They manufacture and market pharmaceutical items in accordance with WHO's (World Health Organization) guidelines.

Industry 4.0 readiness status of Company 'G':

We learned through the semi structured interview with Interviewee 11 that this company has adopted a few fourth industrial revolution technologies in their production process, including barcodes, robotics, and automatic autograph machines like "Trapizeum Latex", IOT etc. We addressed appropriate questions relating to the main dimensions of the 'IMPULS- Industry 4.0 readiness model,' which include strategy and organization, smart operations, smart products, employees, and data driven services, during the semi - structured interviews to assess Company 'G''s readiness status. The information gathered during the semi structured interview was also confirmed during our plant visit to Company 'G'.

The strategy and organization aspect of the readiness model, according to Lichtblau et al., (2015), focuses on strategy, investment, and innovation management. This company has made significant progress in terms of strategy and organization, having successfully implemented industry 4.0 technology adoption strategies into their manufacturing processes, as well as investing in manufacturing process, infrastructure, web and smart application development, and human resources. This corporation also has a separate Research and development department to ensure proper innovation management across the board. The interviewee mentioned their view as bellow:

In manufacturing process for QC testing, we use different auto machines that are run by software. One of the automatic machines is Autograph tester that use the software "Trapizeum Latex". /---/ Top management was positive as the new IT system have huge advantage including cost saving and improved product quality. /---/ We invested heavily on automatic and semi-automatic machines. /---/ We have very big and functioning R&D department. (Interviewee #7)

Figure 18: Syringe Barrel Print Machine

Figure 19: Automated Ribbon Packaging

Additionally, the smart product dimension of the readiness model, according to Lichtblau et al., (2015), focuses on ICT add-on functionalities and data analytics in the utilization phase. During the interview we discovered that Company 'G' uses 14-digit barcode on items to be tracked any time during the manufacturing process. Most of their machine can communicate information between each other. We got the following quotes from the respondent:

90% of our machine can communicate with each other. /---/ Our products has a 14-digit barcode on pouch that can read by machine any point of the production. (Interviewee #7)

Moreover, the readiness model's smart operations dimension focuses on the adoption of information sharing, autonomous processes, IT security, and cloud utilization (Lichtblau et al., 2015). This company uses cloud-based information system to share information across various departments with autonomous and remote functionality for some machines. They have secure IT system with dedicated team as they need to secure the confidential information about their manufacturing process. The interviewee mentioned:

Yes, we have an auto-assembly machine named caulking machine that can perform autonomously. /---/ Yes, we can operate from distance but as we are producing medicine, we need to stay on the plant to make sure the quality is good and everything running perfectly fine. /---/ Yes, we have IT security system, and we need to secure information as we are dealing with expensive drug recipe. (Interviewee #7)

Furthermore, equipment infrastructure, IT systems, data utilization, and digital modeling are the areas that are considered when assessing the 'smart factory' dimension of the ready model, according to Lichtblau et al., (2015). Having this on mind, we found out that this company has an excellent infrastructure to manufacture various medicines and ingredient in their plant. Their factory is well connected through internet and cloud-based system, and they have a detailed website to let their stakeholder know about their products and company. But as they are a medicine company, they maintain strict confidentiality about their production process. In this regards the interviewee mentioned:

Yes, we have auto-assembly machine named caulking machine that can perform autonomously./---/ Yes, we have IT system and we need to secure information as we are dealing with expensive drug recipe. /---/ Yes, we can but as we are producing medicine, we need to stay on the plant to make sure the quality is good and everything running perfectly fine. (Interviewee #7)

It's worth remembering that during our visit, we found a well-organized equipment infrastructure in their manufacturing facility. Various interconnected machines, robotics technology, and multiple layers of conveyers were used to move products from one step to the next during the manufacturing process.

Additionally, data-driven services are an important component of the readiness model proposed by Lichtblau et al., (2015), which focuses on data-driven services, data utilization, and revenue distribution. During our interview we recognized that this company share small amount of data regarding its manufacturing process with his stakeholder as their products are confidential. Although they have a good website that has detailed information regarding their products and company. But they do not sell medicine through their website. The interviewee said:

We have a website through which anyone can view our products, features, medicine indications, dosage quantity, precaution, side effects and storage conditions. /---/ No, we maintain strict confidentiality. /---/ No, revenue is not generated by data sharing with our stakeholders. (Interviewee #7)

The final dimension of the readiness model is 'employees,' which is defined by the degree of available employee skill sets and the company's skill acquisition timeframe (Lichtblau et al., 2015). We learned from the interview that almost all of the employees had training to acquire skills to run

and maintain all the necessary industry 4.0 tools and mechanism. Although they hire new people to deal with the vacancy sometime. They mentioned:

We usually gave three months training to all of the employee to deal with the new system. /---/ In the beginning they might (face problems) but due to proper training all of them manage to cope up. (Interviewee 11)

We can conclude from the previous section that; this company has incorporated industry 4.0 into its strategic orientations. Vast investments have been made in a few areas of the business. Automated data collection is possible thanks to cloud sharing and barcode. Both internal and external communications with business partners are maintained given the availability of data driven services. IT solutions and security are also available. Based on the readiness model introduced by Lichtblau et al., (2015) this company can be levelled as 'Intermediate' level.

Challenges of Industry 4.0 implementation in Company 'G':

We tried to discover what obstacles this company experienced at the organizational, technological, and environmental levels when introducing industry 4.0 technology in the production process using Tornatzky and Fleischer's (1990) Technology-Organization-Environment framework. It was discovered that they did not experience many challenges at the organizational level because their management was eager to adapt new technologies and because they had approximately fifty people, it was not difficult for a company of their size to adopt new technologies. When questioned about the obstacles of focusing on the financial side of the business, the interviewee responded as follows:

No, not that much as this a Joint venture with Japan government, we get a lot of money from them to implement new systems. /--/ Top management was positive as the new IT system have huge advantage including cost saving and improved product quality. (Interviewee #7)

Apart from that, we focused on identifying technological issues, and we discovered that this organization had a number of important technological challenges, including lack of employee skills for new tech and the lack of advanced technology locally. As the interviewee put it, technological obstacles are as follows:

Giving training to existing employee about the new technology was the most difficult part. /---/ We usually gave three months training to all of the employee to deal with the new system. (Interviewee #7)

They also had to contend with environmental variables such as competition, government regulatory organizations, and other external concerns such as the COVID-19 pandemic. The respondent stated that they are constantly under pressure from their competitors, but that the government has provided financial assistance in the implementation of new technology. The

following is how the interviewee responded to the threat of competitors and government technological or financial assistance:

Yes. In Bangladesh there are a lot of good pharma company which produce quality product. if we want to compete with them, we have to introduce better system and thus we feel some pressure. /---/ Yes, we get financial support from government when implementing new IT technology. (Interviewee #7)

To conclude we can say that technological challenge was there in Company 'G' but they also had tools to handle these challenges.

Impact of COVID-19 in the adoption process of Industry 4.0 in Company 'G':

According to Tornatzky and Fleischer's (1990) TOE framework, the COVID-19 pandemic can be considered an external environmental factor which has slight or no impact on Company 'G''s production process, especially because it produces necessary medicine to tackle the pandemic covid 19. The respondent also stated that they have not implemented any new Industry 4.0 technology during the pandemic as they are already efficient in term of human resource and automation, but that they want to adapt more automation in post COVID-19 era. When asked about the effects of automation on unemployment, the interviewee responded as follows:

We have different types of products. All products are not involved automatic production. Some need manual labor. People will have their jobs in these sectors. Plus, we will give them training to adapt with new tech as we would need operator to maintain the automatic machines. (Interviewee #7)

Thus, we can conclude that, COVID-19 could not harm the production of companies like Company 'G' because of its adaption of industry 4.0. This company will move forward to even more automation and adaption of industry 4.0 to maximize its profit and minimize future losses due to pandemic.

4.8 Case 8: Company 'H'

Company 'H' was founded as a virtual Garment manufacturing company by a group of international creative experts with extensive expertise in the apparel sector, with the goal of creating an inspiring mix of items with a strong individual identity and a nonconformist edgy touch. This company was established in 2017 and have assemble factory over 11 countries including display section in Dhaka, Hong Kong, Barcelona and New York.

Industry 4.0 readiness status of Company 'H':

Company 'H' is new company in Bangladesh but they already adopted some industry 4.0 technologies including IoT (Internet of things), CAD which involves additive manufacturing and ERP system in their factories over here.

We asked appropriate questions relating to the main dimensions of the 'IMPULS- Industry 4.0 readiness model,' which includes strategy and organization, smart operations, smart products, employees, and data driven services, during the semi-structured interviews to assess Company 'H' readiness status. The information gathered during the semi structured interview was reviewed during our factory visit to Company 'H'.

The strategy and organization aspect of the readiness model, according to Lichtblau et al., (2015), focuses on strategy, investment, and innovation management. This business has experienced significant strategic and organizational growth as a result of successfully integrating industry 4.0 technology into their production operations, as well as investing in manufacturing processes, infrastructure, and human resources. But this firm does not have any Research and Development department, to ensure innovation management throughout the organization. The interviewee mentioned:

Yes, we use few of the IoT things in production system like CAD & ERP to smooth the production system. /---/ It was a very healthy welcoming view as whole system reflects the ultimate growth of the company. (Interviewee #8)

Besides, the smart product component of the readiness model, according to Lichtblau et al., (2015), focuses on ICT add-on functionalities and data analytics in the production stage. During the interview, we found that Company 'H' has an ERP system that allows them to track inventories at any stage during the manufacturing process. Most of their machines, are unable to communicate with one another as machines are mostly operated by humans. The followings are quotes from the interviewee:

No, not now but it is under supervision to implement the barcode system during the production. As of now items are being tracked under ERP system with numeric form. /---/ Yes, we have this system under ERP & we can keep/track of any information. we can track info of any production even after final delivery till next one year. (Interviewee #8)

Moreover, the readiness model's smart operations aspect focuses on information exchange, autonomous processes, IT security, and cloud utilization (Lichtblau et al., 2015). To transfer information between departments, this company uses a cloud-based information system, with some equipment having autonomous and remote capabilities. They have a safe IT system in place, but the respondent is concerned because it is a new system in Bangladesh's RMG sector. The following was mentioned by the interviewee:

Yes, we have remote controlled machine. it requires command from computer or any related device. /---/ so far it is. But still industry 4.0 is under development in many ways for RMG sector. /---/ Yes, we have this system under ERP & we can keep/track of any information. We can track info of any production even after final delivery till next one year. *(Interviewee #8)*

Furthermore, the areas that are considered while examining the smart factory aspect of the readiness model, according to Lichtblau et al., include equipped infrastructure, IT systems, data use, and digital modeling (Lichtblau et al., 2015). In perspective of this, we noticed that this organization has a good infrastructure for creating a wide range of dresses in their facility. Their facility is well-connected via the internet and a cloud-based system; they have a global website but no Bangladesh-specific one. In this regard, the interviewee mentioned the following:

Yes, our factory is internally connected through internet. /---/ Yes, we have an automatic machine to perform a specific sewing process of the product. /---/ We have a website for our global company but not for the local office. Customer cannot buy but can send us email through website. (Interviewee #8)

However, we realized that this company have not required expertise in the data driven services dimension of the readiness model as though they do not share much information related to their manufacturing process with their business stakeholders and also do not engage in revenue generation through shared data driven services. In regards to the data driven services dimension the respondent shared the following views:

We share some information in our website but not that much. /---/ No, we don't do that. (Generating revenues through data driven services) (Interviewee #8)

The final dimension of the readiness model is 'employees,' which is defined by the availability of employee skill sets and the company's skill acquisition timeframe (Lichtblau et al., 2015). According to the interview, all of the employees have got training on how to operate and maintain all of the necessary tools and systems as most of the garments manufacturing tasks are carried out by humans with the help of some automated machines. Rather than hiring new individuals, they train their existing personnel with the support of their IT team. The following was mentioned by the interviewee:

As garments industry in Bangladesh is very human centric due to availability of cheap labor many garments factory owners do not want to add new technology which need huge investments. We have separate IT personnel to work on the system & we train existing manpower to adopt the system. /---/ It took nearly 3 / 4 months as a whole to adopt the system & we are continuously developing the system to accurate the workflow. (Interviewee #8)

We can conclude from the analysis mentioned above that Company 'H' has implemented few Industry 4.0 aspects into their company. They have good IT infrastructure, cloud-based information system but most of their manufacturing tasks are run by human labor. Also, they do not have any data driven services available in their company. They are still very human oriented

and because of that we can identify this company as a “Beginner” level organization according to the readiness model by Lichtblau et al., (2015).

Figure 20: CAD Machine

Figure 21: Human-Centric RMG Production

Challenges of Industry 4.0 implementation in Company ‘H’:

Using Tornatzky and Fleischer's (1990) Technologies-Organization-Environment model, we tried to investigate what organizational, technological, and environmental challenges this corporation faced when using industry 4.0 technology in the production process.

We found that they face some financial problems. As the RMG sector is a growing sector, they quickly recovered their investment. The interviewee mentioned:

Yes, it’s a new step to adopt & it putted us in financial challenge. But as every new step has a new path to get stronger, we came back with better shape in few months. (Interviewee #8)

Apart from that, we focused on finding technological issues, and we discovered that this company faced a number of significant technological obstacles, including a lack of new technology-skilled individuals and sophisticated technology in the local region. According to the respondent, the following are examples of technological barriers:

Initially we used from local market but to have better performance we adopt our preset system from Germen market. /---/ It took nearly 3 / 4 months as a whole to adopt the system & we are continuously developing the system to accurate the workflow. (Interviewee #8)

External problems, such as the COVID-19 pandemic, were also addressed, as were environmental considerations such as competitiveness and government regulatory bodies. Although new technology is being introduced, the government has provided technical aid and assistance with

importing new technology. The following is the interviewee's answer to the threat of competitors and government assistance:

Obviously, government. is allowing IT techs from global giant to show what is the best they have & we have the options to choose. Also Govt. is investing at their end to introduce new system locally. /---/ Not that much as these systems are demand of time. To compete with the growth of IT worldwide, everyone is part of changes. (Interviewee #8)

To conclude, Company 'H' encountered technological challenges, but they also developed strategies to overcome them.

Impact of COVID-19 in the adoption process of Industry 4.0 in Company 'H':

According to Tornatzky and Fleischer's (1990) TOE framework, the COVID-19 pandemic can be classified as an external environmental component. Company 'H' had issues at the beginning of the epidemic. They also had a strategy in place for what would happen after Covid-19. We also questioned about unemployment and automation with the interviewee. The interviewee mentioned the following:

Yes, it hampered but we recover in a significant way later on. /---/ For safety purpose we replanted the machine setup to avoid/reduce human interactions as much as possible. /---/ We are working on the process to shift a number of workforces to a new work field. But creating a new work field will require an authentic idea with investment & surely need to be a proper participator for country's growing economy. (Interviewee #8)

As a result, we can conclude that COVID-19 has damaged the production of businesses like Company 'H', which is not automated and human oriented. These businesses will invest in more automation and industry 4.0 adaptation in order to maximize profits and avoid future losses due to pandemics.

4.9 Case 9: Company 'I'

Company 'I' is one of the oldest local shoemakers in the footwear industry of Bangladesh. They produce shoes, sandals and slippers and supply them to bigger footwear brands of the local market.

Industry 4.0 readiness status of Company 'I':

Company 'I' adopted few technologies including cloud manufacturing system and cyber physical system including laser cutting machine, adhesive machine, and barcode scanner.

During the semi-structured interviews to assess the readiness status of Company 'I', we asked appropriate questions relating to the main dimensions of the 'IMPULS- Industry 4.0 readiness model,' which include strategy and organization, smart operations, smart products, employees, and

data driven services. Our plant visit to Company 'I' validated the information acquired during the semi structured interview.

According to Lichtblau et al., (2015), the strategy and organization aspect of the readiness model focuses on strategy, investment, and innovation management. This company has made considerable strategic and organizational growth, having successfully adopted industry 4.0 technology adoption methods into their manufacturing processes, as well as investing in manufacturing processes, infrastructure, and human resources. This company also has its own Research and Development department, which ensures that good innovation management is implemented throughout the board. The interviewee quotes:

Yeah, obviously since last two years, we have been using the cyber physical system and also the cloud manufacturing system. /---/ Ok frankly speaking our top management was also a bit tensed with this new implementation because it costs a lot of money, but we have done a lot of research work regarding the outcomes of it. And they had that data and they liked that, so went on with this. (Interviewee #9)

According to Lichtblau et al., (2015), the smart product component of the readiness model focuses on ICT add-on functionalities and data analytics in the production stage. We learned throughout the interview that Company 'I' utilizes barcodes on items so that they may be tracked at any point during the manufacturing process. The majority of their machines can communicate with one another. We get the following reply from the respondent:

Each and every part of my production process each and every component is sealed with a barcode. For example, if I say our production starts with a piece of a leather sheet or leather roll, whatever you'd like to say. And, and it is a process into a specific upper material of the shoe. And then when a roll of leather enters our factory, we install barcode. And the barcode is instantly scanned by the operator. So automatically each and every employee knows that a new role has entered in the production plant, and the production process has started. So, it is a systematic process. And in each of the stages, it is scanned by barcode. /---/ Yes. We have some machine that can communicate with each other. This is a complete automated process and machines work at the same time with individually sending comments to each other. (Interviewee #9)

Moreover, the smart operations dimension of the readiness model focuses on the adoption of information sharing, autonomous processes, IT security, and cloud utilization (Lichtblau et al., 2015). This corporation employs a cloud-based information system to disseminate information between departments, with some equipment having autonomous and remote functionality. They have a secure IT system set up, as well as a dedicated team, to protect the secret information regarding their manufacturing process. The interviewee mentioned the following:

Yes. We have two machines that can do its task autonomously. /---/ We can operate some of the machines remotely, but you also have to keep in mind that these machines are very sophisticated. These are very expensive. So, we do not go for remote operating because these might become a bit risky. Always our operators stay very near to our machine to monitor them. But if yes, it's possible to monitor, to operate them remotely. /---/ We have the IT security system installed. Our system is completely controlled internally. We have to make sure that no information is leaked because every information is controlled centrally. You cannot just enter our system and copy the information. It's very secure. (Interviewee #9)

Furthermore, according to Lichtblau et al., (2015) the areas that are considered while analyzing the smart factory dimension of the readiness model are equipped infrastructure, IT systems, data utilization, and digital modeling. With this in mind, we discovered that this company has a fantastic infrastructure for producing a variety of shoes in their facility. Their plant is well-connected via the internet and a cloud-based system. The interviewee stated the following in this regard:

I have already mentioned that we have a very big production line. It's really a tough task for us to produce it in one place. So, we have three factories and one small factory for production, all connected by internet. /---/ Yes. As I mentioned earlier that we have autonomous machines, in which we use cloud-based system to operate sometime. /---/ One of the machines is laser cutting machine, adhesive machine and another one barcode scanner. All of these machines can be operated through a cloud-based system. (Interviewee #9)

However, despite of having many automated machines, IoT infrastructure and cloud-based manufacturing system this company has lacking in data driven services dimension of the manufacturing process as they do not share manufacturing information with the business stakeholders and do not generate revenue from information exchange. They even do not have a website to share information about their products to their customers. The interviewee stated the following phrases regarding this:

No, we do not have any website for our products. /---/ No, they don't get any access of our production information. /---/ Unfortunately, no, we have not looked into that matter yet (Interviewee #9)

Lastly, the readiness model's final dimension is 'workers,' which is determined by the degree of available employee skill sets and the company's skill acquisition timeline (Lichtblau et al., 2015). Almost all of the staff had received training to understand how to operate and maintain all of the necessary industry 4.0 tools and mechanisms, according to the interview. They do, however, hire fresh persons to fill the vacancy from time to time. The interviewee mentioned the following:

It took around 18 to 20 days for some. Some 10 to 15 people required around one month because they were a bit more untrained in this sector. So, we had to teach them the basics things first and then the technological things. /---/ They, they face a lot of difficulties, but I hired a full IT of 15 members some more operators, around eight people. So, these 24 people were in charge of training. With their help the existing employees deal with the challenges. (Interviewee #9)

From the previous section we can conclude that Company 'I' has introduced some features of industry 4.0 in their organization. They invested in developing a cyber-physical system, IoT infrastructure and cloud manufacturing and automated data collection. Required It solutions are installed in the system as well to protect data. But they do not have any active website, so external communications and data driven services with stakeholders is not available. Lastly their existing employees also need training to master their skill set to operate the newly added technologies So, according to the readiness model by Lichtblau et al., (2015) we can identify this company as an "Intermediate" level company.

Challenges of Industry 4.0 implementation in Company 'I':

Using Tornatzky and Fleischer's (1990) Technologies-Organization-Environment framework, we tried to determine what hurdles this company faced at the organizational, technological, and environmental levels when implementing industry 4.0 technology in the manufacturing process. It was discovered that they did not have many obstacles at the organizational level because their management was keen to adopt new technologies, and because they employed roughly 174 people, adopting new technologies was not difficult for a company of their size. When asked about the challenges of concentrating on the financial aspect of the business, the interviewee said:

Yes. of course. I faced a lot of financial challenges. I had to take some business loan but depending on the order and depending on the delivery, I came over them in a very short time. /--/ No. Okay. And I must say that in this case, while importing these machines from China, my local government really helped with the policies that's how we can import it in a very easier way. And we can clear it from the customs in quick time (Interviewee #9)

Apart from that, we concentrated on identifying technological concerns, and we discovered that this business had a number of significant technological challenges, including a lack of new technology skilled personnel and a shortage of sophisticated technology in the local area. The following are examples of technological barriers, as stated by the interviewee:

The main challenge was to operate both the machines. As the machines were really very costly, we didn't hire any foreign people or any foreign engineers who can stay here for one or two months and help our operators and teach how to operate them. And that was really a big challenge for me because at the beginning we faced some difficulties, the machines were not working properly. So, we were we were really disappointed at that time as we may face a loss. /--/ But day by day, we came to know that there is a very big part of synchronization of every component of the machine. So, by the time we install the synchronization, then it became very

easy to operate. /---/ They, (employees) face a lot of difficulties, but I hired a full IT of 15 members some more operators, around eight people. So, these 24 people were in charge of training. With their help the existing employees deal with the challenges. (Interviewee #9)

On the other hand, they also had to deal with external environmental concerns like the COVID-19 pandemic, competitiveness and government regulatory agencies. The respondent claimed that they are continuously under pressure from their competitors, but that the government has provided financial assistance and assistance with importing new technology while it is being implemented. The interviewee's response to the threat of competitors and government technological or financial help was as follows:

Yes, we get easy loan from government bank to buy this new technology and they also help us to import machines without any hassle. For this we were able to import quality machine in short time. /---/ There was a pressure of that. We were receiving a lot of big quantity orders. So, I mentioned that it took around 15 to 25 days to train my operators with the new machines. So, these 25 days was my planning period of my factories. I had to postpone the production process, and that was the main channel challenge, but after adapting with the technologies it really covered those 25 days. (Interviewee #9)

To summarize, we can say that Company 'I' faced technological obstacles, but they also have implicated methods to deal with them.

Impact of COVID-19 in the adoption process of Industry 4.0 in Company 'I':

The COVID-19 pandemic can be termed as an external environmental component, according to Tornatzky and Fleischer's (1990) TOE framework. Company 'I' faced problems in the beginning of this pandemic. They also had plan for post covid-19 situation. We also asked the interviewee about unemployment and automation. The interviewee mentioned:

Honestly speaking, I really feel this issue because in Bangladesh we have a lot of human beings. But we are trying to give training to our employee in such a way that they might become a freelancer and work for different company at once because their working hour might get less due to automation. And if we introduce new plant the existing employee will always have an advantage. /---/ Yeah, we are planning to introduce a completely automatic sealing machine. This is the only part that is left in our company to turn into an automatic system because the rest of the part is already automated. So, if we can introduce this machine, with a very a smaller number of human resources we can work. /---/ Yes. we have faced some problem in the beginning, as I said because there was a lack of human resource in our factory. (Interviewee #9)

As a result, we may conclude that COVID-19 harmed the production of business such as Company 'I' since it is not entirely automated. To maximize profit and prevent future losses due to pandemic, this company will move forward with even more automation and industry 4.0 adaptation in the coming days.

4.10 Case 10: Company 'J'

Company 'J' is the leading furniture manufacturing company in Bangladesh. Currently this company manufactures furniture items related to bed room, dining room, living room and kitchen room of individual households. Apart from individual household furniture this company also manufactures particle boards, UPVC boards, UPVC doors, designer doors and fire-retardant doors, cabinets, furniture, kitchenware and cables for corporate offices, hospitals and academic institutions.

Industry 4.0 readiness status of Company 'J':

From the semi structured interview conducted with Interviewee 10 we understood that this company has implemented few technologies of the fourth industrial revolution in their production process among which 3D printing, augmented reality and robotics technology are significant. During the semi structured interview, we have asked relevant q
uestions related to the six dimensions of the 'IMPULS- Industry 4.0 readiness model' which are strategy and organization, smart operations, smart products, employees and data driven services to assess the readiness status of Company 'J'. The information collected from the semi structured interview was also validated from our factory observation at Company 'J' factory premises.

According to Lichtblau et al., (2015) the strategy and organization dimension of the readiness model focuses on strategy, investment and innovation management. This company has advanced considerably in the strategy and organization dimension as they have successfully initiated industry 4.0 technologies adoption strategies into their production process, invested in production process infrastructure, web and smart applications development and retail stores. This company has also a dedicated R&D department for proper innovation management across the enterprise. The interviewee described their practices as the followings:

We use 3D printings for the doors and robotics for the board productions. /---/ Yes, we had to make some investments. We are also investing right now to various projects regarding this. /---/ Our top management is very interested to install new technology whenever we have the chance. /---/ Yes, we have a separate R&D unit for that. They work on how to add value to our business process and which technologies can be implemented for better production and product delivery system. (Interviewee #10)

Besides, Lichtblau et al., (2015) refers that smart product dimension of the readiness model focuses on ICT add-on functionalities and data analytics in usage phase. From the interview we identified that this company uses Barcode technology to track the products during the different phases of the production process. They also use ICT add-on functionalities like the hot press machine, sanding machine and conveyer belt that are enabled to exchange information with each other in the production process. The interviewee shared the following views about their product dimension:

We have some hot press machine, sanding machine and conveyer belt that can communicate with each other. /---/ This is a new addition to our product. Recently, we have implemented the

barcode in our system. Specially, in the Board production by which we can track and see details of a production lot in the production line. (Interviewee #10)

In addition, the smart operations dimension of the readiness model gives attention on the implementation of information sharing, autonomous process, IT security and cloud usage (Lichtblau et al., 2015). While asked about the implementation of these features in their production process the Interview expressed that they use 'Oracle' ERP system by which information is shared across different departments of the company. They have IT security systems to protect confidential manufacturing information but they do not have either any cloud-based information system used for manufacturing or any machine that can perform task autonomously. He puts it as mentioned below:

No, we don't have that sort of autonomous machine in our production plant. /---/ No, we do not use any cloud-based information system in our manufacturing process. /---/ Yes, we use 'Oracle' ERP system by which we can keep track of our inventory materials digitally. /---/ Yeah, for data, our IT team maintains the security of it. (Interviewee #10)

Moreover, equipment infrastructure, IT systems, data usage and digital modeling are the areas that are taken into consideration while assessing the 'smart factory' dimension of the readiness model (Lichtblau et al., 2015). While putting light on it we explored that this company has a well-developed equipment infrastructure to produce such variations of furniture under one umbrella. It was possible because they have integrated cyber-physical systems, their factory is well connected through internet, they have digital models like ERP system, website and smart applications to share data with their business stakeholders and they use robotics technology as described by the Interviewee 15. In this regard, he describes the followings:

Yes, we have a website through which customer can view our products, their features, their prices, sales promotion offers and buy according to their needs. We also have launched a smart application by which customers can also see products, compare their prices, view retailer's information and customize door placement in any indoor room using the augmented reality technology (Interviewee #10)

It is important to mention that we have noticed a well-structured equipment infrastructure in their production facility while conducting our observation. They had multiple inter connected machines, robotics technology and multiple layers of conveyers to pass products from one phase to another during the production process.

Figure 22: Interconnected UPVC Board Cutting Machines (Company 'J' Factory Premises)

Furthermore, data driven services is also an important dimension of the readiness model prescribed by Lichtblau et al., (2015) which gives attention to data driven services, share of data used and share of revenues. During the interview we identified that this company have adopted data driven services among their business stakeholders. Through the usage of ERP system necessary information related to the raw materials are shared with suppliers and through website and smart applications communication is maintained with customers. As customers can view products and buy from online application and website, so revenue is also generated significantly. The Interviewee explains these concepts as mentioned below:

Yes to a certain portion they have the access. Our suppliers get information regarding which raw materials are required for production and the retailers or showroom owners get information regarding which finished goods are ready for display in their outlets. However, Customers do not have access to information regarding our manufacturing process but they can customize their products options by visiting our showrooms. /---/ As I have already told you that customers can order our products through our website so yes, through our website we generate a good amount of revenues yearly (Interviewee #10)

However, the last dimension of the readiness model is 'employees' that is determined by the degree of available employee skill sets and skill acquisition timeline of a company (Lichtblau et al., 2015). From the interview we understood that more than half of the employees of this company has the necessary skills to run this cyber-physical manufacturing operation successfully. Though they are given training on a regular basis still sometimes it becomes necessary to hire new employees from outside. The interviewee puts it as-

Well, I would say 60% of the employees have the capability to run the operation successfully. /---/ The training is a continuous process in our company but the HR also recruits new people sometimes. (Interviewee #10)

From the above discussion we can state that as this company has incorporated industry 4.0 into its strategic orientations, investment has been made in few areas of the business, automated data collection is possible due to usage of ERP system, both internal and external communications are maintained with business partners due to the availability of data driven services, IT solutions are available to protect data and products are manufactured with IT based add on functionalities, based on the readiness model introduced by Lichtblau et al., (2015) this company fits the requirements of 'Intermediate' level.

Challenges of Industry 4.0 implementation in Company 'J':

Based on the Technology-Organization-Environment framework introduced by Tornatzky and Fleischer (1990) we have tried to identify what challenges were faced by this company at the organizational, technological and environmental level while implementing industry 4.0 technology in the manufacturing process. It was found that at the organizational level they did not face much challenge as their management was keen to adopt new technologies and as they have around ten thousand employees it was not hard for a company of such size to adopt new technologies. While asked regarding the organizational challenges with focusing on the financial part the Interviewee responded like this:

That is a very common thing as these techs are very expensive, but we always try to manage funds and get the latest tech. /--/ Our top management is very interested to install new technology whenever we have the chance. (Interviewee #10)

Apart from that, focus was given to identify the technological challenges where we found out that this company faced some crucial technological challenges among which the lack of employee skills, lack of technological infrastructure process changes became difficult and unavailability of advanced technology locally were significant. As the Interviewee described the technological challenges in such way:

They faced some difficulties initially, but our team is very good, they give us good support and with proper training they manage it perfectly. /---/ To me teaching new tech to people is the hardest thing. We get training from the foreigner, and we apply this to our production. To me learning new tech in short time the most difficult things. So that means technological problem or adoption is the main or most difficult problem that we faced so far. (Interviewee #10)

Again, they also faced some challenges from the environmental factors like competitors, government regulatory bodies and other external factors like pandemic COVID-19. The interviewee mentioned that they are always under pressure from their competitors and they did not receive any financial or technological support from the government while implementing new technologies. The interviewee responded to the challenge of competitors and technological or financial support from the government as the follows:

Yes, of course! /--Maybe we get some facilities from the government on this, but I'm not sure about that. (Interviewee #10)

So, in short, we can say that technological challenge was the most difficult challenge faced by Company 'J'.

Impact of COVID-19 in the adoption process of Industry 4.0 in Company 'J':

According to TOE framework by Tornatzky and Fleischer (1990) COVID-19 pandemic can be considered as an external environmental factor which has also affected the production process of Company 'J', especially due to the lack of human resources. The interviewee also responded that they have not adopted any new Industry 4.0 technology during this pandemic but they have plans in post COVID-19 situation to adopt new technologies. While asked about the unemployment issues due to automation the Interviewee responded in the following statement:

We have plan for people who might lose jobs due to automation. We are a big company with lots of sectors in our production line. We actually appoint the people who lose they're in other sector so that they have the opportunity to work with us (Interviewee 15)

Thus, we can conclude that, COVID-19 has opened our eyes and companies like Company 'J' also has plans to move towards automation in order to tackle pandemic like this in future.

Chapter 5: Discussion

In this chapter we are going to summarize the analysis of our empirical findings and provide answers to our research questions.

5.1 Summary of readiness status of Industry 4.0 in the manufacturing industries of Bangladesh:

According to the readiness model of industry 4.0 by Lichtblau et al., (2015) there are six levels of readiness which are Level 0: Outsider, Level 1: Beginner, Level 2: Intermediate, Level 3: Experienced, Level 4: Expert and Level 5: Top Performer. Based on the six dimensions of readiness models which are strategy and organization, smart operation, smart product, smart factory, data driven services and employees we have analyzed the readiness status of ten manufacturing companies of Bangladesh from cement, FMCG, food and beverage, automobile, pharmaceuticals, readymade garments, footwear, furniture and electrical appliance industry.

From our analysis it has come to light that companies of readymade garments, automobile industry and FMCG industry falls into the 'Beginner' category. On the other hand, companies cement, electrical appliance, food and beverage, pharmaceuticals, footwear and furniture industry fall into the category of 'Intermediate' category according to the readiness model of Industry 4.0 by Lichtblau et al., (2015). Lichtblau et al., (2015) further described in their readiness model that companies once categorized into these six levels can further be characterized into three levels which are new comers, learners and leaders to give an overall idea of the manufacturing industry. In order to understand the readiness status of the manufacturing industry of Bangladesh we need to portray the overall picture of the industry which can be explained in the following:

1) **Newcomers:** Lichtblau et al., (2015) states that when manufacturing organizations fall under the Level from 0 to 1 of the readiness models then they would be considered as newcomers. According to our analysis the companies of readymade garments, automobile and FMCG industry can be considered as new comers as they have fall into the Beginner level of the readiness model. The readymade garments industry is still human labor oriented as human labor is cheap in Bangladesh the readymade garments manufacturer highly rely on them. But they have started to bring some advanced technologies and machineries into their production process which will bring benefits to them in the long run. On the other hand, the automobile industry of Bangladesh is not that big and this market is highly penetrated by importing brand new vehicles and reconditioned vehicles from foreign countries. As a result, the market becomes even more saturated for the local assemblers or manufacturers and which is why they are still depending on human centric assembly plants. If the production volume expands the manufacturing companies in this industry can also implement high end industry 4.0 technologies for large amount of production in short period of time. It can be seen from the case of Company 'F' that they have plan to develop a new automobile manufacturing plant which will be equipped with state-of-the-art

technologies. And finally, if we put our focus on the FMCG industry of Bangladesh it can be seen from the case of Company 'E' that they are the first one to bring automation to the FMCG sector specially in the flour and food grain industry. Before that there was no automation in this industry which is why these companies have met a beginner level requirement of implementation of Industry 4.0. The companies in the automobile, readymade garments and FMCG industry have high potential to expand the implementation process of Industry 4.0 in the future.

2) **Learners:** According to Lichtblau et al., (2015) learners are those companies which falls under the 'Intermediate' level based on the readiness model of industry 4.0. Based on our analysis we have realized that the companies of cement industry, electrical appliance industry, food and beverage industry, pharmaceuticals industry, footwear and furniture industry can be considered as learners. Company 'A' of the cement industry of Bangladesh showed high potential by establishing world's largest single unit Vertical Rolling Grinding Machine in their manufacturing process. Their factory is well equipped with cyber physical systems and supervisory control and data acquisition system. Again, Company 'B' and 'C' of the electrical appliances industry have realized the importance of industry 4.0 technology in their production process specially as they are the manufacturers of sophisticated and complex electrical appliances products. The electrical appliances industry is booming with millions of possibilities to maximize profit. The companies in this lucrative industry thus need to adopt more advanced technologies so that manufacture quality electronics products at a shorter period of time. Moreover, Company 'D' of the food and beverage industry has also put industry 4.0 technologies into its strategic orientations and they are constantly bringing new innovative technologies to their production plant to produce more quality beverages products so that by fulfilling the demand of the local market they can export internationally. Furthermore, the pharmaceuticals Company 'G' and footwear company 'I' are also not falling behind as they also have implemented cloud-based information systems in their production process. Lastly, Company 'J' from case 10 gave us insight they have introduced additive manufacturing process with the help of augmented reality so that customers can customize their door designs virtually through smart applications. These multiple case study shows that the electrical appliance, food and beverage, pharmaceuticals, footwear and the furniture industry will soon become not only automated but autonomous within very short period of time if their progress continues like this.

3) **Leaders:** Companies that falls under the Level of 3 to 5 which means Experienced, Expert and Top Performer they are considered leaders of the industry in implementing industry 4.0 technologies. Unfortunately, among the ten case studies we have not found any company which falls under these categories. Actually, the adoption of industry 4.0 technologies is emerging in the different manufacturing industries of Bangladesh and in near future the learner companies will become the leaders eventually due to this rapid technological progress.

5.2 Answer to Research Question 1:

Our first research question was what is the current state of Industry 4.0 in the manufacturing sector in Bangladesh? In regards to that based on our analysis and above discussion we can state that readymade garments, automobile industry and FMCG industry of Bangladesh have started to adopt the industry 4.0 technologies as beginners or newcomers. They have either planned or initiated some sort of automation in their respective industries. They are at the very initial stage of adopting these disruptive technologies. On the other hand, cement industry, electrical appliance industry, food and beverage industry, pharmaceuticals industry, footwear and furniture industry of Bangladesh have advanced to some good extent in regards to implementing industry 4.0 technologies. They have initiated automation at different areas of the production level and now they are heading towards autonomous manufacturing in the coming days.

5.3 Summary of challenges of implementing industry 4.0 in manufacturing Industries of Bangladesh:

According to the Technology-Organization-Environment Framework developed by Tornatzky and Fleischer (1990) we identified some of the challenges that might be faced by manufacturing companies while adopting new technology at organization, technological and environmental context. From the ten case studies on the manufacturing industries of Bangladesh we found out that companies face different challenges at organization, technological and environmental context. Based on the analysis of those case studies the following table has been prepared to identify the crucial challenges that are faced by companies at organization, technological and environmental context at present.

Challenges	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Total Response
Lack of resource and support from top management (CH1)	No	No	No	No	No	Yes	No	No	No	No	1
Lack of digital culture (CH2)	No	No	Yes	No	No	Yes	No	No	No	No	2
High implementation cost (CH3)	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	8
Lack of trained staff (CH4)	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	7
Complexity of process changes (CH4)	No	No	Yes	No	No	Yes	No	No	Yes	No	3
Lack of technological	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	7

infrastructure (CH5)											
Lack of technical expertise of employees (CH6)	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	7
Time Constraint to adopt new technology (CH7)	No	No	Yes	No	No	No	No	No	No	Yes	2
Cyber security issues (CH8)	No	No	No	No	No	No	No	No	No	No	0
Lack of support from government (CH9)	No	No	Yes	No	No	Yes	No	No	No	Yes	3
Pressure from competitor (CH10)	Yes	No	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Legal uncertainty (CH11)	No	No	No	No	No	Yes	No	No	No	No	1
External environmental factors (CH12)	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	No	6

Table 3: Challenges faced in manufacturing industries of Bangladesh (own illustration)

From the above table we can see that in the organizational context high investment cost to implement any industry 4.0 technology has been the most crucial challenge in the manufacturing industries of Bangladesh as 8 out of 10 companies mentioned they have faced financial difficulties to invest in Industry 4.0 technologies implementation in the manufacturing process. Lack of trained staff has also been a significant challenge in the organizational context as 7 out of 10 companies have mentioned that they have suffered in the implementation of Industry 4.0 technologies due to lacking in sufficient trained staff available in the industries.

On the other hand, in the technological context we have seen that lack of technological infrastructure and lack of technical expertise have been the vital impediments to adopt industry 4.0 technologies as 7 out of 10 companies mentioned these barriers as crucial in the technological context. From the analysis also we realized that most of the latest industry 4.0 technologies and the relevant technologies are not available in Bangladesh and manufacturing companies have to import these machines and technologies from abroad in exchange of hefty amount of money which becomes a big issue for small and medium enterprises of the company to get the benefits of these technologies.

Apart from that, in the environmental context we can see that lack of government support has been very significant to manufacturing companies. It is important to mention that as this research was carried out during the COVID-19 pandemic 6 out of 10 companies mentioned that they have faced problems to implement new technology because of the COVID-19 pandemic.

5.4 Answer to research question no 2:

Our second research question was what challenges were faced while implementing Industry 4.0 technologies in the manufacturing industries of Bangladesh. In regards to that, based on the analysis of our findings we can state that manufacturing industries of Bangladesh have faced crucial challenges like high investment cost, lack of trained staff, lack of technological infrastructure, lack of technical expertise, lack of government support, lack of digital culture, complexity of process changes and time constraints to adopt new technology, especially Industry 4.0 technologies.

5.5 Summary of impact of COVID-19 on the adoption process of industry 4.0 in manufacturing Industries of Bangladesh:

The recent outbreak of global pestilence COVID-19 has affected the production process of almost every country around the world to some extent. Bangladesh, a small South Asian country is no exception from that. COVID-19 has hampered the manufacturing process of different industries. From our empirical findings we can see that Company 'A' of the cement industry of Bangladesh has been affected by this pandemic but they did not implement any new technology during this pandemic rather they have realized the importance of having industry 4.0 technologies for which they are going to implement new technology in post COVID-19 situation.

Similarly, Company 'B' of the electrical appliance industry faced a major production drop due to lack of human involvement in their refrigerator production line. They soon managed the situation by activating the pre-obtained Industry 4.0 technologies that were not installed in the plants before the pandemic. Again, Company 'C' of the electrical appliance industry faced problem due to lack of raw materials and human resources but as they had pre-installed automation with the help of Industry 4.0, they continued their production process.

However, Company 'D' of the food and beverage industry implied that they did not adopt any new technology neither do they need to adopt any new technology in post COVID-19 situation as they already have good amount of automation running by dint of industry 4.0 technologies which will make them sustain in the business easily in the coming couple of years. Again, any new industry 4.0 technology was not adopted to mitigate the loss caused by COVID-19 in Company 'E' and they even do not have any plan to take preventive initiative for future.

Moreover, from our findings we got insight about Company 'F' which is a company in the automobile industry of Bangladesh that due to lockdown and delay in international trade

transactions this company suffered due to lack of raw materials and production workers. At that point of time, they realized the importance of having automation could help them. But they did not have the technological infrastructure to adopt new industry 4.0 technology at that moment for which they have plan to adopt the new technologies in post COVID-19 situation.

Furthermore, empirical data analysis of Company 'G' and Company 'I' showed us that though they have been affected by the pandemic they did not adopt any technology during the pandemic but they have plan to integrate more automation with the help of industry 4.0 technologies to avoid problems related to pandemic like this in future.

Lastly, it can be stated that the readymade garments industry which is very human centric have suffered a huge loss due to this pandemic situation and so organizations of this industry like Company 'H' have made plans to adopt industry 4.0 technologies in the future. And likewise, COVID-19 pandemic came as a lesson to many manufacturing companies like Company 'J' which has also made plans to move towards automation in order to tackle pandemic like this in future.

5.6 Answer to research question no 3:

Our third research question was 'does the pandemic COVID-19 have any impact on the adoption process of Industry 4.0 technologies in the manufacturing industries of Bangladesh?' From the analysis of our findings, we can answer that COVID-19 has affected almost every industry of Bangladesh more or less. Some industries tackled the situation successfully and quickly for having some sort of automation in their manufacturing process. But some of the industries faced big problems related to their production process for not having advanced automated technologies which could minimize the loss. Few manufacturing organizations from the cement, electrical appliance, food and beverage and FMCG industry did not adopt any new industry 4.0 technology during the pandemic as they already had some sort of automation in their manufacturing process. On the other hand, manufacturing organization from the automobile industry though affected by COVID-19 pandemic could not adopt any new technology related to industry 4.0 due to lack of technological infrastructure and government support. However, manufacturing organizations of the pharmaceuticals, readymade garments, footwear and furniture industry of Bangladesh have been affected by COVID-19 and this pandemic has triggered their plans to adopt industry 4.0 technologies in post pandemic situation.

Chapter 6: Conclusion

This final chapter aims to conclude our research by presenting the societal implications, theoretical contributions and future research areas.

6.1 Conclusion

Civilizations have been hailed throughout ages for their uniqueness in the fields of innovation. Yet we have arrived at a point where global standards dictate our success rate and we are bound to imitate them. Consequently, we are witnessing a fall- not a fall of innovation or ideas, but a fall of acceptance. Such reluctance to accept technological change in developing countries is persisting due to the financial unfeasibility. Couple that with lack of expertise and infrastructural problems, and we have got ourselves in a tunnel where the light at the end is barely visible. But it is visible nonetheless. Because in this study, we have seen multiple industries in Bangladesh using automated process and it may be a strong indicator towards development. But for an overall growth in the ever-changing industrial landscape, Industry 4.0 technologies are the future and Bangladesh still struggles to implement them due to the aforementioned reasons.

This is where the fall of acceptance comes in. With the widespread adoption of cutting-edge digital systems and automated machineries, anything less in industrial production is considered primordial methods. This is the great dilemma of third-world countries in terms of industrial progress and it is very perspicuous. Incentives to adopt more and more technologies in the manufacturing process is undoubtedly high. But Bangladeshi companies are hesitant about the risks and unwilling to come out of their comfort zones. They are still not willing to gamble huge chunks of investments in order to conform to the novelties the 21st century offers. Despite that, conglomerates dominating their respective markets have come forth in implementing Industry 4.0 technologies. Because they understand that modern technologies are no longer luxurious, but necessary to maintain production of international quality, even more so in this era of the COVID-19 pandemic.

Ergo, the study on the readiness status and challenges of implementing Industry 4.0 technologies in the evolving dynamics of Bangladesh to properly understand the possibilities this country has and the barriers it faces even today. As mentioned earlier, the light at the end of the tunnel may be dim but the narrowing path may lead Bangladesh to an epoch of enlightenment.

6.2 Societal Implications

Implementation of Industry 4.0 technologies in under-developed countries like Bangladesh is troublesome to say the least. Plagued by illiteracy and financial constraints, these countries are in dire need to embrace certain regulations before they can achieve automation in their production. These are as follows:

Firstly, vocational training programs should be influenced besides regular academic curriculum for the purpose of skill development.

Secondly, Bangladeshi government should improve ICT sectors for the ease of educating the mass population in order to operate relevant technologies. This requires additional allocation of budget in the ICT sectors.

Thirdly, government should focus on providing tax benefits to small and medium sized industries on importing machines from abroad. Apart from that, more export processing zones should be established for newer ventures along with the reformation of regulatory policies to ensure smooth transition of such companies towards sustainable production in the foreseeable future.

Fourthly, new power stations or green power plants should be established for renewable energy and digital production in the coming years. Infrastructural development is heavily essential to materialize these concepts.

Fifthly, creating mass awareness about Industry 4.0 technologies and their advantages can encourage adoption of these groundbreaking facilities despite the cost. So, the Bangladeshi government must preach the wonders of modern technologies to the local industries

Lastly, government should inspire further research & development projects to manufacture automated machines and digital systems locally. So that domestic enterprises can afford these technologies with ease and implement them in their production lines without constantly worrying about the return on investment.

6.3 Theoretical Contribution

The research on the readiness status of implementing Industry 4.0 in the manufacturing sector of Bangladesh is a pioneering study in this field as no research has been conducted on the readiness status of Industry 4.0 technologies in context of Bangladesh. So, this thesis will significantly contribute to future researches on this topic. We have found minimal information as exhibited in the literature review that caused huge research limitations. This paper has the potential to be used as future references for academic and pragmatic purposes.

This paper has also focused on pointing out the various challenges that local companies here face even 2021 while implementing Industry 4.0. Consequently, it will be an asset for the overall development of Bangladeshi manufacturing industries, encouraging adoption of automation in local companies. The in-depth analysis further stretches up to the global pandemic of COVID-19 to better understand the importance of automation and how to deal with such crises. We have summarized how Industry 4.0 will increasingly contribute to the replacement of manual labor with distant controlled operations and automation, ensuring health security in times of such harrowing pestilence.

So, this thesis paper will be a hallmark for Bangladesh in efficiently utilizing finite natural resources and implementing advanced technologies with a view to increasing productivity and profitability.

6.4 Future Research Areas

Much work remains to be done in the domains of Industry 4.0 and post-COVID-19 scenario to improve the research area, regardless of what has been accomplished in prior researches and what this study contributes. We have conducted our research in the middle of a pandemic and we have faced a great obstacle to collect data due to restrictions and safety issues. There are various opportunities for future research in this regard. These are as follows:

- Focus on the transformation of manpower into "Smart Operators" for factory work due to digitalization.
- Unemployment issue or lack of low and medium skilled job positions due to automation.
- How Industry 4.0 will lead to circular economy for resource optimization.
- How Industry 4.0 will help to ensure sustainability in developing countries.
- More research opportunities regarding the post-COVID-19 scenario.

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Appendix 1: Draft Email to Case Company

Dear Sir,

Hope this mail finds you well.

I am M Nafees Emtiaz Chowdhury, currently pursuing Master of Service Management with specialization in Supply Chain Management from Lund University, Sweden. Me and my research partner Mr. Golam Kibria need to carry out a thesis research project to accomplish our Master Degree. On behalf of my research partner, I am giving you this mail. We humbly seek your kind permission to take an interview with any of your concerned personnel regarding the manufacturing process of your renowned company via Zoom. If given permission we would also like to visit your factory to gather practical knowledge regarding the manufacturing process.

Our research topic is "Industry 4.0: Assessing the readiness, implementation challenges and impact of COVID-19 in the manufacturing industries of Bangladesh''. I have attached the interview questions herewith for your kind perusal. Most importantly, we would like to assure you that the information which you will share will be kept strictly confidential and will be used only for academic research purposes.

Thus, it will be so nice of you if you could go through the questions at once and let me know which time will be convenient for you to give the interview via Zoom and also allow me to visit your factory someday soon. I will share the Zoom link accordingly.

Looking forward to your prompt reply.

Kind regards,
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Appendix 2. Case Study Protocol

Purpose:

The purpose of this research is threefold. Firstly, we aim to explore the readiness status of industry 4.0 in the manufacturing industries of Bangladesh. Secondly, we want to identify the challenges associated with the implementation of industry 4.0 in the manufacturing industries of Bangladesh. Finally, we want to scrutinize the impact of pandemic COVID-19 on the adoption process of Industry 4.0 in the manufacturing industries of Bangladesh.

Case Study Questions:

The purpose of this case study was to get answer of the following three research questions of this study:

RQ1: What is the current state of Industry 4.0 in the manufacturing sector in Bangladesh?
RQ2: What challenges were faced while implementing Industry 4.0 technologies in the manufacturing industries of Bangladesh?
RQ3: Does the pandemic COVID-19 have any impact on the adoption process of Industry 4.0 technologies in the manufacturing industries of Bangladesh?

Theoretical Framework:

The following theoretical framework are selected to analyze the empirical data and answer the research questions:

1. IMPULS Industry 4.0 Readiness Model
2. Technology-Organization-Environment Framework

Data Collection Plan:

The companies which have agreed to take part in this study are all manufacturing companies of different industries of Bangladesh. The researchers have reached the respondents via email communication. Upon prior permission the researchers have conducted semi-structured interviews with the company respondents and visited their factories for structured observation. The collected information was then transcribed and coded for further analysis.

Research Preparation:

In order to perform several case studies, the researchers used a literature review, semi-structured interview, and structured observation to gain an in-depth understanding of the research problem.

Appendix 3: Interview Guide

Master Thesis Title-

'Industry 4.0: Assessing the readiness, implementation challenges and impact of COVID-19 in the manufacturing industries of Bangladesh'

Master of Service Management, Lund University, Sweden

Researchers: M Nafees Emtiaz Chowdhury and Md Golam Kibria

Semi-Structured Interview Questions:

General Questions:

Q. What is your name?
Q. What is the name of the company you are currently working?
Q. What is your position in the company you are currently working?

**** (Questions related to Readiness Status of Industry 4.0)**

Q1. What products are being manufactured by your company**?**
Q2. What do you understand by the term industry 4.0?
Q3. Do you use any Industry 4.0 technologies like (Cyber Physical systems, Internet of Things (IoT), Cloud manufacturing, Robotics, 3D printing) etc. in the manufacturing process of your company?
Q4. What was the purpose to implement any Industry 4.0 technologies in the manufacturing process in your company?
Q5. Did you have to make an investment to implement any IT technology in your manufacturing process?
Q6. Is your factory connected internally through the internet?
Q7. Do your products carry any communication sensor like RFID or barcode by which it can be tracked during the manufacturing process by the machines or personnel?
Q8. Does any of your machines in the production line has the capability to communicate and exchange information with other parts of the production line?
Q9. Can you operate any machine in your production line from distance?
Q10. Do you have any machine in your factory that can perform a task in the manufacturing process autonomously?

Q11. Do you use a cloud-based information system for your manufacturing process?
Q12. Can you track the movement of inventory materials in the production line digitally?
Q13. Has the production efficiency been improved after implementing new IT technologies?
Q14. Does adapting to this new innovative technology gave you any advantage over your competitors?
Q15. What do you think about the IT security system in your company? Are your data safe and responsive or not?
Q16. Do you manage any information sharing system by which data can be shared across the different departments of the organization?
Q17. Do your existing employees have the required expertise to operate the IT system?
Q18. Did you hire any new skilled employee or provided training to your existing employees to adapt with the IT embedded manufacturing system?
Q19. Do your company have a specific R&D department for innovation management?
Q20. Do you have any website or smart application through which customers can view products and their features, customize or order products?
Q21. Do your supplier, retailer or customer have access of information to your manufacturing process?
Q22. Do you generate any revenue through sharing data with your stakeholders?

**** (Questions related to Challenges of Industry 4.0 implementation)**

Q23. How many employees are there in your organization?
Q24. What was your top management's view regarding the decision of implementing any new technology system?
Q25. What was your existing employees' attitude towards change? Was it positive or negative?
Q26. Have you faced any financial challenges while investing in the new the IT system/machine?
Q27. Did your existing employees face any difficulties technologically to adopt the new IT system?
Q28. How much time did your employees require to adapt to the new IT system in your company?
Q29. Did you face any legal policy related pressure from government to implement any new technology?
Q30: Did you feel any pressure from your competitor to adopt a new IT technology in your manufacturing system?
Q31. Was there any financial or technological support from the government to adopt the new technology?
Q32. Did you have to import the new IT technology from abroad or it was available in the local market?
Q33. Did you face any complexity while shifting from your traditional operation to automation process?

Q34. According to your experience, which is the most difficult challenge that you faced while implementing any IT technologies in your company?

**** (Questions Related to Impact of COVID-19 in the manufacturing process)**

Q35. Has your manufacturing process being hampered during the COVID-19 pandemic?
Q36. Did you face any problem in your manufacturing process due to lack of human resource during the COVID-19 pandemic era?
Q37. Do you think having some sort of automation in your manufacturing process could help you fight the COVID-19 pandemic in a better way?
Q38. Have you adopted any IT technology or used any machine to reduce the human interaction for safety issues during the COVID-19 pandemic?
Q39. Do you have any plan to implement new IT technology to reduce human interaction in post COVID situation?
Q40. Do you have any plan regarding the unemployment of employees due to automated manufacturing process?