The Fourth Industrial Revolution in Apparel Industry: Opportunities and Challenges for Bangladesh

A Thesis Submitted to the Department of Management in Partial Fulfillment of the Requirements of the Degree of Doctor of Business Administration (DBA)

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November, 2022

Doctor of Business Administration (DBA)

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Acknowledgment

First, I express my profound gratitude to the most beneficent and the most merciful Almighty Allah for blessing me with the opportunity to undergo the DBA program at the University of Dhaka under the supervision of Prof. Ali Akkas, Department of Management. I am grateful to Almighty for guiding me toward the path of peace and prosperity.

I am heavily indebted to my thesis advisor, Prof. Ali Akkas, Department of Management at the University of Dhaka for his continuous support, valuable guidance, and inspiration to accomplish my research. His whole-hearted support and cooperation paved the way for my journey toward warding the research report.

I would like to thank Prof. Dr. Faruq Ahmed, Dr. Md. Ataur Rahman Khan, Prof. Ali Ahsan, late Dr. Syed Golam Maola, Dr. Shyam Sundar Karmaker, Department of Management and Dr. Md Shariat Ullah, Department of Organisation Strategy and Leadership University of Dhaka who were involved in the validation of this research work, without their passionate involvement and input, the research could not have been supplanted. I would like to thank the rest of the thesis committee members and other Department of Management personnel for their cooperation.

I might want to thank those specialists and RMG expert Md. Alimuzzaman, Dr. Kazi Mahmudur Rahman, Kishore Kumer Basak, Engineer Rupali Biswas, and Engineer Azim Mohammad who provided me with valuable responses and technical support for my research.

Finally, I must express my profound gratefulness to my parents, my husband Sheikh Muhammad Muzibul Alam, my daughter Afrida Mahzabin, my siblings and siblings-in-law, my parents-in-law, and my uncle Sheikh Farid Ahmed for their continuous support and encouragement.

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DEDICATION

Humbly dedicate to my dearest parents

Declaration

I, hereby, affirm that the dissertation entitled "The Fourth Industrial Revolution in Apparel Industry: Opportunities and Challenges for Bangladesh" and the presented study have been completely executed by me from both field survey and empirical perspectives. The study holds the potential to become an important addition to the existing field of knowledge regarding the subject at hand. With absolute humbleness, I submit this thesis to the Department of Management, the University of Dhaka, Bangladesh, for the achievement of the degree of Doctor of Business Administration (DBA). I must also state that the writings and comments of this thesis have neither partly nor fully been submitted to any other institutions for obtaining an academic degree or diploma.

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Letter of Transmittal

29 November, 2022

Prof. Md. Ali Akkas
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Subject: Submission of Thesis paper for the degree of DBA titled "The Fourth Industrial Revolution in Apparel Industry: Opportunities and Challenges for Bangladesh".

Dear Sir,

Please find the enclosed Thesis Paper titled "The Fourth Industrial Revolution in Apparel Industry: Opportunities and Challenges for Bangladesh" as the final requirement for the degree of Doctor of Business Administration, University of Dhaka, Bangladesh.

May I further state that I am always ready to deal with any sort of query at your end.

Very sincerely yours,

Sadia Sharmin
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Certificate

With great delight, I certify that the dissertation entitled "The Fourth Industrial Revolution in Apparel Industry: Opportunities and Challenges for Bangladesh" has been proffered by Ms Sadia Sharmin, Doctor of Business Administration (DBA) Candidate of the University of Dhaka and Joint Secretary of Finance Division, Ministry of Finance. This thesis report has been prepared through field study analysis and empirical research. Authenticity and viability have been preserved all throw throughout the research, augmenting relevant researchers' knowledge spectrum of individuals involved in the realization of this research. I have meticulously looked into the draft and the final version of the thesis report and found it satisfactory for submission to the Department of Management, the University of Dhaka for the fulfillment of the degree of Doctor of Business Administration (DBA). To the best of my knowledge, no fraction of this thesis has been presented elsewhere for attaining an academic degree or diploma. I deem, that this work fulfills the requirements of the DBA thesis. She is allowed to submit the thesis in its present form. Therefore, I recommend that Ms. Sadia Sharmin may be awarded the degree of Doctor of Business Administration.

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Abstract

Over the past decade, the world is heading towards the fourth industrial revolution or Industry 4.0 (or IR 4.0), with many countries adopting the latest innovations and technological upgrades which essentially are meant to meet the growing demands of consumers in every sector of an economy. Since the concept of IR 4.0 is still quite new, its definitions and theories are mostly curved out as per the requirements and ambitions of each nation. However, some core elements of IR 4.0, for instance, the idea of smart factories, can be found in every established theory, and are readily explored in this thesis. Before execution though, a readiness model, again subjective to each country, is constructed to accurately chalk out the roadmap for the adoption of IR 4.0. Against such premises, this thesis aims to find out whether the apparel industry of Bangladesh is ready or not to embrace the fourth industrial revolution. This is because, Bangladesh, too, due to its impressive economic growth in the recent past, a change in her status of development, and her vision of becoming a developed country by 2041, is considering harnessing the benefits. In addition, the sector which will be most impacted by such a move is the apparel industry because of its massive contribution to the economy, making it the flagship industry of the country.

The thesis first looks into the existing theories and concepts regarding IR 4.0, and then utilizes the "Industry 4.0 Readiness" model developed by the Association of Germany's Engineering Industry (Verband Deutscher Maschinen- und Anlagenbau (VDMA)) as the guiding framework for devising an original, suitable, readiness model to evaluate 135 apparel/RMG factories (big, medium and small) of Bangladesh. A mixed methodology approach is followed in the thesis, implying the utilization of both quantitative and qualitative tools.

The findings of the thesis, if broadly put forth, reveal that the apparel industry of Bangladesh is still not ready to implement IR 4.0. The thorough evaluation of the thesis comprising of different variables and parameters suggests that the majority of the factories are at an intermediate level in terms of IR 4.0 readiness index. The results of the thesis call for further attention from the industrialists, policymakers and academicians as well toward understanding first where Bangladesh stands in the face of fourth industrial revolution before hastily implementing it.

***Keywords*:** Apparel industry, Bangladesh, Fourth Industrial Revolution, IR 4.0, Readiness, VDMA

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Acronyms

IR 4.0	Fourth Industrial Revolution
RMG	Ready-made garment
PLCs	Programmable Logic Controllers
CPS	Cyber-Physical Systems
ICT	Information & Communications Technologies
EPB	Export Promotion Bureau
NTPA	National Tripartite Plan of Action
GSP	Generalized System of Preferences
CPD	Centre for Policy Dialogue
LDC	Least Developed Country
GTAI	Germany Trade and Invest
FoF	Factory of Future
IoT	Internet of things
IT	Information Technology
ADB	Asian Development Bank
ILO	International Labour Organization
IMF	International Monetary Fund (IMF)
UNCTAD	UN Conference on Trade and Development
UNIDO	United Nations Industrial Development Organization
UNDP	United Nations Development Programme
OECD	Organization for Economic Co-operation and Development
TFP	Total Factor Productivity
APS	Automation-prone Sector
ARS	Automation-resistant Sector
GDP	Gross Domestic Product
3G	3rd Generation
4G	4th Generation
VDMA	Verband Deutscher Maschinen-und Anlagenbau (Association of Germany’s engineering industry)

SIRI	Smart Industry Readiness Index
M2M	Machine-to-machine
MOCI	Ministry of Industry and Trade
MES	Manufacturing Execution System
TVET	Technical and Vocational Education and Training
STEM	Science, Technology, Engineering, and Mathematics
NVQ	National Vocational Qualification
ERP	Enterprise Resource Planning
RFID	Radio Frequency Identification
3D	Three-dimensional
SMV	Standard Minute Value
GSD	General Sewing Data
BBA	Bachelor of Business Administration
MBA	Master of Business Administration
NIP	National Industrial Policy
BGMEA	Bangladesh Garment Manufacturers and Exporters Association
KSAs	Knowledge Skills, and Attitudes
CS	Competency Standard
CBLM	Competency-based learning material
NHRDF	National Human Resource Development Fund
RTLS	Real-time location systems
RTE	Real-time Evaluation
AI	Artificial intelligence
ML	Machine Learning
OEE	Overall equipment effectiveness
PLM	Product Lifecycle Management
PDM	Product Data Management
PDA	Production Data Acquisition
CAD	Computer-aided design
SCM	Supply Chain Management

1. Chapter One: Introduction

1.1 Background

There are numerous facts and figures, and subsequent movements in the economy of Bangladesh which are inclined towards a massive potential of growth in technology-driven manufacturing and service sectors in this country in the coming future. To begin with, during the last decade, Bangladesh's economy has maintained 6 to 8 percent (on average) GDP growth rate (Business Inspection, 2021). In the fiscal year 2021-22, the growth rate has surpassed 7.25 percent threshold and now growing at a rate of 7.28 percent (BBS, 2022). Recent estimates from BBS (2022) show that the agriculture sector had the lowest growth in the last six years, which is 2.2 percent of GDP. The growth of the service sector is estimated to have 6.31 percent growth in FY2021-22. However, the growth of the industrial sector slightly went up from 36.01 percent of GDP in FY2020-21 to 37.07 percent of GDP in FY2021-22. Out of the fifteen sectors known to affect national income, manufacturing is one of the most important to overall GDP growth. It uses modern technologies in a big way. BBS (2021-22) says that the manufacturing sector grew 13.7 percent in the fiscal year 2021-22, in the previous financial year (FY 2020-21), it was 18.6 percent (Daily Star, 2022).

Following these growth dynamics, local and foreign investments have been focusing on technological improvements for the last couple of years. For instance, popular local brands like Walton (The Asian Age, 2018) and Aamra Holdings (WE) (The Daily Star, 2017b) have started their state-of-the-art production facilities in Gazipur district and Mirpur area of Dhaka respectively in recent years. Global brands like Symphony, Samsung, and LG have started to kick-off their production operations in Bangladesh (The Daily Star, 2017a). Moreover, according to recent news reports (The Daily Star, 2018), global e-retailer giants like Amazon and Walmart are in negotiation with the government authority to start their operations in Bangladesh in the next couple of years. These movements from different market-leading companies indicate a bright prospective for the future of technology-led manufacturing and service sectors in Bangladesh.

On the other hand, readymade garments (RMG) (in this paper readymade garments industry and apparel industry will be synonymous) sector in Bangladesh, a $38.52 billion industry (Export Promotion Bureau, July-May 2021-2022) and the largest export earner have initiated green manufacturing by establishing 135 eco-friendly green buildings (Dhaka Tribune, 2017), the highest in the world. Keeping up with the blistering technological changes, both the worlds of apparels and fashion are on the verge of a drastic evolution. Technological progress, coupled with innovation, are flooding the fashion landscapes, especially in manufacturing, electronic retailing, mass customization, and consumer expectations. Consequently, it has now become pertinent for the government to design evidence-informed policy instruments for the establishment of green industry, while keeping in line with the existing national laws, rules, and acts associated with the environment, water, electricity, energy, and international standards. Besides, businesses must now strategically pursue a series of changes, both from an organizational productivity perspective as well as from a technologically supportive one.

Recent evidence suggests that technology is pushing the reality into 4th industrial revolution for some countries. Experts argue that 4th industrial revolution will present opportunities to maximize wealth through uninterrupted boost of inclusive GDP, and improve upon social development indicators like education, health, and environment.

Sustaining output growth, achieving employment, and wage growth require technological upgradation and movement up the value chain, and the problems faced by developing country firms in implementing so are quite extensively known. These include problems of (1) funding the purchase of new (hence, riskier) technologies, (2) upskilling workers and employees, and (3) obtaining land for horizontal expansion, especially in locational clusters. Alongside these issues exist the notorious infrastructural constraints, utility supplies, and predictability of policies, and to tackle the overall problems related to technology upgradation, this second set of issues are prioritized while forming policy responses through good governance and by enhancing the practice of investment. International evidence, however, do not deem these initiatives to reap any benefit either in the short or medium term; rather, a thorough understanding of each problem, and a tailor-made solution/policy from the government to tackle that problem is required to find a way forward.

It is about time to take an assertive move towards elevating our level of competitiveness and become compatible with industry 4.0 (or IR 4.0). For us, the big questions are: where are we standing (stages) in terms of industrial revolution? Do we have the right kind of strategies and policies to build an enabling environment? Do we have the exact knowledge, skills, resources, and incentive to implement smart factories? Do we know the impacts of these changes on the economy in general and labor market in particular? Therefore, to understand the depth of the situation, it will require careful consideration of the readiness of the RMG industry to embrace the IR 4.0.

After three industrial revolutions, the world is in the midst of the fourth one, which comprises Cyber-Physical Systems, the Internet of Things, and the Industrial Internet of Things. (We will talk more about these revolutions in the next section.) This revolution comprises technologies and ideas of value chain organization that bring together Cyber-Physical Systems, the Internet of Things, and the Industrial Internet of Things. The German government started this revolution with its "Industry 4.0" movement, and some US multinational corporations called it the "Industrial Internet Consortium." Other parts of the world, like India and China, have since taken up the idea, calling it "Make in India" and "Internet +," respectively (Wan, Wang, Li, & Zhang, 2016).

This fourth industrial revolution aims to change the way things are made in industry by using information and technology and making the most of the benefits of modern innovations. So, an Industry 4.0 production system is smart and flexible, and it lets businesses make more customized products with high efficiency.

Industry 4.0 is of utmost relevance to emerging industrial nations that heavily rely on production and export since it is commonly linked to the evolving process of managing production and manufacturing as well as chain production. Most developing nations, including Bangladesh, Pakistan, India, the Philippines, and Nigeria, rely on the production of goods shipped to other nations or businesses. Therefore, the current rate of unit output would be significantly higher than unit input, which is a crucial, consequent parameter of Industry 4.0 to consider for these countries to move forward if they can adapt to the management of their manufacturing and chain productions, however.

The growth of information technology (IT) throughout all industries, including the primary, secondary, and tertiary industries, may be seen as a logical result of the development of the 4th I.R. Everything seems to have altered because of I.R., from our everyday activities to our means of subsistence to even the structure of our society. The effects of technology are already being felt in the labor market, and they will undoubtedly impact it in the future. For example, technology will make certain jobs obsolete (McKinsey & Company, 2017). According to McKinsey Global Institute (2016), the present technology can automate more than 3/5 of all industrial tasks. Workers' productivity increased by 47% in the USA during the previous 20 years across all industries, mostly due to the adoption and invention of new technologies (U.S. Bureau of Labor Statistics, 2017). According to McKinsey Global Institute's research from 2017, 33% of the new occupations generated in the U.S. during the previous 25 years were almost nonexistent. Self-employment prospects are being created by the most recent methods of service delivery, such as marketplace-based e-commerce platforms (such as the "Uber" model). Technology may be a double-edged sword, increasing productivity and creating new job prospects while replacing some people with automation and contributing to the current unemployment issue.

While there are noteworthy debatable issues both for and against IR, it is safe to conclude that it still quite a new phrase and therefore not homogeneously defined for every nation, which in turn, means a thorough measurement of the readiness of a country of deploying this phenomenon. The West might have been reaping its benefits for some time now, but for countries like Bangladesh, a lot of questions loom in the preparation of embracing IR 4.0. This is specifically because the most significant manufacturing industry of Bangladesh is the apparel sector, which has been predominantly characterized by cheap labour, a feature which seems to be in peril with the supposedly automated IR 4.0 future.

1.2 Industrial Revolutions

Industrial Revolutions have been the driving force of economic development all over the world. These revolutions also shaped the economic and social structure from bringing down the production cost to changing the lifestyle of people. The industrial revolution started with machines that can do simple tasks and now it has been developed into newer technologies with complex activities. This technological development enabled to increase labour productivity and resulted in numerous outcomes and services.

1.2.1 First industrial revolution:

The utilization of steam power initiated the first industrial revolution in the 18th century plus the shift from manual labour to the mechanization of production (George & George, 2020). The country where this revolution originated was the Great Britain, and the phenomenon spread gradually over the whole of Europe. Suddenly, nations began to make the transition from an agriculturally based economy to an industrial one, particularly Great Britain. The famous spinning jenny, which was the novel multipurpose spindle machine for spinning cotton or wool emerged during this time, resulting in the practice of division of labour, laying the foundations of the first modern industry. Workers needed skills not to just use hand tools but also operate machines. Communication and transport system, too, saw drastic progress, thanks to the inventions of the telegraph or the radio or the locomotive. Regions which were getting industrialized attracted a lot of working forces, which eventually, led to the establishment or the advancement of cities (Kumar, Bawge, & Kumar, 2021).

1.2.2 Second industrial revolution:

The second industrial revolution is also known as the technological revolution and was driven primarily by the invention of electricity (Kumar, Bawge, & Kumar, 2021). Beginning in the 19^{th} century, this revolution came about because electricity, as a major source of power, was much more convenient to use rather than water or steam machines, and it enabled businesses to concentrate power supply to certain machines (George & George, 2020). Eventually machines with their own power sources were made which made them more mobile. Many management programs too came into existence to enhance the productivity of production facilities. Assembly lines were used for the very first time, paving the way for future mass production. Frederick Taylor, an American mechanical engineer, was a significant figure at this time. He established techniques for analyzing jobs to increase employees' efficiency as well as manufacturing techniques (George & George, 2020). Quick and lean production principles also emerged during this revolution, thus enabling the manufacturing companies to produce better and more quality products. Transportation and communication technologies also felt the upgrade as they began to spawn over larger areas, rather than being concentrated in few industrial regions, which in a way, initiated the first wave of globalization (Kumar, Bawge, & Kumar, 2021).

1.2.3 Third industrial revolution:

The information age or the Digital Revolution is usually attributed to the Industry 3.0 timeline which began in the 20^{th} century after the Second World War. People living today could relate more to this revolution since experts consider its time from 1970 till 2012, during which we have seen the shift from analogue and mechanical technologies to digital ones; electronics were transformed into computer technologies. With this development of computers and information and communication technologies, and importantly, the World Wide Web, industries began to rely on digital technologies in production. Mass production and mass consumerism became the norm, and that change in demand and supply was only made possible by the various computer-aided tools discovered during this revolution. Numerous elements with varying purposes and high efficiency sprung from the development of information technology, which led to automation in manufacturing, thanks to programmable logic controllers (PLCs) and robotics (Kumar, Bawge, & Kumar, 2021).

1.2.4 Fourth Industrial Revolution:

We are currently on the verge of the fourth industrial revolution, often known as IR 4.0 or Industry 4.0, which, in a nutshell, is an enhanced extension of the preceding revolution. Manufacturing systems that had already implemented computer technology will now be augmented with network connectivity and will be able to communicate digitally or over the internet with other facilities (George & George, 2020). Cyber-Physical Systems (CPS) and its networking, often known as the Internet of Things, are two of the most significant components of this revolution (IoT). It will be possible to communicate inside systems, their components, and persons, resulting in the construction of smart factories (Kumar, Bawge, & Kumar, 2021). Through the development of these technologies, which promise to improve every element of industry disciplines, communication between the physical, digital, and biological worlds will be indistinguishable. With so much automation and digitization, the goal of this transformation is to make our lives more convenient and to make production processes significantly more efficient and, in reality, autonomous. The components of IR- 4.0 are mentioned in the figure 1 graphically.

Figure 1: A graphical explanation of Industry 4.0

Source: (*What Is Industry 4.0? | Global Manufacturer & Distributor of Component Solutions — Essentra Components*, 2020)

Currently the world is following the technology of Industry 3.0, which is primarily driven by Information & Communications Technologies (ICT). It enables both manufacturing and service sectors to expedite process in many folds. In the current technological evolution sensors, RFID chips, 'cyber physical' systems and the Internet of Things (IoT) are transforming manufacturing and services across the entire supply chain. (Srivastava, 2016). But to put things into perspective, such initiatives have not found their ways into the apparel industry of Bangladesh yet and to ensure their intervention without disrupting the progress made by this sector is a daunting task and must be thought, in fact, scrutinized twice before making such a leap. Neighbouring countries like Pakistan, India, basically the competitors of Bangladesh have already begun using various readiness models to assess themselves for IR 4.0.

1.3 Context and relevance of the study

The first industrial revolution started with mechanization and mechanical power generation during the 1800s. It made possible the transition from manual work to the first manufacturing and production processes; mostly in garments and apparel industry. An ameliorated quality of life was a main factor of the change. The later industrial revolution was introduced by electrification that made the ability of industrialization and mass production. The 3rd industrial revolution began with digitalization, with introduction of microelectronics and automation in production. In manufacturing, this facilitates flexible production, where different products are manufactured on flexible and automated production lines with programmable machines or robots. Unfortunately, such production systems, however, still do not have flexibility regarding production quantity. While previous technological revolutions have focused on the manufacturing structure at the factory floor level, the 4th IR is set to become the next manufacturing paradigm. Therefore, it is essential for organizations to self-evaluate their position and/or their readiness level to survive and flourish in the era of the Fourth Industrial Revolution. Henceforth, an obvious requirement is the conceptualization or development of an Industry 4.0 readiness model.

Usually, such readiness models are designed with two distinct avenues: one which explores the practicality or feasibility of the model(s)'s application, and the other considers the potential users of those respective models. Both academia and industry have been relentlessly working to identify and develop the proper literature and tools required for the scaffolding of IR 4.0 models, and they have succeeded to quite an extent in the last few years to give us some interesting ideas. However, most of the academic Industry 4.0 readiness models have been found to be lacking adaptability for an apparel industry, since they do not bode well with the practicality of rapidly changing goals of apparel industry. Table 1: Various models for assessing Industry 4.0 readiness below shows several models developed for assessing Industry 4.0 readiness.

Table 1: Various models for assessing Industry 4.0 readiness

Model names	**Authors (references)**
Industry 4.0 Maturity Model	Lee Bibby and Benjamin Dehe (2018)
Industry 4.0 Readiness Evaluation for Manufacturing Enterprises	Josef Basl and Petr Doucek (2019)
IMPULS—Industry 4.0 Readiness	Verband Deutscher Maschinen- und Anlagenbau (VDMA) (Association of Germany's Engineering Industry)
Readiness for Industry 4.0	D. Horvat, T. Stahlecker, A. Zenker, C. Lerch, M. Mladineo (2018)
Benchmarking Readiness IR 4.0	Fraunhofer Institute for Systems and Innovation
Industry 4.0 Future Readiness	Anthon P Botha (2018)

Source: Authors' compilation

Under this purview, a customized or tailored made readiness model index seems imminent for Bangladesh too, as the nation has been keenly involved in the discourses related to IR 4.0 and is eager to complement its Digital Bangladesh narrative with the help of this revolution. Bangladesh should consider adopting the notion since it would demonstrate to the world market that its international competitiveness is not confined to cheap labor alone but can also move toward a technical standardization process with the smart factory concept. The Bangladeshi apparel industry is on the verge of adopting the best manufacturing practices, lean and sustainability concepts; the country has always been highly regarded worldwide for its high-quality garment manufacturing, rapid product delivery, and even green manufacturing, for which many local businesses have been praised. Some were granted the Leadership in Energy and Environmental Design award for their ideas about environmentally friendly businesses.

Implementing the principles of the fourth industrial revolution in the Bangladeshi clothing sector will be the "next" smarter step" from its existing benchmark to remain competitive with the rest of the globe. In the long run, the clothing industry will try to be more efficient by making the most of its resources with as little human input as possible. In this way, Bangladeshi clothing makers have shown that they can use ideas like "smart factories" that work well with their business plans. In this study, the German Impulse Foundation of the Mechanical Engineering Sector Association (VDMA) readiness model has been chosen to justify preparedness of Bangladesh's garment industry in adopting IR 4.0. This research changes a few parts of the model to understand better how ready the Bangladeshi clothing sector is for IR 4.0.

1.3.1 What are the Changes in the Apparel Industry?

The garment industry accounted for 82.89 percent of Bangladesh's total export revenues in January-March of the fiscal year 2022, significantly contributing to the country's economic growth (EPB). The garment sector has the highest growth and foreign exchange revenues. This aids Bangladesh in maintaining its trade balance. In the 2019–20 fiscal year, this industry contributed 8.49% to the nation's GDP (Bangladesh Bank, 2021). The global condition of the new coronavirus illness hurt exports in FY2020–21. The sector generated 7.66% of Bangladesh's GDP in fiscal year 21. (Bangladesh Bank, 2022).

Figure 2: Trend in RMG export in selected years

Source: Export Promotion Bureau (EPB)

The major alteration which has brought changes and will bring more changes in apparel industry of Bangladesh, is automation in swing machine, fabric cutting software technology, use of software in management and many more. Moreover, smart fabric space offers a huge platform for fashion designers to showcase their creativity, and in a way, enrich human capacities.

In response to the worst industrial accident in history, Rana Plaza, three major monitoring bodies, Alliance (led by the United States), Accord (led by the European Union), and the National Tripartite Plan of Action (NTPA), have been established to inspect the building structure, fire safety, and electrical systems of factories.To conduct these activities, factories were required to undergo significant technological changes within their respective factories. Amidst the hype of Industry 4.0 in the market, the country has been observing an introduction of world class certified platinum green factories to seek buyer's confidence building measures. Besides, the woven sector which was not as technologically sound as the knit one previously, particularly because the woven sector had guaranteed market access and did not need technological adaption and/or upgradation, since 2011 had developed and embraced technological changes after the introduction of EU's single stage GSP.

The major changes required in the apparel industry for being competitive in the market include Upgrade to Automate, Cross-train Employees, and Low Employee Turnover. Add to these changes the growing role of new platform of production orders. It has also been observed that 28% of enterprises have been taking orders through online platforms mainly by large-scale enterprises (CPD, 2018). Factories are introducing seamless hi-tech type of glue that fuses layers of fabric together, which saves production time by 25 to 35% compared to cut-and-sew methods, resulting in lower labour input. It has also been projected that adopting new cutting technology in the garment sector can lower production costs by 10%; the specific technique necessary to reap this benefit is a software-based technology that will cost between $250,000 and $300,000 to set up in the factories. However, the invested money can be recouped within two years or within a year if efficiency is maintained. Recently, new technology has been introduced in sportswear, which provides more sweat absorption and comfortability. Adoption of such technology will ensure the entry of Bangladesh in the technology driven clothing market which is valued at about $150 million. According to World Bank data, the number of jobs added each year in the garments sector has fallen significantly from 300,000 annually from 2003 to 2010 to 60,000. This fall in the addition of jobs is attributed to the adoption of automated technology in the garment factories. As the owners do not need the workers as much as they used to, they are now better able to resist worker demands. According to research from the International Labour Organization that came out in 2016, automation could threaten around 80% of jobs in the textile and garment industries. In 2015, the female-to-male worker participation ratio was 64:36, but it declined to 60.8:39.2 three years later (CPD, 2018).

1.3.2 Rationale of the study

The extensive grounds on which this study is firmly built upon can be broadly classified into two folds: the impressive progress of Bangladesh as per the global development yardsticks and the massive contribution of apparel industry to that very progress. Bangladesh was recently changed from a "less developed country" to a "developing nation," and it will be officially recognized as a "developing nation" in 2026. The Bangladesh government also aims to become a fully developed nation by 2041, so it makes sense for academics to look at the country's strengths and weaknesses. Because the RMG industry has done so much, the apparel sector is often at the center of discussions about development. Bangladesh's apparel industry is known as a trendsetter, and in 2021, it made up 81.16 per cent of the country's total exports. Its readiness for IR 4.0 and the possible effects of putting it into place will determine whether or not the entire industrial sector can keep up with and achieve the fourth industrial revolution in the long run.t. Hence, though IR 4.0 is seen as a natural transition towards further development of a country, the preparation that goes into implementing it and the spillover effects it could induce must be assessed in the most dominating industrial sector first, which is the apparel industry for Bangladesh.

1.3.3 Uniqueness of the study

The first and foremost feature of the study that makes it one of a kind is that it fills the existing gaps in literatures related to the readiness of Bangladesh's apparel sector for undertaking the 4th industrial revolution. The study's apparatus is chosen purposively with emphasis on quintessential factors regarding the readiness level for IR 4.0, and they are discussed below:

- *Organisational strategy*: This component examines the current approach an organisation has planned or executed to incorporate IR 4.0 and finds out whether it complements the rest of the workflow or not. It also considers the potential areas where investment could be made, both in terms of innovation and/or technological upgradation and support system, by underscoring both opportunities and challenges of any move from the organisation.
- *Organisational infrastructure*: This assessment tool investigates the infrastructural ability of an organisation to install and also maintain high tech IR 4.0 equipment, machines, and even digital systems. In addition, it also unfolds whether the required installation of IR 4.0 oriented machines will blend with the rest of the organisation's infrastructure or not.
- *Smart Operations*: This assessment tool examines whether the existing i.e., known smart operations of IR 4.0 such as the practice of cross-departmental information sharing or autonomous functionality of production or instant, real time IT solutions, can be implemented in the apparel industry or not.
- *Smart Products and Data Driven Services*: This assessment tool gave a deeper understanding of the functionality of smart products and services which completely rely on ICT, and whether there is any scope of incorporating them at factory level.

- *Employees*: Quite self-explanatorily, this assessment tool examines the level of knowledge and skills of employees in relation to IR 4.0.

1.3.4 Significance of the Study

Since the study explores current capacity and future strategy of apparel industry of Bangladesh in their quest of achieving the Industrial Revolution 4.0, its findings are likely to be significant for multiple stakeholders.

- *For policymakers*: They will be able to witness and understand the infirmities as well as the strengths of the apparel industry in instilling IR 4.0, thereby, giving them the scope of planning and acting accordingly in line with Bangladesh’s vision 2041.
- *For investors*: To make the transition from mid-level factories to advanced ones with automation of 4th industrial revolution’s stature, understandably, a lot of investment is needed, but most importantly, investment needs to be directed in the right areas, and in this regard, the findings of the study will be crucial to potential investors of the apparel sector.
- *For academicians*: Quite limited literature exists at present in terms of readiness level for IR 4.0 in the context of Bangladesh, and even none, when it comes to narrowing it down the focus on country’s largest export contributor, the apparel industry. Therefore, this study acts as the building block for academicians to develop further discourses, and in turn, aid the decisions of policymakers.

1.4 Objectives

Broad objective:

The main goal of this study is to find out how ready Bangladesh's garment industry is to start using the methods and practices of Industry 4.0.

Specific objectives:

The following sub-goals are developed to help bring about the primary goal:

1. To assess the level of Industry 4.0 readiness of the apparel industry.
2. To examine whether factory size is a determinant for the Industry 4.0 readiness.

3. To explore the areas where apparel industry needs to be prepared in adopting and implementing Industry 4.0.
4. To find out challenges and opportunities for apparel industry in implementing Industry 4.0.

1.5 Scope of the study

The study only focuses on the apparel industry sector of Bangladesh, meaning that it does not take into consideration the textile and other backward linkage industries, which too will be impacted upon the introduction of IR 4.0. In addition, the study derives results from the perception of management of organisations and does not consider the accounts of RMG workers.

1.6 Limitation of the Study

The major shortcoming of the research was the lack of research or study conducted about the implementation of IR 4.0 in the apparel industry in Bangladesh. There are only few write-ups available regarding IR 4.0, and the impact of IR 4.0 in cheap labor engagement in Bangladeshi apparel industry, which made it difficult to review literature. Therefore, literature of studies like this research conducted in other countries are mostly used in the literature review process. Besides, since IR. 4.0 is a new concept for Bangladesh, many misconceptions are prevalent.

The results of this study show how adopting Industry 4.0 could help or hurt Bangladesh's clothing industry and whether or not it would help. If IR 4.0 is used, the clothing industry will be more vertically and horizontally integrated. However, for Industry 4.0 to work well in a local setting, the whole lifecycle of the value chain needs to be reengineered. Internet and its supporting technologies (like the Internet of Things, embedded systems, robotics, CPS big data, etc.) mostly cover human factors, production lines, intelligent machines, physical objects, and processes in the apparel industry to make an agile value chain. Several important facts about opportunities can be drawn from this study. For example, the IT and apparel industries had skilled and knowledgeable workers, which would be the biggest benefit of using the new and different ideas in Industry 4.0. This study will show that the clothing industry needs to rethink the fourth industrial revolution as a new business model instead of just seeing it as the introduction of information and communication technology. The study concludes that more research into the use of Industry 4.0 in the clothing industry and the feasibility of smart factories is required. The government should also help the clothing industry in a big way. For Industry 4.0 to work, the government and business owners should be able to work together.

2. Chapter Two: Literature Review

Though the fourth industrial revolution is still at nascent stage in Bangladesh, it has been in practice in different parts of the globe for quite some time. Hence, a thorough review of the existing literatures on IR 4.0, along with the limited ones available even with modest correlation with the apparel sector of Bangladesh, is imperative, and presented below, starting from the very roots of the revolution – its conceptual understanding.

2.1 Conceptual understanding

The different ways to describe the fourth industrial revolution show that this idea is still changing and needs to be improved. In their Deloitte AG report, Sniderman et al. defined Industry 4.0 as "smart and connected manufacturing" (Sniderman et al., 2016). Brettel et al. (2014) say, "Industry 4.0 is about making intelligent products and production processes." They also say that cyber-physical systems (or CPS) will allow humans, machines, and products to share information in the future factory. Since CPS can collect and process data, they can do some tasks independently while interacting with people through interfaces (Brettel et al., 2014). Along with these changes, scholars, countries, and even industries came up with different words to describe Industry 4.0. Industrial Internet, Connected Enterprise, SMART Manufacturing, Smart Factory, Manufacturing 4.0, Internet of Everything, and Internet of Things for manufacturing are all names for the same thing.

The first industrial revolution began in the late 1700s when manufacturing processes were mechanized. A century later, electricity became widespread in businesses that relied on the the division of labour to produce large quantities of goods. The third industrial revolution arose in 1970 with the introduction of electronics and information technology (IT) to achieve more automation in manufacturing activities. Nevertheless, the current Industry 4.0 project has made much progress and uses IoT and networked technologies in production (Lee, 2015). Let us take a closer look at the definitions of Industry 4.0 to explain it further.

During the 2011 Hannover Fair, the German government first introduced the concept of Industry 4.0 and provided a description for it. Industry 4.0 is defined by Germany's Trade and Invest (GTAI) as:

"*A paradigm shift made possible by technological advances which constitute a reversal of conventional production process logic. Simply put, this means that industrial production machinery no longer simply 'processes' the product, but that the product communicates with the machinery to tell it exactly what to do*" (Sniderman, Mahto & Cotteleer, 2016).

The "factory of the future" (FoF), more often known as a "smart factory," is a central tenet of Industry 4.0. Irwin Welber originally used the term "FoF" in a talk he gave at the 1986 international conference on robot manipulators. He predicted that FoF would evolve into a complex AI system. This would run on a well-structured and comprehensive body of information. He also mentioned how providers and buyers would each have to play important parts in the FoF ecosystem (Haddara & Elragala, 2015). By using the phrase "intelligent machinery," both Welber's "Factory of the Future" and the underlying notion of Industry 4.0 are mutually reinforcing. The German Industry 4.0 group's final report proposes a "dual approach" to create and supply new, profitable markets for Cyber-Physical Systems' technology and goods. The strategy's three main tenets are the creation of inter-company value chains and networks through horizontal integration; the use of end-to-end digital engineering throughout the product's value chain and the manufacturing system's value chain; and the design, implementation, and vertical integration of manufacturing systems that are both flexible and reconfigurable (Kagermann, Wahlster, & Helbig, 2013).

In 2013, the Frauenhofer Institute researched the effectiveness and growth potential of companies implementing Industry 4.0 technology. Five areas of technology—embedded systems, intelligent factories, robust networks, cloud computing, and IT (Information Technology) security—are particularly affected (Bauer, W.; Schlund, S.; Marrenbach, D.; Ganschar, O. 2014).

However, Rüßmann et al. compiled nine technologies crucial to developing businesses and organizations in the era of IR 4.0. Some examples are autonomous robotics, simulation, horizontal and vertical system integration, the Internet of Things (IoT) in industry, cyber security, cloud computing, 3D printing, augmented reality, and big data analysis (Rüßmann et al., 2015).

An IR 4.0 factory is a community of interconnected machines that require sophisticated prediction tools to turn raw data into knowledge that can spot patterns, identify anomalies, and make more accurate decisions (Bildstein et al., 2016). Industry 4.0 implies significant changes to the production system, mostly through IT; these enhancements suggest that businesses will need to be ready for technical and many other sorts of reverberations (Lasi, H. et al.).

However, Hermann et al. consider IR 4.0 the genuine digitization of industry, as it incorporates novel technology developments and concepts surrounding the value chain organization. Industry 4.0 creates a standardized layout for a smart factory by using cyber-physical Systems (CPS) to monitor physical processes, create digital representations of the real world, and distribute control over how things are run (Hermann et al., 2016).

Organizational predictions are a key factor in determining whether or not the adoption of new technologies will increase productivity; based on the forecasts that are now available, investments in IR 4.0 will undoubtedly increase the investor's productivity (Bughin, J. et al. 2016). Given the promising initiatives, it is important to analyze when the research led to the reported outcomes. Most investments during the last decade came from large, well-established companies with deep pockets, suggesting that these trends cannot be extrapolated to the whole economy. At the same time, a national-level analysis (Graetz, G. et al., 2015) indicates the obvious influence of industrial robots on economic development and productivity across 17 countries. Investing in information technology has been shown to increase productivity, which has increased income and profit and greatly enhanced product quality and performance due to the development of cutting-edge equipment (Popp, J. et al., 2018).

Industries are opting to escalate digitisation in order to meet the demands of consumers which seem to be always changing. Not only do consumers demand new products, but they also expect variations, which in turn, reduce the lifecycle of each product. Henceforth, factories need to constantly innovate their products, and must possess the most advanced technologies to do so. Besides the constant change of the product itself, a mechanism or a production technology needs to be present which is conveniently flexible to adapt to the haphazard change in demand of consumers (Herrmann, C. et all, 2014). More and more businesses realize the value of adopting digital strategies and one sector that stands to gain the most in manufacturing. This sector could see significant savings in inventory, logistics, and material handling costs, as well as reduced delivery times and fewer product shortages (Heynitz, H.V. et al. 2016).

Based on their research into the current situation of the Croatian manufacturing industry, Veza et al. (2015) define the major characteristics of a smart firm to be a high degree of collaboration, the provision of both goods and services, and the use of smart, individualized goods.

In addition, the four enablers of a Smart Factory have been recognized as a "Smart operator," "Smart product," "Smart machine," and a "Smart planner" (Kolberg & Zühlke, Lean Automation supported by Industry 4.0 Technologies, 2015). Considering how recently the notion of Industry 4.0 was coined, there are now hardly any academic works related to the topic in Bangladesh. Nonetheless, several articles and reports on implementing Industry 4.0 ideas in the West are available. Even though Bangladesh is an emerging country, the benefits of Industry 4.0, as detailed in research by Deloitte, can be implemented there just as easily as they can in any other country. The success and failure, advantages and disadvantages, of Swiss industrial firms throughout this digital transformation—dubbed "IR 4.0"—are also tracked in this research. Increased competitiveness, better use of opportunities, reduced risks, adapted people and IT resources, new opportunities for targeted business sectors, and capitalizing on the momentum of exponential technologies are some potential advantages (Deloitte, 2015).

To realize Industry 4.0, Wang et al. suggest that the value chain must be integrated horizontally, vertically, and networkedly, and that engineering design must be digitized from beginning to finish. They claim that new innovations like the Internet of Things (IoT), wireless sensor networks, big data, cloud-based services, embedded systems, and mobile Internet can help meet these requirements (Wang et al. 2016).

After reviewing fifty research, Hermann, Pentek, and Otto identified the four foundational resources every company needs to embrace Industry 4.0. (Hermann, Pentek and Otto, 2016). These are the concepts of Cyber-Physical Systems (CPS), the Internet of Things (IoT), the Internet of Services (IoS), and the Smart Factory.

2.2 Further delineating Industry 4.0

Although the unprecedented coronavirus pandemic has made "The New Normal" the most popular phrase in the lifestyles of people all over the world, the same phrase has been connoted with the Fourth Industrial Revolution (IR 4.0) for all types of businesses due to the exponential growth of technology and, thus, digitalization (Ochs & Riemann, 2016). The German government introduced the initial concept of the "Fourth Industrial Revolution," or "Industry 4.0," during the 2011 Hannover Fair. The Internet of Things (IoT) and cyber-physical systems (CPS) would usher in a new era of ubiquitous connectivity that would provide seamless two-way communication between machines and between machines and humans in real-time (Kagermann, Wahlster, & Helbig, 2013).To put things into perspective, the real world will be reproduced in a virtual environment where decentralized choices will be undertaken by machines or robots, thereby, allowing businesses to operate more efficiently, enhance productivity and transparency, gain more control over monitoring of systems, easily identify errors, lower down cost of production, and needless to say, become more adaptable to changes in demand and supply (Porter & Heppelmann, 2014).

For a layman understanding of two of the most essential terms affiliated with IR 4.0, that is CPS and IoT, the latter can be considered a space where all objects are connected to the Internet, and can interact with each other without the need for human intervention, hence, these very objects, also referred to as smart objects, will automatically figure out human preferences and act accordingly (Soumyalatha, 2016); for instance, after coming home late from work, if an individual prefers to listen to soothing jazz music, he or she does not need to act upon that will, rather the smart objects of home will sense the tension in the air and turn on the right playlist, at the right volume. On the other hand, CPS are systems built on the foundation of IoT, which can assist the construction of Smart Factories by fusing real and digital/virtual world; it must be noted that ‘Smart Factory’ is considered to be one of the core visions of IR 4.0 (Chen & Mueller, 2017). According to Chen & Mueller (2017), the features of ‘smartness’ include:

"Integrated functions for identification, localization and diagnosis of internal parameters, capability to detect on the physical data and measuring on the performance, capability to process data for the determination on relevant information, capability to interact with other smart objects and centralized information system, standardization with uniform standards or protocols, openness for accessibility, and multi-functionality for different applications."

With all the aforementioned smart features, Industry 4.0 aims to solve "real-world" problems with minimal assist from human kind (Al-Mhiqani, et al., 2018). But to better understand the context of the Fourth Industrial Revolution, few other definitions can be looked at: for instance, some experts call it an "integration of complex machinery and devices, with sensor and software, used to predict and control business results" (Haber, Juanes, Toro, & Beruvides, 2015) while others simply view it as "a smart manufacturing concept where machines and products interact with each other without human control" (Kang, et al., 2016). Some literatures call it "the interaction of digital and physical processes in cross geographic and organization setting" (Adler, Schmitt, Wolter, & Kyas, 2015) while others phrase it as "a holistic system of people and machines for flow of goods, services and data with a high degree of autonomy in decision making" (Hermann, Pentek, & Otto, 2016).

2.3 Theories related to technological changes and automation

This section basically sets the tone of associated theoretical and conceptual consideration of the linkages of technological changes with the growth trajectories. Technological changes cannot be tuned without a robust enabling environment and as such, this section also sheds light about the state of enabling environment that Bangladesh currently is experiencing to embrace the changes of technology in various sectors.

Schlogl and Sumner (2018) argue that "a specter is haunting the industrialized and developing world—the specter of automation." Recently international organizations like, UNIDO (2016), IMF (2017), UNCTAD (2017), ILO (2017), the World Bank (2016), , and UNDP (2015) have flagged the issues of technology upgradation and job automation in their global reports.The International Labour Organization (ILO) established a Global Commission on the Future of Work in August 2017 "to undertake an in-depth assessment of the future of work that can offer the analytical framework for the implementation of social justice in the 21st century" (ILO, 2017). Premature deindustrialization" (Palma, 2005; Rodrik, 2016) and weak employment elasticities of growth have been cited as two of the main obstacles to economic growth and job security, drawing much attention to the topic of job security.

These topics are receiving increasing attention from academics (Arntz, Gregory, & Zierahn, 2016; Grace, Salvatier, Dafoe, Zhang, & Evans, 2017; Mishel & Bivens, 2017; Acemoglu & Restrepo, 2017), government and business organizations (McKinsey Global Institute, 2017; World Economic Forum, 2017; Frey, Osborne, & Holmes 2016), and the general public. However, most studies undertaken up to this point have been centred on high-income Organization for Economic Co-operation and Development (OECD) nations like the United States. Therefore, the effects of automation on emerging economies remain extremely contentious and understudied. Nevertheless, the OECD is one of many groups worried about IR 4.0. (Ahmed, 2017). "the percentage of occupations that potentially see major automation is actually larger in poorer nations than in more sophisticated ones, where many of these jobs have already vanished," says the World Bank (2016, p.22). They note, however, that the effects will be mitigated due to wage increases and the rapid use of technology. Despite the abundance of estimates for job displacement, most of which are published in grey literature, all of them are based on questionable assumptions, and investigation of underdeveloped nations is seldom observed.

As stated by the neoclassical standard model of growth, technical progress is vital to sustaining economic expansion over the long run. Innovations in automation technology are commonly seen as a key contributor to increasing total factor productivity (TFP), as demonstrated by Solow's (1956) model. This can be achieved by increasing production inputs, such as the labour force or capital intensity, or by combining inputs more efficiently to produce a higher output.

Schlogl and Sumner (2018) divide an economy into an automation-prone sector (APS) and an automation-resistant sector (ARS) based on the ease or difficulty with which machines may perform certain jobs. Lifting, drilling, and other such arduous tasks are APS's forte. ARS, on the other hand, includes activities that rely on creative thinking and face-to-face communication.

According to the Lewis model of economic growth, automation results in an "infinite supply of artificial labor" in the APS. More and more robots mean a stronger APS labour force, a "robot reserve army," and lower salaries and bargaining power for human workers in the APS. The manual labour force will be pushed out of the APS and into the ARS, essentially an automation-driven structural transformation if automation is feasible (technologically, legally, politically, and socially).

As defined, automation causes a supply shock by shifting the labour supply curve in the APS to the right, which lowers the equilibrium pay not just in the APS but also in the ARS, which will absorb the extra workers. If the unit cost of automated manufacturing falls below the reservation pay of employees, a labour surplus will be produced. The freed-up workforce can then be put toward jobs that cannot be automated. This surplus may lead to technological unemployment and the chance of being absorbed by ARS. Similarly to the Lewis model, the functional distribution of income changes to benefit those who possess capital.

The benchmark for digital transformation is the industrial revolution. According to Avent (2017, p.162), the developing world was "bypassed for long decades" during the Industrial Revolution, and this will happen all over again during the digital revolution. Avent goes even further, arguing that the South's rapid growth as a result of supply chain integration and "export-led industrialization" is temporary, as it will be replaced by "reshoring"—the relocation of outsourced production—or will be limited to small high-tech clusters in developing economies (Yusuf, 2017). These hubs will not generate as many jobs overall as more dispersed industrial activity in the past did. Therefore, according to Avent (2017, p. 163), "it will be more difficult in the future for poor countries to repeat the performance of the past twenty years," and "once again, rich economies will enjoy a near monopoly on the sorts of social capital required to generate a rich-world income," including democracy, property rights, and accountable governance. This may be seen as a red flag for the development of catch-up technology.

2.4 Industrial Revolution in the Apparel Sector

The adoption of advanced technologies of IR 4.0 like automation, robotics and artificial intelligence, is critical for Bangladesh’s readymade garments (RMG) sector. The IR 4.0 will prompt complete automation and digitalization processes, along with extensive utilization of electronics and IT in manufacturing and services industries, in a private climate (Sommer, 2015).

The Internet, big data, cloud computing, artificial intelligence, autonomous vehicles, advanced robotics, new additive manufacturing technologies, especially 3D printing, hybrid manufacturing, machines, new materials, and generic and synthetic microbiology are all factors that contribute to the rise of IR 4.0 (Hofmann & Rüsch, 2017; Klaus Schwab & Davis, 2018). Big data is a key technology in Industry 4.0 because it allows smart algorithms to collect, process, and analyze data. One of the most important aspects of IR 4.0 is the ability to manage massive amounts of data on open systems and establish a real-time connection with the production system; cloud computing would prove useful in this regard because it would enable access to data regardless of time or location, thereby fostering adaptability in business operations (Anderl, 2015; Atanasov, Nikolov, Pencheva, Dimova, & Ivanov, 2015; Faller & Feldmüller, 2015).

In apparel sector, the managerial tasks comprise of receiving orders from consumers, production planning, obtaining necessary fabrics and materials, customer approval and enterprise resource management, etc. End to end digital integration, real time production planning and order tracking is important for Industry 4.0.

Additive manufacturing and 3D printing technologies have already been developed to meet consumers' diverse, ever-evolving demands (Gokalp et al., 2016). With the advent of the Fourth Industrial Revolution, however, the time it takes to introduce new products will decrease even further as a result of more adaptable product lines, increased productivity, and a much finer and more ideal use of resources that will enable a larger number of companies to enter global value chains (Angelo et al., 2017; Huckle et al., 2016). However, for IR 4.0 to be tailored and practised in the manufacturing and service industries, measures in terms of policy and investment support, infrastructural development, education, and training for upgrading and upskilling need to be administered by both public and private organizations (M. A. Islam et al., 2018).

As a developing nation, Bangladesh has lots of challenges in the implementation of Industry 4.0 and certainly lacks awareness, labour skills, factory infrastructure, technology applications, lack of adequate investment, etc. As a matter of fact, Bangladesh has been criticized for its labour skills, technological implementation in manufacturing, and factory infrastructure (Jabbour et al., 2017; Sarkar et al., 2017).

2.5 Where does Bangladesh Stand in terms of IR 4.0

Nowadays, Bangladesh is having a good number of individuals who are technologically advanced for the apparel sector, but they lack awareness and knowledge regarding the latest technological advancements such as automation and artificial intelligence whereas at present, the world largely depends on advanced technologies. Industry 4.0 is currently omnipresent globally and Bangladesh need to adopt new technologies and build operational structure for their business immediately.

Lately, IR 4.0 with its extensive industrial automation, is interrupting almost every industry, starting from Readymade Garments (RMG) and Textile to Furniture, from Agro-processing to Leather and Footwear, and even Tourism and Hospitality sectors of Bangladesh. The nation’s RMG and Textile industries comprise of a massive 14.07% share of GDP, responsible for 85% of the aggregate export earnings and employ 4 million labour, and despite the threats of unemployment, RMG is slowly adapting automation technologies, mainly to stay on par with efficiency, growth, and international competition.

In order to improve production and company management, businesses in Bangladesh's light engineering, furniture manufacturing, shipbuilding and breaking, agro-processing, leather and footwear, tourism, and hospitality sectors have started investing more in automated capital machinery, robotics, sensors, software programming, the Internet of Things (IoT), and big data. This poses serious risks to the employment of unskilled, lower-skilled, and semi-skilled workers. Digitalization affects every part of our lives, from the economy to our relationships and the rest of the world. So it is easy to guess what will happen.

Bangladesh, a country which has been arguably an exemplary developing nation, is embracing revolutionary technologies slowly but certainly in every sector for socioeconomic development, despite her existing shortcomings such as unawareness, inadequate financial strength, an abundance of cheap labour, lack of digital infrastructure, and skills. Nevertheless, at present, public and private authorities are taking initiatives to develop infrastructure and human, technical, and financial capacity, to improve the education and training systems, in order to fully enjoy the advantages offered by IR 4.0.

International competitiveness is perhaps fiercely faced by the apparel sector and in order to maintain an edge over the competitors, BGMEA needs to formulate polices which are inclusive of latest technologies and innovations. Industry 4.0 can be crucial in this regard, as it is completely steered with IoT, thereby, presenting the opportunity to reduce lead time and improve customer responsiveness at optimal expenses. The study suggested three frameworks that are effective, practical, and substantial for realizing IR 4.0 in the apparel industry of Bangladesh. Needless to say, to resolve the traditional supply chain concerns, Bangladesh Government and BGMEA should collaborate to change infrastructure, and establish a digital ecosystem for a brighter tomorrow. Industries must also quickly embrace these new revolutionary frameworks to challenge the global market (Fahim, 2019).

2.6 Research Puzzle

Even though most value chains are thought of as production-based and may be supplemented by logistical activities, it is safe to assume that Industry 4.0 permeates every link in a company's value chain. The scope of Industry 4.0 can grow at the edges of businesses to include the whole supply chain or network. At the heart of IR 4.0 are new networked technologies (like sensors and RFID) and new processes (like data analysis software, the cloud, and programming). However, for a company to fully take advantage of IR 4.0, it needs to develop skills like seamless innovation, continuous education, trust within the organization, and transparency in data sharing. It may even call for the creation of entirely new business models. So, Industry 4.0 is a phenomenon that connects the corporate value chain and the supply chain to a new level of value creation for consumers by using technological assets and activities to improve process transparency and make the most of the benefits of digitalization.

In addition to the above general discussion of Industry 4.0, many academics have also written about how it is being used in the textile and clothing manufacturing sector. Taking China's textile industry as an example, Chen and Xing (2015) found that technological innovation and personnel are fundamental drivers of industry transformation. They also urged the industry to cautiously tailor Industry 4.0 as Textiles 4.0 to serve the textile sector. Mini factories, purchase-activated manufacturing, active tunnel infusion, automated apparel systems, social manufacturing, smart textiles and wearable technology, 3D printing, and 4D printing are all examples of cutting-edge technologies that academics have identified as having the potential to boost Brazilian apparel and textile manufacturing industry's transition to adopting the principles of Industry 4.0.

The process automation efficiency in the garment sector has been studied, even though publications in IR 4.0 from Bangladesh could be much higher (or more present). Hasarali et al. (2012) (Evaluating the Efficacy of Process Automation in Textile Manufacturing) discovered that MAS holdings have the highest effectiveness for process automation, followed by Hidramani and Brandix, based on their analysis of three major participants in the garment business. Process automation is the real beginning of the fourth industrial revolution. Therefore, this conclusion is relevant in light of the local divergence towards Industry 4.0.

The results of this exploratory study will shed light on how IR 4.0 will impact organizations' use of technological tools and practices. The questionnaire data we collect would add something new to the paper because it would show how different businesses could use IR 4.0. In addition, consulting with industry professionals would shed light on the advantages, disadvantages, and potential of implementing these technologies in businesses.

2.7 Organisation of the Chapters:

After the introduction, a detailed literature review is given in the second chapter. Followed by this the conceptual framework and methodology are explained in the third and fourth chapter respectively. Chapter five describes and presents the data analysis, findings, the challenges and opportunities in Bangladesh context with regard to Industry 4.0 adoption in apparel industry. Finally, chapter six highlights the recommendations, the future scopes of research along with a conclusion.

3. Chapter Three: Framework Development of the study

This chapter explores the various dimensions of a readiness model that could be best suited for measuring the preparedness of the apparel industry in its pursuit towards IR 4.0. Therefore, it discusses the opinions of different scholars on organisational readiness. Followed by the discussion is a brief understanding of the guiding framework of the study, and the chosen variables and framework implemented for the study.

3.1 Measurement of IR readiness

A readiness model pays regard to recent innovations within an organisation for the purpose of attaining sustainability and performing with comparative advantages in its very current setup. For the fear of job security, employees might feel bothered, and cause problems during the transition phase to IR 4.0 since it will involve numerous automation changes in workflow. Sasanto (2008) argues that there are 6 triggering factors behind an organisational readiness change, which are "observation towards changes, efforts, vision, shared faith, plans offered, and management support. To take advantage of Industry 4.0, manufacturers must first accept cutting-edge technology and use it in their operations, such as production, marketing, design, and so on. (Susanto, 2008). In Table 2, the criteria for each part of the VDMA model that is used to judge Industry 4.0 are listed.

A total of 30 Industry 4.0 readiness models were analyzed by Hizam-Hanafiah, Soomro, and Abdullah (2020), and the authors discovered a wide range of model dimensions. After conducting a comprehensive analysis of the current Industry 4.0 models, they found 158 unique aspects. In their research, they identified six dimensions that cut across all of the models. Technology (a), People (b), Strategy (c), Leadership (d), Process (e), and Innovation (f) are the proposed aspects. Table 1 explains parameters from the VDMA's (Association of Germany's engineering industry) IMPULS-Industry 4.0 readiness model, which are extremely close to those suggested by Hizam-Hanafiah..

Table 2: Dimensions explained in the VDMA model for Industry 4.0 assessment

Dimensions	Criteria
Strategy and organsiation	- Status of the Industry Strategy 4.0 implementation - Review of the strategy using indicators - Investment for Industry 4.0 - Use of technology and innovation
Smart factory	- Digital integration - Machines and infrastructure - Data utilization - IT infrastructure
Smart operations	- Use of cloud storage - Sharing of information - Security in the IT system - Automatic processes
Smart products	- Quality ensured by data analysing
Data-driven services	- Availability of various services using data - Data sharing among various departments
Employees	- Related skills in IT - Related skills in new technologies

Source: Lichtblau et. al 2015

On the other hand, Alayon, Safsten, and Johansson (2017) recommends "optimum utilisation of resources", coupled by a natural control over discharge, to accomplish sustainability. According to them, "reducing, reusing, recycling (3Rs)" approach can expand the lifecycle of products, and technological processes can be utilized positively for the environment. Many important aspects fall under the umbrella of sustainability, including finance, environment, social wellbeing, and so on; hence, Alayon et al. (2017) emphasises on building an enhanced body of knowledge that can find ways to blend the intervention of Industry 4.0 with naturally sustainable production processes, and argues the need for quantitative studies on organisational readiness.

Industry 4.0 readiness models tend to have two distinct dimensions; one of them tries to identify means of implementation, and the other one locates the users for those respective models (Botha, 2018). Through a readiness model, an organisation can find out whether it has the capacity or not to facilitate changes and can act upon the existing shortcomings (Hizam-Hanafiah, 2020). Gokalp and Eren (2018) identified some of the most important aspects of the fourth industrial revolution. These are interoperability, virtualization, autonomous management, real-time management, the Internet of Services, and modular structure. Organisations can study and understand diverse Industry 4.0 models to not only find benchmarks but to take a leaf out of those leaders' books who have effectively achieved the digital transformation. What works, and what does not work, in terms of planning, strategies, and executing, is of sheer importance to an organisation which is willing to move forward with IR 4.0, as well as to policymakers for designing the most appropriate blueprint, and therein lies the significance of learning. Lack of attention to the readiness models will only create a digital divide among organisations, and those who will hastily, ignorantly, without any preparation try to capitalize on IR 4.0, will eventually crash out of the market (Canetta et. al., 2018; Ivanov et. al., 2019). Most Industry 4.0 readiness models seem to prioritize technological aspects; for instance, a study titled 'Industry 4.0 readiness models: a systematic literature review of model dimensions' states that "70 (44%) out of a total of 158 unique dimensions on Industry 4.0 pertain to the assessment of technology alone," which clearly indicate that organisations must be technologically sound first before jumping into IR 4.0 (Hizam-Hanafiah, 2020).

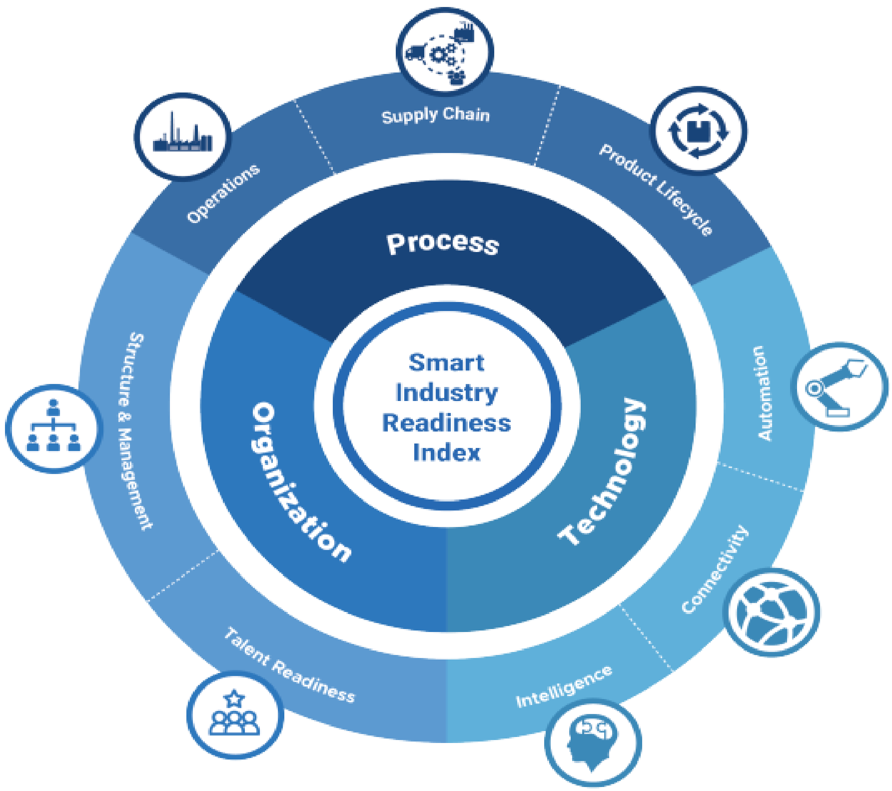
Industrial excellence is distinguished by the level of sophistication in production processes, the extent of automation, the preparedness of workforce, and the intensity of innovation; to add further value, there is the likes of industry receptiveness, innovation network and internet sophistication. In Europe, industries are segregated in four ways, in terms of IR 4.0; they are known as "the frontrunners, the traditionalists, the hesitators, and the potentialists" (Atik et. al., 2019). In addition, there are tools for gauging a city's preparedness, such as the Smart Collaboration Index (Nick & Pongrácz, 2016), which considers "performance indicators versus enablement indicators" and the input from various groups like the business sector, government agencies, and academics. Each category's "prerequisites, management, wiser systems, and outcomes" must be analyzed separately (Atik et al., 2019).

3.2 Guiding Conceptual Framework

The Smart Industry Readiness Index (SIRI), which was made by the Singapore Economic Development Board to deal with the challenges of implementing IR 4.0, is the basis for this study's main ideas (Singapore Economic Development Board, 2018). The SIRI framework comprises of 3 elementary building blocks which are Technology, Process, and Organisation.

Underlying the building blocks are 8 pillars which organisations must take into consideration for adopting the fourth industrial revolution. The characteristics of SIRI are briefly discussed below:

Figure 3: Smart Industry Readiness Index (SIRI) at a glance



Source: Smart Industry Readiness Index (Singapore Economic Development Board, 2018)

3.2.1 Technology

To implement and sustain IR 4.0, organisations require powerful automation, pervasive connectivity, and intelligent systems. Hence, this building block is divided into three pillars of Automation, Connectivity, and Intelligence.

- *Automation*: Both manufacturing and markets have changed a lot. Nowadays, there is a growing need for faster or on-demand delivery of products and services, which in turn, affects the production, for instance, small batches are more desirable. To keep up with these changes, the notion developed by SIRI is to make automation flexible rather than fixed. This is because with flexible automation, a variety of products can be manufactured in small batches without straining capital or time. This will enable the manufacturers to make business with diverse clients across the globe and also meet the volatile demands of consumers.

- *Connectivity*: Interoperability, which means that different devices and systems can connect and share data, is key to making IR 4.0 work. Therefore, businesses should employ supplementary communication technologies and guidelines to create more accessible, inclusive, and transparent communication networks. Nevertheless, adequate measures must be taken to address the risks of cyber-attacks involved in such hyper-connected operations.

- *Intelligence*: While automation and connectivity form the linkages between equipment, machines, and computer-based systems, it is the intelligence that processes and analyses data. Manufacturing today is not all about fast production in minimal time with minimal expenses; it is also concerned with future opportunities and challenges, which can be predicted and acted upon if there is an established intelligent system that can process the collected data and give useful insights to the manufacturers. Therefore, this pillar is also built to cater to the rapidly changing global market demands, that too in certain cases autonomously.

3.2.2 Process

When technology is applied to an advanced process, it is bound to work more efficiently, and produce an output worthy of more value. Therefore, it comes as no surprise that improvement in process is prioritised in IR 4.0, with special emphasis on amalgamation of Operations, Supply Chain, and Product Lifecyle of an organisation.

- *Operations*: This pillar revolves around the planning and executing of manufacturing which organisations can achieve better and faster with access to new technologies under the purview of IR 4.0. Manufacturers could identify incompetent processes with the help of data analytics, and act accordingly. In addition, they could decentralise their authority on assets, and monitor them remotely by taking advantage of wireless communications.

- *Supply Chain*: Starting with the collection of raw materials till the consumption of the respective product or service, this entire chain, is divided into many stages for every organisation, and therefore requires extensive planning and management. With the fourth industrial revolution, this work can be performed through a central data hub and a sensor network, thus enabling real-time intervention for any changing needs, and becoming more transparent for all the involved partners/stakeholders.

- *Product Lifecycle*: Every product goes through multiple stages from its very first conceptualisation till its purchase, and that is known as the product lifecycle. Over the years, product lifecycle has kept on shortening, and that means, integration and digitalisation across its different stages, has kept on becoming more essential, and this is where IR 4.0 intervenes with its "digital twin" concept. A digital twin basically virtually represents the entire lifecycle of a product, including the assets involved, the process, and systems. Since it is a virtual representation and can be shared easily with all the partners, for any one of them can adapt to changes, if required, or innovate new designs at a shorter time digitally, without taking the burden of producing physical prototypes.

3.2.3 Organisation

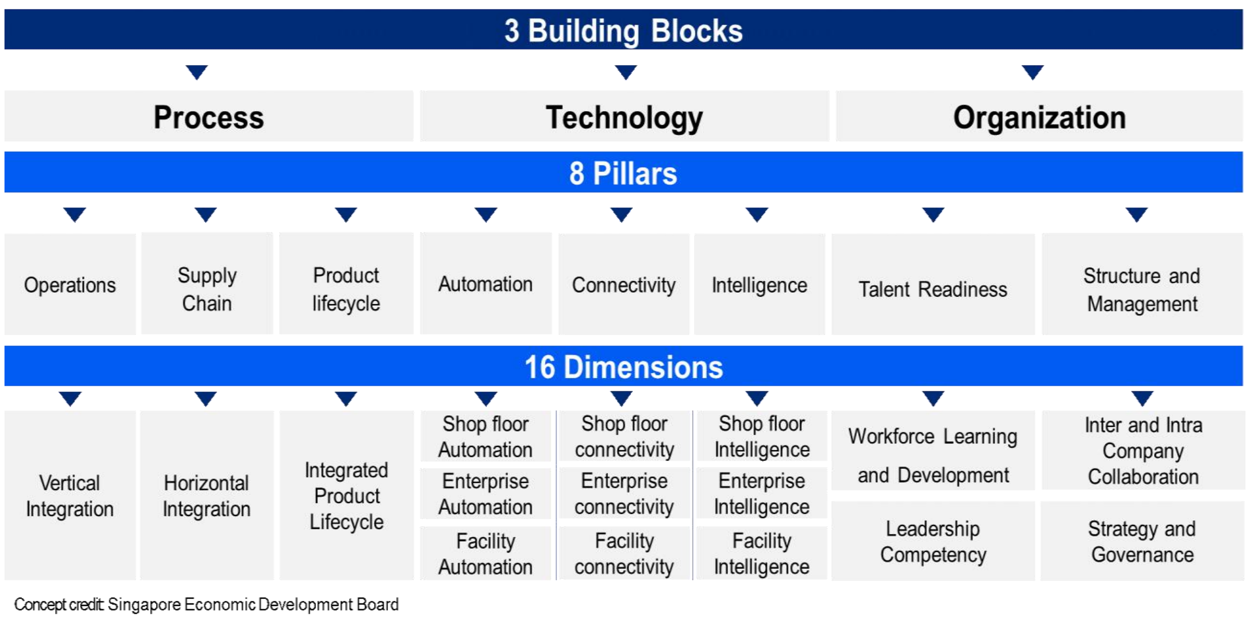
The third building block encompasses the organisational structures and processes, and the people involved, the workforce, who will be the actual ones to steer the ship of IR 4.0 in their organisations. Henceforth, it consists of two pillars, Talent Readiness, and Structure & Management.

- *Talent Readiness*: To put it simply, it refers to the ability of a workforce to effectively realise the ambitions of the fourth industrial revolution. In order to enhance that ability, organisations need to provide spaces for learning so that workers stay updated with the latest developments of IR 4.0, and also be able to operate with them.

Moreover, the skill levels of the workforce must be multifaceted because the IR 4.0 uses dynamic and digitalised operations, thereby, making it imperative for organisations to augment their training facilities.

- *Structure & Management*: Structure deals with rules and policies that govern the workflow of an organisation, and in the age of IR 4.0, it is bound to be designed to facilitate further decentralisation of decision-making, more transparency of information, and more collaboration among internal and external partners. On the other hand, management of an organisation ensures that its workforce reaches the desired goal, and that too needs drastic improvements, in terms of leadership, to match up with the highly complex working mechanisms of IR 4.0.

Figure 4: Components of third building blocks



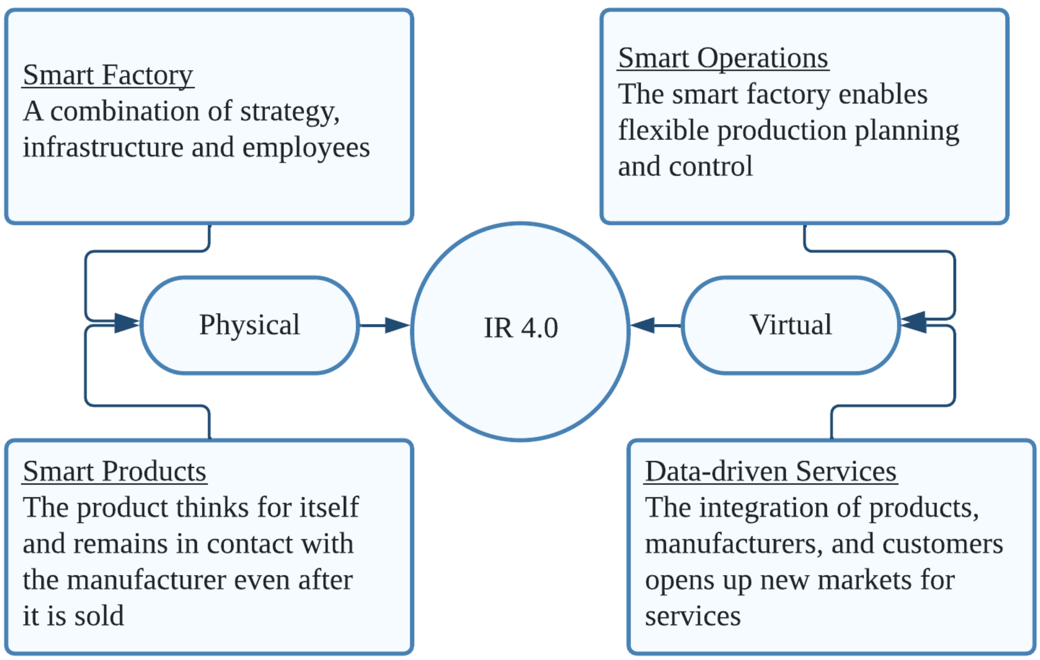
3.3 Conceptual Framework

Industry 4.0 has four basic components – smart factory, smart operations, smart products and data-driven services which was explained by a German research team while looking for Industry 4.0 readiness in the Germany’s mechanical engineering industry (Lichtblau et. al 2015). Their work suggested that there are six external variables that are directly linked with various intense to achieving industry 4.0.

Smart factory is a coordination of three variables such as organizational strategy, organizational infrastructure and the employees. Along with these three variables smart products is another variable that are physical inputs to achieving industry 4.0.

At the same time smart operations data-driven services are virtual variables that support in achieving the industry 4.0. Based on the concept the study framework is given below. The framework connects all the six variables physically and virtually to achieving industry 4.0.

Figure 5: Conceptual framework of industry 4.0

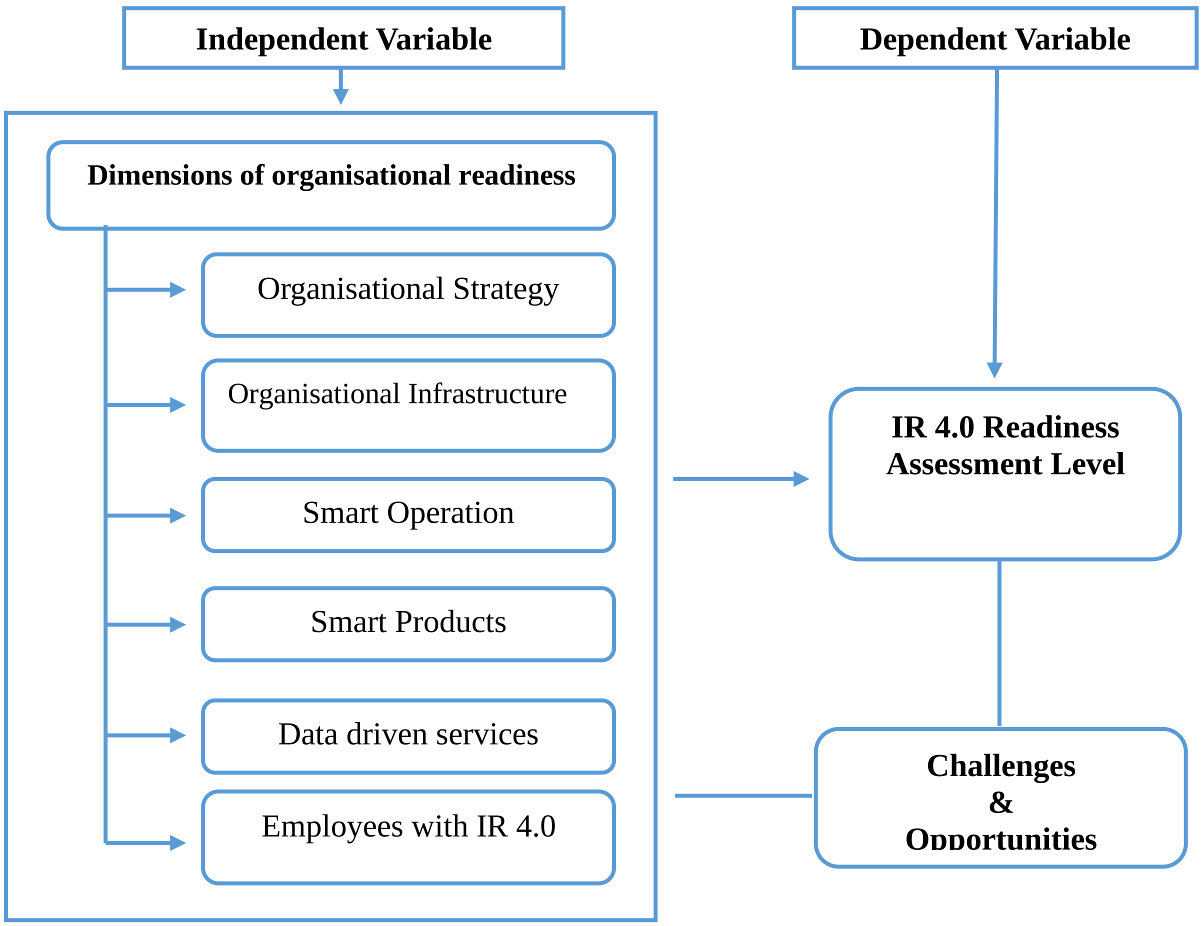


3.4 Variables

The independent variables chosen for the study are the conditions and/or features within an organisation that are subjected to changes while each remain unaffected by the other variables and can be measured during the study both quantitatively and qualitatively by exploring their different levels. These variables have been selected purposively in hindsight with key established characteristics of IR 4.0 to determine the organisational readiness of RMG industries. The independent variables include organisational strategy, organisational infrastructure, smart operation, smart products, data driven services and employees with IR 4.0 skills.

The dependent variable on the other hand emerges naturally, and it is the presumed result/effect due to changes in the independent variables. For this study, the dependent variable is the IR 4.0 readiness assessment level.

Figure 6: Variables used in the study



3.5 Research Questions:

In this research the following questions were investigated in the form of questionnaire survey, KIIs (Key Informants Interviews) and Case Study analysis. The key questions are as follows:

1. What is the level of RMG factories (large, medium and small) in Bangladesh in terms of their IR 4.0 readiness?

a. Readiness in terms of organization strategy
b. Readiness in terms of organization infrastructure
c. Readiness in terms of smart operation
d. Readiness in terms of smart products
e. Readiness in terms of data driven services
f. Readiness in terms of employment/talent/skill match strategy

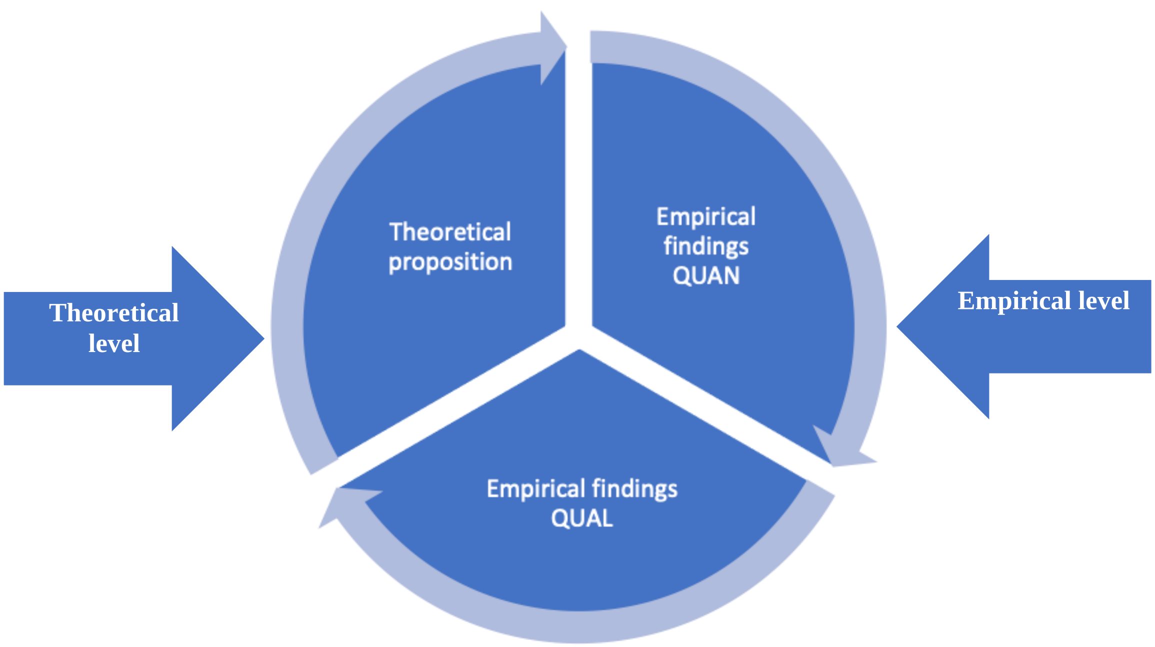
2. Is the size of the factories the important determinant for the IR 4.0 readiness?
3. What are areas where apparel industry in Bangladesh need to prepare themselves to adopt and implement IR.4.0?
4. What are the challenges and opportunities for apparel industry in Bangladesh to implement Industry 4.0?

4. Chapter Four: Methodology of the study

There are three research approaches to adopt from in order to answer the research question while conducting research. These approaches are quantitative, qualitative and mixed methods. In the quantitative method data is collected in numerical forms, in the qualitative method data is collected in textual form and in the mixed method data is collected in both forms (Williams, 2007). Choosing an appropriate method of research depends mostly on the type of the research such as explanatory or action research (Chapman et. al, 2005).

Since it may bolster arguments and disclose previously undiscovered facts, the mixed-method approach has become increasingly popular in recent years. Figure 7: An illustration of data triangulation. Using triangulation as a methodological metaphor may help understand the connections between theory and empirical findings when using a mixed-methods approach (stlund et al., 2011).

Figure 7: Illustration of data triangulation

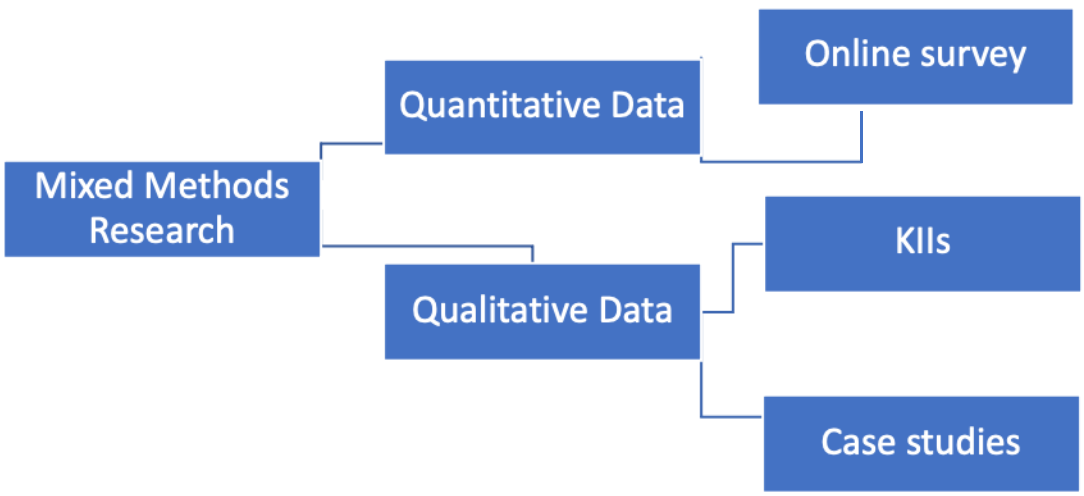


Source: Erzberger and Kelle, 2003

To assess the readiness of Bangladesh apparel industry a mixed method approach has been taken into consideration. Mixed methods research involves the mechanism of collecting and then analysing the collected quantitative and qualitative data. Both types of data need to collect in a systematic pattern complementing each other. Also, these data can be collected in different stages of the research (Teddlie & Tashakkori, 2003).

In this approach, the quantitative data collected through an online survey due to Covid-19 pandemic and the qualitative data obtained through KIIs and case studies.

Figure 8: Data collection method



Qualitative Data are defined as the characteristics or qualities that cannot be attached to numerical value. It is also known as qualities or characteristics, e.g. honesty, motivation, integrity, confidence etc. Quantitative Data are the characteristics or qualities that can be expressed with numerical values, are called variables, e.g., age, length, width etc. (Singh, 2006).

Key informant interviews (KIIs) are conducted with a selected group of people having considerable knowledge on the research questions or the population or any significant characteristics of a research (Kumar, 1989). Most often, these interviews are taken with a semi-structure questionnaire as a tool where based on the respondents' experience or knowledge the questions are generally set. In the cases of KIIs, the respondents are selected based on non-probability sampling such as purposive or convenience sampling.

Case studies are in-depth, qualitative interviews with insiders of a certain community or institution. The purpose of considering case studies is to obtain data from people who have firsthand experience with the study topic and objectives at hand, such as community leaders, professionals, or citizens (Marshall, 1996).

4.1 Industrial Revolution Readiness Assessment Tool

Researchers found that the VDMA Industry 4.0 Readiness Assessment was a great tool for figuring out how ready an organization is for Industry 4.0. Hence, it was also used in this study (Lichtblau et al., 2015).

This evaluation tool looks at six aspects of how a factory works to determine its readiness for Industry 4.0. These include (a) organizational strategy, (b) organizational infrastructure, (c) intelligent operations, (d) intelligent products, (e) data-driven services, and (f) employees. The following illustrates how these dimensions are composed of further sub-categories that is shown in the Table 3: Industry 4.0 reediness assessment.

Table 3: Industry 4.0 reediness assessment

Dimensions	Sub-category	Indicators
Organisational strategy	Industry 4.0 strategy implementation	• Status of strategy implementation • Overall organisational strategy and compatibility
	Organisational investments	• Investment plans for implementing Industry 4.0
	Systematic technology and innovation management	• Coordinated management of technology and innovation
	Industry 4.0 technologies	• Total technologies are used
Organisational infrastructure	Equipment functionalities	• Making use of IT for controlling machine systems • Making use of Machine-to-Machine communication • Functions of machines' interoperability
	Equipment functionalities' adaptability	• Making use of M2M communication • Making use of machines' interoperability
	Digital modelling	• Data collecting from machines and its processing

	Systems, and interface to leading system	• How many systems in use • How many systems have leading interface
Smart operations	Cross-departmental information sharing	• How many departments are internally integrated and share information internally • How many departments are externally integrated and share information externally
	Autonomous functionality	• Guides for autonomous workpiece • Providing response in real time for autonomous production
	IT solutions	• Structure of IT • Level of implementation of Security solutions • Level of use of cloud services
Smart products	Products functionality based on ICT	• How many add-on functionalities
Data-driven services	Data usage and analysis	• Making use of data and processing data for enabling new services • Making use of data analytics
Employees	Industry 4.0 skills	• Availability of required skills

Source: Lichtblau et. al 2015

4.1.1 Assessment Method

All the important questions were quantitative in nature and were coded so that a total score could be calculated for all readiness assessment domains. The maximum possible score on each dimension of preparedness is listed in the table below; This was determined by determining the maximum possible score on each question on that dimension and then summing together all the scores on all the questions on that dimension. For each question, a score was calculated in one of two ways: (a) by treating all binary responses as either 1 (yes) or 0 (no) and then adding up all the possible total score and (b) by treating Likert scales (or responses with a positive progression) as interval data, translating the verbal Likert rating scale into a numeric Likert rating scale, and then adding up all the possible total scores.

Table 4: Possible total score for each readiness dimension

Readiness dimension	Possible total score
Organisational strategy	189
Organisational infrastructure	144
Smart operations	45

Readiness dimension	Possible total score
Smart products	40
Data-driven services	12
Employees	31

Source: Lichtblau et. al 2015

Readiness Dimension Scoring

- Sum of all assigned values to each relevant questions responded by the factories

All six dimensions were looked at during the analysis, and a weighted average was used to figure out the projected readiness score. Table 5 shows the weighted score for each of the six aspects taken into account, as determined by the VDMA "Industry 4.0 Readiness" model. By asking businesses how each dimension affected the adoption of Industry 4.0, I was able to come up with a way to weight the dimension scores.

Table 5: Dimensions' weighted scores

Dimensions	Weighted Score
Organisational strategy	25%
Smart factory	14%
Smart operations	10%
Smart products	19%
Data-driven services	14%
Employees	18%

Source: Lichtblau et. al 2015

Industry 4.0 Readiness Assessment

- 25% Organisational strategy + 14% Smart factory + 10% Smart operations + 19% Smart products +14% Data driven services + 18% Employees

Table 6: Industry 4.0 preparedness categories outlines the five stages of readiness used in this concept, adapted from the VDMA paradigm. Based on their research, Basl and Kopp created the table below to evaluate the level of preparedness among Czech businesses. In this case, they applied the VDMA readiness model, and the degrees of readiness was determined using the description and criteria in the table below.

Table 6:Industry 4.0 preparedness categories

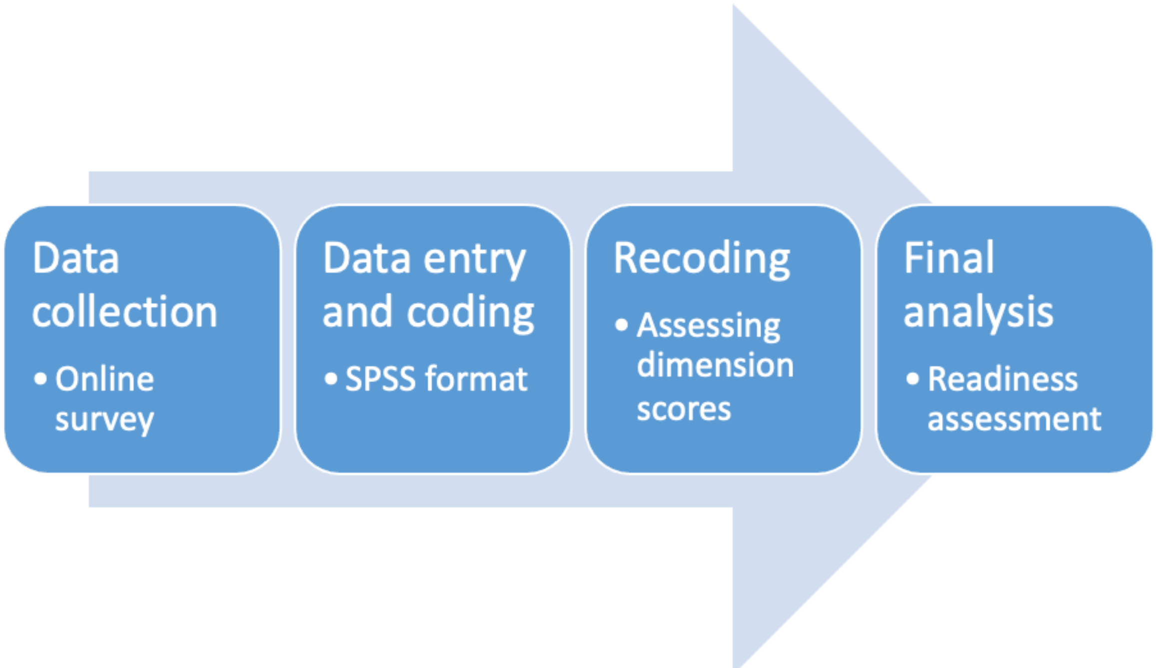
Readiness level	Description	Criteria
Level 1: Beginner	• Initiatives and investment have made for Industry 4.0. • Infrastructure is little for future requirements. • There are skills available.	0 < Points ≤ 50
Level 2: Intermediate	• Company strategy will incorporate Industry 4.0. • Investments are made in areas. • Data are collecting from partial autonomous production. • Better skills available.	50 < Points ≤ 90
Level 3: Experienced	• Strategy is complete for the companies. • Major investment is done. • Upgradable infrastructure is present. • IT security is in place.	90 < Points ≤ 120
Level 4: Expert	• Strategy is in use for Industry 4.0. • Investment is found in all departments. • Huge data collected automatically and processed for various purposes. • Various add-on information technology functionalities are available.	120 < Points ≤ 145
Level 5: Top performer	• Industry 4.0 strategy is fully implemented and is being monitored. • Investment has been made in the entire company and all departments. • Satisfactory infrastructure for Industry 4.0 requirements.	145 < Points ≤ 160

Source: Lichtblau et. al 2015

4.1.2 Process of Assessing Industry 4.0 Readiness

The assessment of Industry 4.0 Readiness index process starts with collecting data using an online data collection tool. Link of this tool was shared with the management committee of selected RMG factories. Online data was collected on a Google Sheet which acted as the main database. All these data then coded and transformed to an SPSS data file for final assessment using the formulas given above.

Figure 9: Process of assessing Industry 4.0 readiness



4.2 Hypothesis Testing

Analysis of Variance (ANOVA) has been used to test a number of hypotheses considering the dimensions of Industry 4.0 and the size of the factories (small, medium and large). The result of this analysis provided necessary evidence regarding the size of the factories and Industry 4.0 achievement. In the following table, a list of hypotheses has been mentioned that was tested after finishing the VDMA analysis.

Table 7: List of hypotheses that were tested

Test	Hypothesis
ANOVA	1. H_0: There is no difference in terms of the factory sizes and organizational strategy for industry 4.0
	2. H_0: There is no difference in terms of the factory sizes and organizational infrastructure for industry 4.0
	3. H_0: There is no difference in terms of the factory sizes and smart operations for industry 4.0

Test	Hypothesis
	4. H_0: There is no difference in terms of the factory sizes and smart products for industry 4.0
	5. H_0: There is no difference in terms of the factory sizes and data-driven services for industry 4.0
	6. H_0: There is no difference in terms of the factory sizes and employees for industry 4.0
	7. H_0: There is no difference in terms of the factory sizes and their industry 4.0 readiness level

ANOVA is a statistical technique which is applied to determine whether or not the means of two or more groups are significantly different from each other. ANOVA checks the impact of one or more factors by comparing the variation in the means of different samples (Stigler, 1986).

The samples could have been also compared with the use of a 't-test'. When there are only two samples, t-test and ANOVA produce the same results (Stigler, 1986). However, a t-test measurement is unreliable in cases where there are more than 2 samples. In this case, there are three samples based on the factory size – large, medium and small. Therefore, t-test was not needed in this regard.

4.3 Questionnaire Structure

A questionnaire instrument with quantitative criteria was used as the research strategy in this study, while taking a leaf from a study performed by VDMA, and the questions have been tailor-made for Bangladesh's apparel industry.

The survey questionnaire was designed to collect input from at least 134 industries of selected apparel industry in Bangladesh. Multiple choice form and a Likert-type scale was used for survey items.

The Likert scale range was **1 = Strongly Disagree to 5 = Strongly Agree.** The entire instrument consists of four parts which are given in the below table.

Table 8: Different sections of survey questionnaire

First Section:	Demographic information of the respondents and their organisation which are closed-ended two-point questions or multiple-choice questions in nature.
Second Section:	Questions related to the strategy level.
Third Section:	Questions related to the adoption level. In this section the answers were filled with using Likert scale responses.
Forth Section:	Questionnaire for collecting mid-level manager's opinion regarding IR 4.0 adoption in the apparel industry. For this section, the answers were taken through multiple choice questions and also open-ended.

4.3.1 Validity and Reliability of the Research

The principles of reliability and validity are used to evaluate the quality of research. They reflect the accuracy with which a method, approach, or test measure something. The consistency of a measure is referred to as its reliability, whereas the accuracy of a measure is referred to as its validity.

The two most significant and fundamental criteria in the evaluation of any measurement instrument or tool for successful research are reliability and validity. The validity of an instrument is concerned with what it measures and how successfully it does so. Reliability refers to one's confidence in the data acquired from the use of an instrument, or the extent to which any measuring equipment compensates for random error.

4.3.1.2 Validity

The validity of a research study refers to how well the findings among study participants correspond to genuine findings among similar individuals outside of the study. This definition of validity applies to all clinical research, including those on prevalence, relationships, therapies, and diagnosis. Following steps were taken to ensure the validity of the research and its instruments.

- Conducting key informant interviews (KIIs) prior to selecting appropriate methodology. The industry experts provided necessary information with regard to selecting methodology, developing questionnaire.

- Knowledge sharing meeting with relevant industry people was conducted to share the methodology, questionnaire and sampling procedure in order to receive their opinions and incorporating them in the final methodology and sampling. The expert panel was selected from industry experts consisting experienced senior level and mid-level managers, industry engineers and head of HR having in-depth knowledge in the area of automation and digitisation i.e. smart industry concept, IR 4.0 and also having knowledge in research methodology and statistical analysis
- Primary findings of the readiness assessment were shared with the academics and industry people in a seminar.

4.3.1.3 Reliability

Establishing reliability in research is critical to ensuring that data is sound and replicable, and that outcomes are correct. Evidence of reliability are required to ensure a measurement instrument's integrity and quality (Kimberlin & Winterstein, 2008).

A reliability test for the research instrument has been conducted. Responses that were collected using Likert scale and were used for the readiness assessment considered for this test. There is a total for 34 variables and all variables come out significant at either 0.1 or 0.05 level for a two tailed Pearson Correlation test except one variable that is difficulties with integrating data from various sources to enable initial connectivity. The results are shown in

Appendix VI: Results from Reliability Test of the Instruments.

4.4 Sampling and Sampling Frame

The following formula was used for determining the sample size (n) for this study:

$$n = N*X / (X + N – 1),$$

where,

$$X = Z_{\alpha/2}^2 *p*(1-p) / MOE^2,$$

here $Z_{\alpha/2}$ is the critical value of the Normal distribution at α/2 (e.g. for a confidence level of 95%, α is 0.05 and the critical value is 1.96), margin of error is noted as MOE (explained below), sample proportion is denoted as p, and population size is denoted as N (Cochran, 1963). Definitions of these terms are given below from Daniel and Cross (2018).

- *Margin of error:* Required precision level is recorded with the margin of error. It is sometime defined as confidence interval or population proportion. The true population proportion expressed in percentage such as ±5%.
- *Confidence level*: It is explained by the probability in which the margin of error have the true population proportion. Higher confidence level comes with high number of sample size.
- *Population size*: Here, the population size is the total number of distinct RMG factories in Bangladesh.
- *Sample proportion*: The sample proportion for a study often comes or estimated from a previous study with similar population and relatively close research question or from a pilot study.
- *Sample size*: Using the formula given above putting MOE 5%, confidence level 95% and population size 4000 and sample proportion 90%, the sample size is 134.

Sample proportion is taken from previous study conducted by CPD titled "New Dynamics in Bangladesh's Apparels Enterprises: Perspectives on Upgradation, Restructuring and Compliance Assurance" (CPD, 2019).

Calculation,

N = 4000, $Z_{\alpha/2}$ = 1.96, p = 0.9, MOE = 0.05

$$X = (1.96)^2 \times 0.9(1-0.9) \div (0.05)^2 \cong 138$$

$$Sample\ size, n = \frac{(4000 \times 138)}{(138 + 4000 - 1)} = 134$$

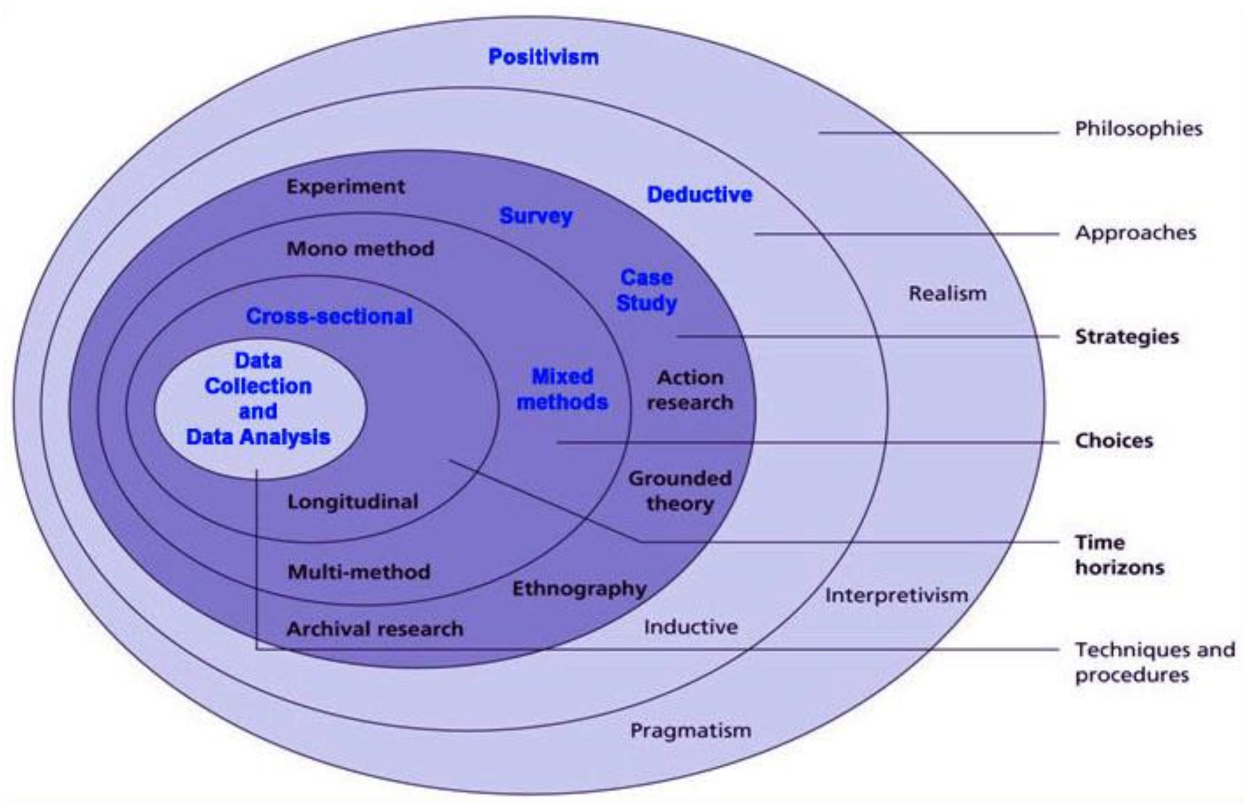
- *Sampling frame*: A sampling frame is a list of all the items in the population. It's a complete list of everyone or everything that needs to be studied. In this case, the member list of BGMEA and BKMEA have been used as sampling frame for the survey.

A total of 200 factories were reached randomly from the list through email using the sampling. Upon which 138 responses were received. However, during the data cleaning process 3 responses could not be used for analysis due to lack of adequate responses. At the end, the analysis was made using the responses from 135 factories.

4.5 Summary of the Research Methodology

Based on the theoretical concept of Research Onion by Saunders et al (2016) the summary of my research methodology is shown below for quick review.

Figure 10: Research Onion



Sourse: Saunders et al (2016)

5. Chapter Five: Data Analysis and Findings

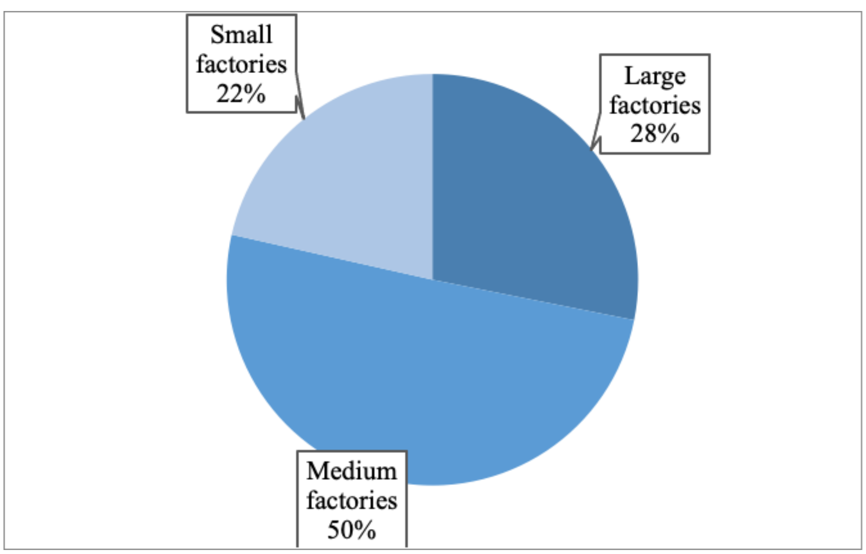
5.1 Findings from the Survey

This chapter shows the result of the survey findings which have been collected from 135 factories. The findings from the survey illustrate industry status and the perception the management of the survey factories with regard to IR 4.0.

5.1.1 Characteristics of Factories

In this study, total 135 responses were collected from the sampled factories. Factories have been classified according to size, such as small, medium, and large. The factories having less than 500 workers are considered small factories. The factories having workers between 500-1000 are considered as medium factories, and the rest are considered as large factories. The percentage of their representation in the entire sample is shown in the graph below: 22 percent of factories are small (29 factories), 50 percent of factories are medium (68 factories), and the remaining 28 percent of factories are large (38 factories).

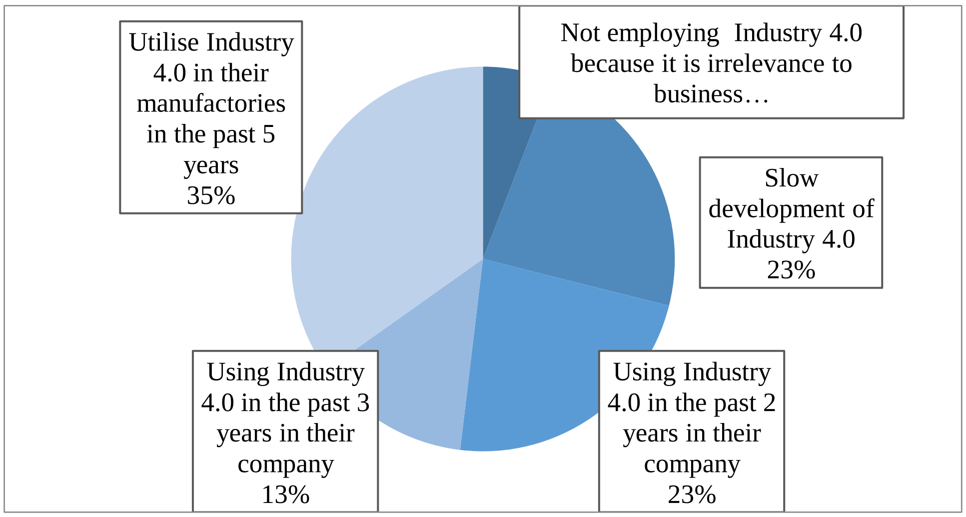
Figure 11: Sample distribution according to factory size



5.1.2 Present Condition of Industry 4.0 in the company

Three-fifths of the respondents said they had fully implemented Industry 4.0 in the last five years to make their company more competitive. Only six per cent indicated they had yet to implement any aspect of Industry 4.0 since it was irrelevant to their company.

Figure 12: Current level of employing IR 4.0 in companies



As manufacturing companies need to remain competitive and future-ready, they need to have adequate talents to run the digitally sophisticated factory. According to the below table, 63.4 % of the respondents confirmed that they have adequate talented employees who already adopted sophisticated technology tools.

Table 9: Adequate talents to run the digitally sophisticated factory

Responses	Percentage (%)
Yes	63.4
No	2.3
Partly	34.4
Total	**100.0**

Almost three-quarters (65.9%) of the respondents have skilled workers in certain areas to implement Industry 4.0 in their companies. Moreover, only few of them have stated that they do not have skilled employees. A recent study of Asian Development Bank (ADB) revealed that manual workers have mainly faced displacement due to Industry 4.0 technologies adoption in factories; for instance, male workers are affected by job displacement in Vietnam, and female workers in the garments of Cambodia (ADB, 2021).

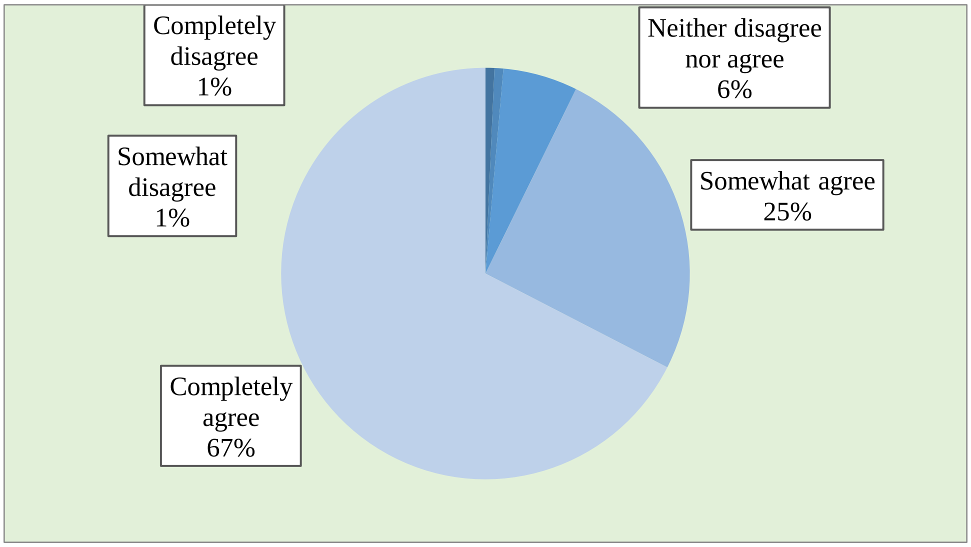
Table 10: Skilled workers/talents/employees to implement industry 4.0

Responses	Percentage (%)
Has the skilled workers/talents/employees as needed	28.0
Has the skilled workers/talents/employees in certain areas	65.9
Completely lacked the necessary skilled workers/talents/employees	6.1
Total	**100.0**

5.1.3. Strategy level of Organisation in IR 4.0

This section illustrates the organizational strategies used to measure automation's readiness and present status in Bangladesh's apparel industry. To evaluate the strategy level of an organization, one needs to understand how the Bangladeshi industry's competitiveness has been boosted, the company's stance on the impact of digital transformation, the implementation status of IR 4.0, tracking indicators of implementation, what are the using technologies for enhancing business competitiveness, what are the benefits of digital transformation, how is the systematic technological management, then the degree of digitalized and individualized product portfolio, the skill level of workers who are implementing IR 4.0, the infrastructural adaptability, and security concerning issues regarding digitalization and automation.

Figure 13: Boosting global competitiveness through digital transformation



This study showed that 67.4% of the participants believed that the digital transformation to Industry 4.0 in the apparel sector could boost Bangladesh's global competitiveness. In comparison, only a few of them (5.9%) have a neutral opinion in this regard. The Deloitte study shows that digital transformation is not only altering global competitiveness but also bringing up resource issues (Deloitte, 2017). The study also shows that most Swiss industries are making some progress because of digital transformation, and companies stressed the importance of digital transformation to Industry 4.0 (Deloitte, 2017).

Figure 14: Impact of digital transformation

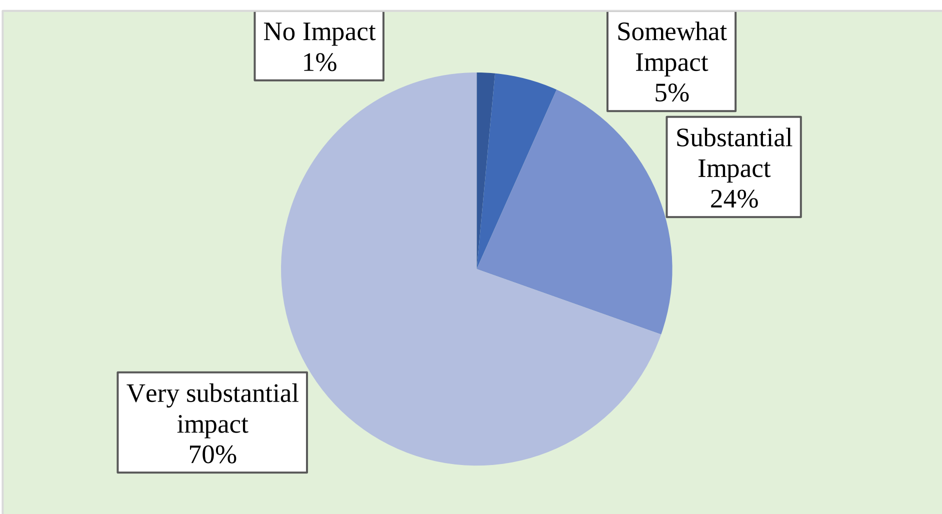


Figure 14 illustrates that 69.6% of participants believed that digital transformation could enable a small factory to optimize the manufacturing system, which substantially impacts Industry 4.0. Medium and small-size factories can easily implement digital transformation or automation rather than very large manufacturing factories, and it is because large companies have more complexity in their organizational structure and groups (Deloitte, 2015).

From the two pie charts displayed above, it can be deduced that in the journey of the fourth industrial revolution, the competitiveness of Bangladeshi industries will be boosted by the digital transformation in the apparel sector, and the digital transformation will vary substantially impact the industries. For instance, in Vietnam, labour productivity in industry enterprises has improved due to new machinery, technology, and Industry 4.0 created new job opportunities and improved employees' qualifications and skills (Oanh, N. T., Hanh, P. T. M., & Dung, N. T., 2021).

Figure 15: IR 4.0 strategy implementation status

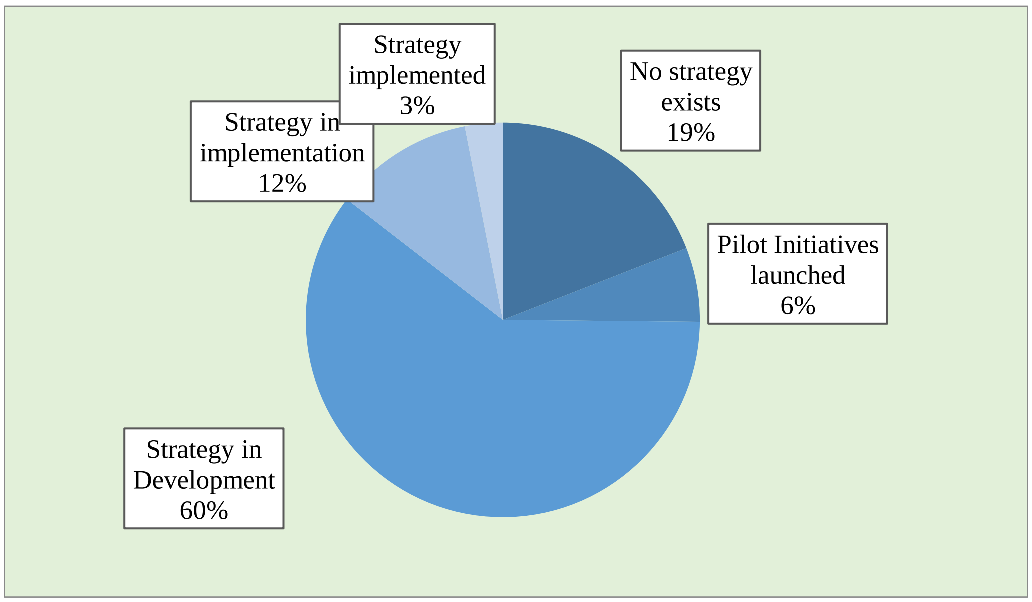
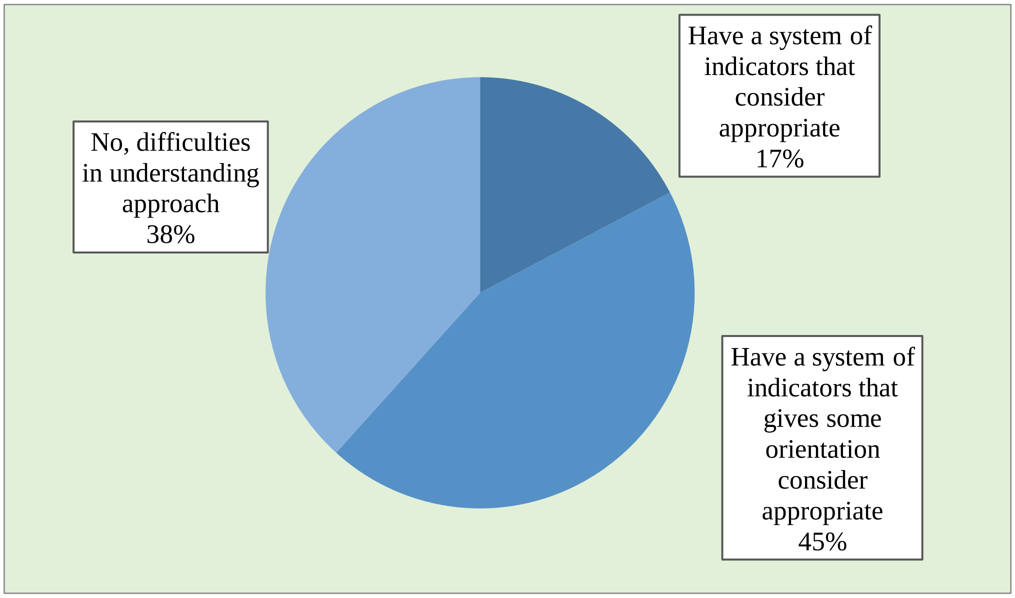


Figure 15 shows that more than half of the respondents (60%) mentioned that they are analyzing their company's status and gradually developing the Industry 4.0 strategy. Only a few participants (3.0%) stated that they had already implemented the new approaches for tackling the company's new supply and demand challenges. However, 1.5% of respondents confirmed that they still need to compose a strategy for Industry 4.0.

Figure 16: Strategy formulation status



According to Figure 16, almost half of the respondents (44.4%) seem to be more concerned about Industry 4.0 strategy formulation, and 17.3 % of the respondents have a system of progress indicators to track the implementation status of the Industry 4.0 strategy.

Table 11: Potential areas for implementing IR 4.0

Areas	No potential	Potential	Neutral	Very potential	Great potential
Research and development	0.8%	11.6%	13.2%	23.3%	51.2%
Production/manufacturing	0.8%	10.6%	5.3%	25.8%	57.6%
Procurement/purchasing	1.6%	9.3%	10.1%	47.3%	31.8%
Warehousing/logistics	1.6%	6.3%	22.0%	36.2%	33.9%
Marketing	1.6%	7.8%	7.8%	48.1%	34.9%
Sales	2.4%	20.6%	19.8%	32.5%	24.6%
Services	0.8%	23.4%	15.6%	33.6%	26.6%
IT	0.0%	9.4%	7.0%	36.7%	46.9%

According to Table 11, 57.6% of respondents consider investment in the production or manufacturing department to have great potential for realizing the ambitions of Industry 4.0. The Research and Development segment holds the second greatest potential with a percentage of 51.2%, and the other areas, such as procurement, logistics, and sales, have a lower potential for

IR 4.0. However, the study showed that IT is the third-greatest potential area (46.9% of respondents mentioned it), and marketing is a very potential area for IR 4.0.

Table 12: Level of transformation

Areas	No transformation	Transformation	Neutral	Moderate transformation	Strong transformation
Research and development	7.1%	13.4%	18.9%	46.5%	14.2%
Production/manufacturing	3.1%	13.7%	8.4%	50.4%	24.4%
Procurement/purchasing	7.9%	7.9%	27.0%	45.2%	11.9%
Warehousing/logistics	7.0%	19.5%	32.0%	31.3%	10.2%
Marketing	7.0%	9.3%	29.5%	38.8%	15.5%
Sales	8.9%	23.6%	26.8%	29.3%	11.4%
Services	8.8%	20.8%	28.8%	29.6%	12.0%
IT	3.8%	11.5%	25.4%	41.5%	17.7%

In accordance with Table 12, Research and Development, Production/Manufacturing, Procurement/Purchasing, and IT (46.5%, 50.4%, 45.2% and 41.5% respectively) are indicating moderate transformation to embrace the latest manufacturing technologies in their companies. However, the other departments such as Warehousing/Logistics, Marketing, Sales, and Service have lower potential for IR 4.0

Table 13: Level of investment in the potential areas during last two years

Areas	Large	Medium	Small	None
Research and development	21.4%	45.0%	29.8%	3.8%
Production/manufacturing	59.0%	28.4%	9.0%	3.7%
Procurement/purchasing	15.6%	64.8%	13.3%	6.3%
Warehousing/logistics	14.1%	49.2%	30.5%	6.3%
Marketing	39.8%	46.9%	9.4%	3.9%
Sales	14.3%	45.2%	20.6%	19.8%
Services	18.6%	43.4%	19.4%	18.6%
IT	28.7%	57.4%	8.5%	5.4%

Table 13 reveals that companies are mostly investing in Production/Manufacturing (59.0%), Marketing (39.8%) areas to digitise essential operational functions in the past two years. While in Procurement/purchasing (64.8%), IT (57.4%), Warehousing/logistics (49.2%), and Sales (45.2%) departments, they have made a medium range of investment.

The results show that the most important parts of a business are production, research and development, information technology, and marketing. These sections stand to gain the most from Industry 4.0's digital revolution. On the other hand, the likelihood of success is lower in areas like sales, services, warehousing/logistics, and purchasing.

5.1.4. Digitisation and Competencies

The figure below shows the technologies companies require to enhance their business competitiveness. It has been observed that ERP (almost 19%), Big Data (17%), Cloud (13%), and M2M Communication (12%) have been mentioned as the essential technologies in the organizations' pursuit of Industry 4.0.

Figure 17: Technologies require to enhance competitiveness

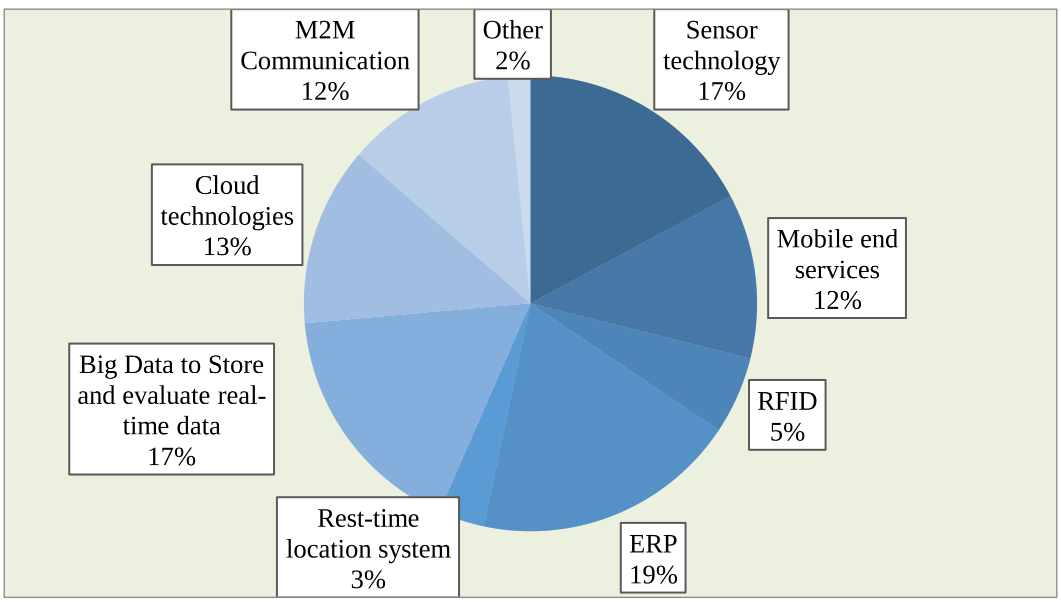
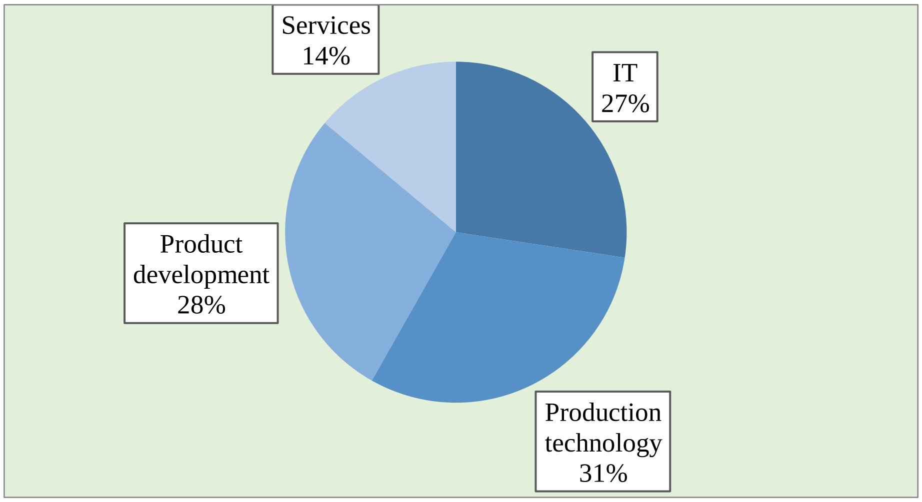


Figure 18 shows the responding companies' areas for systematic management of technology and new ideas. The main areas for the implementation of Industry 4.0 are production technology (31%), product development (28%), and IT (27%). While for Thailand-based companies, the core areas to be focussed on for realizing IR 4.0 are Production technology, IT, and product development (P. Koomsap et al., 2019).

Figure 18: Systematic technology and innovation management



Automation, sensors, IoT connections, digital monitoring, and control are essential to IR 4.0. According to Table 14, almost half of the responding (46.5%) companies have medium-digitized factories, meaning they have interconnected production equipment that allows for IT access and information for some part of the production in the factory. In Bangladesh, few textile and RMG industries have used automation applications. In contrast, Myanmar has many sophisticated factories that use various types of automated equipment in production (ILO, 2020).

Table 14: Digitisation of production equipment (sensors, IoT connection; digital monitoring, control, optimization & automation)

Responses	**%**
1. Purely physical factory	19.4
2. Low digitized factory	18.6
3. Medium digitized factory	46.5
4. High digitized factory	11.6
5. Fully digitized factory	3.9
Total	**100.0**

Note:
Purely physical – Production equipment is entirely cut off from IT systems and no real-time information can be gathered
Low: Production equipment is connected to the Internet and information is fed into a machine in the factory
Medium-digitized: Some of the factory's production equipment is connected to the Internet and information is fed to it.
High: Production equipment is connected to the Internet and information is fed into a virtual representation of the factory's main products.
Fully digitalized: All production equipment is connected to the Internet, and information is fed into a computer model of the factory.

From Table 15, it can be seen that the advancement of digital enablement impacted reactive communication highly (33.1%). The other interactions that enable the sales forces, such as one-way communication for information (21%), one way communication for responses (12.9%), proactive communication 32.3%, interaction via social media platforms (0.8%)

Table 15: Advancement of Digital Enablement of sales forces

Responses	Percentage (%)
1. One-way communication	21.0
2. Two-way communication	12.9
3. Reactive communication	33.1
4. Proactive communication	32.3
5. Interactive communication	0.8
Total	**100.0**

Note:
One-way communication is when traditional ways of communicating (like a company's website or newsletters) are only used to share information.
Two-way communication – Using traditional channels of communication (like a company website) to respond to a customer.
Reactive communication is when digital channels are used to respond to customers. For example, you could use information from customers in the past to help make new products.
Proactive communication is the use of digital channels to interact with customers. For example, some companies involve customers in the development of their products.
Interactive communication is the use of multiple digital channels to encourage customer interaction, such as letting customers help develop products through social media.

According to table16, fewer than half of the respondents (42.5%) mentioned that they have only 25% of digital operations capabilities (25% of products and services are digitised), and have somewhat digital features, and augmented their existing portfolio. However, only 7.5% respondents confirmed that their products and services are completely digitized, and they enhanced their product portfolio with digital functionalities.

Table 16: Degree of digitalised products and services

Responses	Percentage (%)
All our product and services are completely digitized and our portfolio is **never** based solely on digitized serviced/product	7.5
At least 25% of our product and services are digitized and our portfolio is **somewhat** based on digitized serviced/product	42.5
At least 50% of our product and services are digitized and our portfolio is based on digitized serviced/product	26.1
At least 75% of our product and services are digitized and our portfolio is **strongly** based on digitized serviced/product	16.4
All our product and services are **completely** digitized and our portfolio is **completely** based on digitized serviced/product	7.5
Total	**100.0**

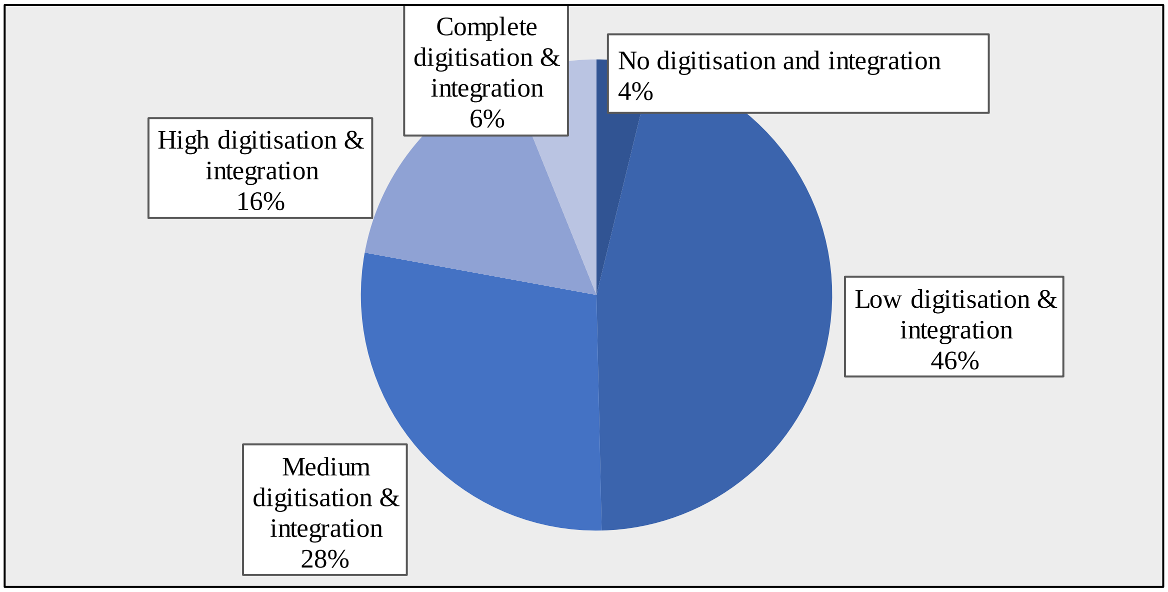
Table 17 illustrates that almost half of the respondents (42.4%) said that 75% of their products and services are defined by the customer via configuration tools; whereas only 5.3% of them mentioned that all of their products and services are standardized mass production and are independent of customer's demands.

Table 17: Degree of indivisualisation of products that customers order

Responses	**Percentage (%)**
All our product and services are standardised mass production, cannot be defined by customer via configuration tools)	5.3
At least 25% of our product and services can be defined by customer via configuration tools depending on lot size	6.8
At least 50% of our product and services can be defined by customer via configuration tools but cannot have lot size of 1	28.8
At least 75% of our product and services are defined by customer via configuration tools for customers, can have lot size of 1	42.4
All our product and services are completely defined customer by via configuration tools for customers, can have lot size of 1	16.7
Total	**100.0**

Figure 19 illustrates the life cycle phase of the product's digitization. It has been found out that 46% of the products and phases have gone through low digitization and integration where the products are partly digitized. In addition, 28% of the industry has implemented the medium level of digitization and integration. However, the percentage of complete digitization is very much poor (6%).

Figure 19: Life cycle phases of products being digitized



Note:

No digitization and integration—none of the phases are digitalized, and we don't use IoT or IT as our main way of doing things.

Low digitization and integration: For basic operation, only some phases, like design, planning, and engineering, are partially digitized (e.g., using IT and software designed specifically for company operation)

Medium digitization and integration: Only the design, planning, and engineering phases are digitalized (e.g., producibility can directly be evaluated via virtual prototyping, virtual design)

High digitization and integration: Most of the design, planning, engineering, production, service, and recycling stages of a product's life cycle are done digitally (e.g., producibility can directly be tested during product development via virtual prototyping)

Complete digitization and integration: All parts of a product's life cycle, such as design, planning, engineering, production, services, and recycling, are all done digitally (e.g., Quality, Producibility, Productivity can directly be tested during product development via virtual prototyping, virtual process)

Research (Yang, S., MR, A. R., Kaminski, J., & Pepin, H., 2018) shows that inefficient data extraction could hurt the efficiency and quality of product lifecycle management. According to the results of this study, the digital transformation of Industry 4.0 helps make it easier to share data and build a platform for sharing data so that all parties involved in a product's lifecycle can share information globally.

To get the best competitive position possible, the organization must understand how important it is to use and analyze data. According to Table 18, more than a quarter (40.9%) of respondents who have been continuously evaluating and monitoring these generated data for the last 3-5 years believe that data is the primary value generator in their business model. Businesses can improve their services and attract more customers by collecting and analyzing data about their customers, products, and machines.

Table 18: Usage and analysis of data (customer data, product or machine-generated data) for business model

Responses	(%)
No data analytics are relevant or leveraged to our business model. Customer data, product or machine data are not relevant to our operation. We plan to analyze and monitor those data in the next 3-5 years	1.5
Customer data, product or machine generated data is **somewhat** relevant to business, can be value driver of the business model and we will be analysing and monitoring these generated data in the **next** 1-3 years	12.1
Customer data, product or machine generated data is relevant to business, the value driver of the business model and we have analyzed and monitored these generated data in the **past** 1-3 years	25.8
All customer data, product or machine generated data is **very** relevant to business, the main value driver of the business model and we have analyzed and monitored these generated data in the **past** 2-3 years	19.7
Crucial - Data is the main value driver of the business model. All customer data, product or machine generated data is **strongly** relevant to business and we are continuously analyzing and monitoring these generated data in the past 3-5 years	40.9
Total	**100.0**

Figure 20 shows how the organization works with its clients, suppliers, and other partners to create new goods and services. More than half of the respondents (51%) said they worked closely with suppliers and other executives to create a clear, observable demand pattern across the whole supply chain for the benefit of partners and customers.

Figure 20: Degree of collaboration with partners and clients in the past 1-3 years

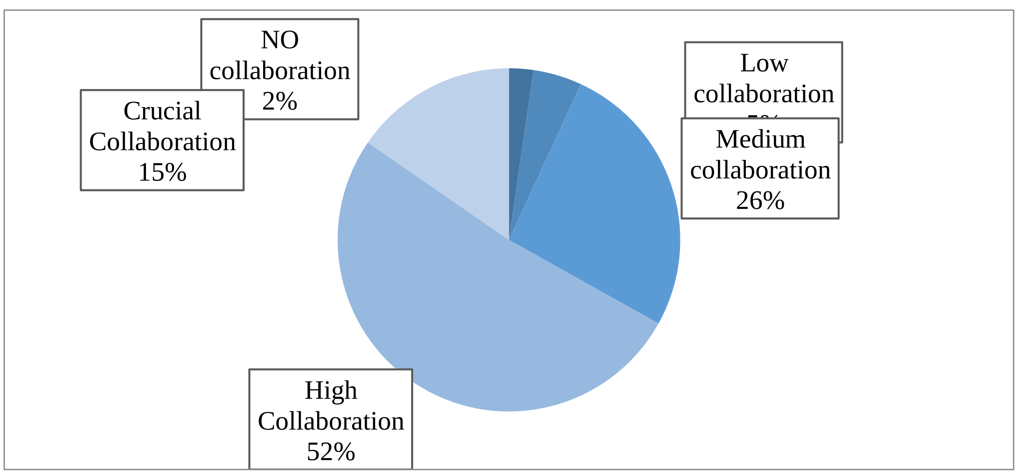


Table 19 shows that more than three-fourths of respondents (38.3%) agree that Industry 4.0 is important for businesses to adopt. That is why nearly as many people believe it is important to businesses and must be implemented within the next three years to boost business competitiveness and the overall value creation of the company's products and services.

Table 19: Level of the contribution of Industry4.0 in increasing the competitiveness and value creation of products & service

Responses	%
Industry4.0 is **not relevant** to business and we do not need to adopt it in next 5 years	5.3
Industry4.0 is **somewhat relevant** to business and we will need to adopt it in next 3	9.8
Industry4.0 is **relevant** to business and we will need to adopt it in next 3 years	38.3
Industry4.0 is **very relevant** to business and we will need to adopt since past 3 years	7.5
Industry4.0 is **strongly relevant** to business and we need to adopt it since past 5 years	38.3
Total	**100.0**

5.1.5. Services, Evaluating, Monitoring, and Planning

According to Table 20, 66.4% of Security/Communication Security exists in the industries but is inadequate according to the demand. 52.8% of industries have adequacy in the IT infrastructure, 62.6% industries have the existence of automation technology but inadequate, and 59.2% of industries have the existence of data analytics but that is not adequate for attaining the skilled workers' target under the Industry 4.0. Another requirement is non-technical skills, according to the survey 60.2% of industries have the existence of non-technical skills such as systems thinking and process understanding but not adequately available.

Table 20: Future Requirements for an employee under Industry 4.0

Requirements	Not relevant	Non-existent	Existent but inadequate	Adequate
IT infrastructure	0.0%	3.9%	43.3%	52.8%
Automation technology	1.5%	10.7%	62.6%	25.2%
Data analytics	0.0%	12.3%	59.2%	28.5%
Data security / communications security	0.0%	8.6%	66.4%	25.0%
Development or application of assistance systems	0.0%	46.5%	28.7%	24.8%
Collaboration software	.8%	14.2%	58.3%	26.8%
Non-technical skills such as systems thinking and process understanding	2.3%	12.5%	60.2%	25.0%

As seen in Table 21, mostly, in the production technology (27.0%), product development (25.7%) and IT (23.5%) sectors, companies need to attain Industry 4.0.

In connection to this considering Vietnam's perspective, a study by Swarnima, C., Mehra, P., & Dasot, A. (2017) identified that most of Vietnam's industries have a limited understanding of Industry 4.0 processes and they are still at Industry 2.0. The study also shows that most of Vietnam's industries are weak in the automation process, and manufacturers over there are seeking contribution from their government to reform their policies, and adopt new technologies and investments.

Table 21: Areas of attaining Industry 4.0

Areas	Percentage %
IT	23.5%
Production technology	27.0%
Product development	25.7%
Services	15.3%
Centralised management	8.1%
Do not need	0.4%
Total	**100.0%**

The level of concern of a company about the competence of its employees is presented above in Table 22. More than half of the respondents think that IT infrastructure (60.5%) and automation technology (59.2%) will need a very strong level of competence for new employees for the transition to Industry 4.0. Besides, there are four skill sets which can provide a basic framework for a new employee or youth to adopt Industry 4.0, and the skills are workforce readiness, soft skills or essential human skills, technical skills, and entrepreneurship (Armstrong et al., 2018). On the other hand, 54.7% of the respondents mentioned that development or application of assistance systems which can help to handle the data-based system would need a strong level of competence for new employees.

Table 22: Level of competency for new employees

Employees with skills	Low	Medium	Strong	Very strong
IT infrastructure	2.3%	17.1%	20.2%	60.5%
Automation technology	1.5%	17.7%	21.5%	59.2%
Data analytics	5.3%	10.7%	47.3%	36.6%
Data security / communications security	6.3%	14.8%	44.5%	34.4%
Development or application of assistance systems	4.7%	10.9%	54.7%	29.7%

Employees with skills	Low	Medium	Strong	Very strong
Collaboration software	4.7%	14.1%	45.3%	35.9%
Non-technical skills such as systems thinking and process understanding	3.1%	19.5%	46.9%	30.5%

According to Table 23, almost half of the respondents (49.2%) state that machines/systems can be controlled 25%-50% percent through IT, more than one-fourth (38.8%) of them believe it to be true for M2M: machine-to-machine communications, and 34.6% of them have similar views about integration with another machine systems.

Table 23: Evaluation of equipment infrastructure

Functions	No	Yes but 25%-50%	Yes but 51%-75%	Yes but 76%+
Machines/systems can be controlled through IT	6.2%	49.2%	27.7%	16.9%
M2M: machine-to-machine communications	27.1%	38.8%	17.1%	17.1%
Interoperability: integration and collaboration with other machines/systems possible	36.2%	34.6%	12.6%	16.5%

As per Table 24, the adaptability level of Industry 4.0 in the sampled industries can be understood. 13.4% of respondents state that M2M has high adaptability in the Industry 4.0, while 11.1% state that collaboration with other machine systems/machines have low adaptability in the Industry 4.0.

Table 24: Evaluation of equipments for IR 4.0 adaptability

Functions	Not relevant	Relevant, but not upgradable	Upgradable	High, because functionality already available
M2M: machine-to-machine communications	5.5%	13.4%	67.7%	13.4%
Interoperability: integration and collaboration with other machines/systems possible	4.8%	17.5%	66.7%	11.1%

It is quite clear from Table 25 that most of the respondents want to invest a large amount for the company's Production/Manufacturing (51.1%) department, and a medium amount for Procurement/Purchasing (60.2%) in the next five years for implementing Industry 4.0. Moreover, the table shows that many of the respondents want to invest a large amount for the company's IT

(44.2%) department. Moreover, the table shows that many of the respondents want to invest a large amount for the company's IT (44.2%) department.

Table 25: Areas of investment in the next five years

Area/ investment size	Large	Medium	Small	None
Research and development	41.5%	39.2%	16.2%	3.1%
Production/manufacturing	51.1%	38.3%	9.8%	.8%
Procurement/purchasing	18.0%	60.2%	18.0%	3.9%
Warehousing/logistics	37.2%	36.4%	21.7%	4.7%
Marketing	41.9%	40.3%	14.0%	3.9%
Sales	18.1%	52.0%	22.8%	7.1%
Services	17.1%	57.4%	19.4%	6.2%
IT	44.2%	41.9%	11.6%	2.3%

5.2 Industry 4.0 Readiness Assessment

According to Lichtblau and et. al 2015 industry 4.0 model there are six levels of industry 4.0 implementation level. Levels and its explanation are given in the below table. A detailed description has been provided in Table 6 (chapter 4).

Table 26: Levels of Industry 4.0

Levels	Name	Explanation
Level 1	Beginner	Factories at this level are involved in Industry 4.0 through pilot initiatives in various departments and investments in a single area.
Level 2	Intermediate	Factories at this level develop strategy to implement Industry 4.0 and the appropriate indicators to measure the implementation status.
Level 3	Experienced	Experienced level factories make Industry 4.0–related investments in multiple areas and promote the introduction of Industry 4.0 through department-oriented innovation management.
Level 4	Expert	Expert factories are already using an Industry 4.0 strategy and monitoring it with appropriate indicators. Investments are being made in nearly all relevant areas, and the process is supported by interdepartmental innovation management.
Level 5	Top Performer	Factories at this level have already implemented its Industry 4.0 strategy and regularly monitors the implementation status of other projects. This is supported by investments throughout the company.

Source: Lichtblau and et. al 2015

Since there has not been any top performer in the findings of this study, this level is omitted in the tables below for better viewing and understanding.

5.2.1 Industry 4.0 readiness assessment by various categories

For analysing IR 4.0 readiness in this research VDMA readiness model had been used. The results as per the model is described below.

Category 1: Organisational Strategy

According to Table 27, more than half of the sampled factories are at an intermediate level in terms of organisational strategy readiness which is an important prerequisite for realising Industry 4.0. Only 1 factory is deemed as an expert in this category, and 43.7% factories are experienced enough to incorporate IR 4.0. In addition, 2.96% of factories are at beginner level under this category. Therefore, though many factories have the experience to plan or execute a strategy which will be effective for the entire chain of workflow with them, the ones who are at an intermediate stage, more than half that is, are yet to devise such approaches for adopting IR 4.0.

Table 27: Industry 4.0 readiness assessment - Organisational Strategy

Readiness level	Frequency	Percent
Beginner	4	2.96
Intermediate	71	52.59
Experienced	59	43.70
Expert	1	0.74
Total	**135**	**100**

Category 2: Organisational Infrastructure

Table 28 reveals that factories are lagging more behind in infrastructural readiness than strategical one. Once again, more than half of the factories are at an intermediate level, but the number of experienced factories is lower (37.78% to be precise) than that found in the measurement of organisational strategy. In addition, no organisation has become an infrastructural expert yet to adopt IR 4.0. In fact, 8.89% of factories are at the beginner level of readiness. Exercising IR 4.0 means the installation of high-tech equipment, machines, digital systems, and the ability of a factory to perform this adoption, and also sustain, is paramount, and to that regard, majority of the factories are struggling as of now.

Table 28: Industry 4.0 readiness assessment - Organisational Infrastructure

Readiness level	Frequency	Percent
Beginner	12	8.89
Intermediate	72	53.33
Experienced	51	37.78
Expert	0	0
Total	**135**	**100**

Category 3: Smart Operation

From Table 29, it can be easily concluded that the majority of factories (81.48%) has miles to traverse to execute smart operations of IR 4.0 as they are all at an intermediate level. Only a handful of factories (8.89%) are experienced in this category, and the rest stand at beginner level. Among all the categories, which are in fact the founding blocks of IR 4.0, factories are struggling the most in terms of smart operation. Having no experts in this field, and with 4 out of every 5 factories still intermediately ready for IR 4.0, this finding is a major concern.

Table 29: Industry 4.0 readiness assessment - Smart Operation

Readiness level	Frequency	Percent
Beginner	13	9.63
Intermediate	110	81.48
Experienced	12	8.89
Expert	0	0
Total	**135**	**100**

Category 4: Smart Products

According to Table 30, more than one third (35.56%) factories are at an experienced level of readiness to reap the benefits of IR 4.0's smart products. 12.59% factories have expert level of readiness, and a little over that figure, 14.07% factories are at an infant stage. The highest proportion of factories (37.78%) once again belongs to the ones at intermediate level of readiness. However, these figures are particularly better than those found in the category of 'smart operation', implying that the factories perhaps do possess a basic understanding of the functionality of smart products, but are not ready yet to implement them in their operations.

Table 30: Industry 4.0 readiness assessment - Smart Products

Readiness level	Frequency	Percent
Beginner	19	14.07
Intermediate	51	37.78
Experienced	48	35.56
Expert	17	12.59
Total	**135**	**100**

Category 5: Data-driven services

Table 31 reveals that the preparedness for utilizing data-driven services is quite low among the sampled factories, with 76.3% of them at an intermediate level, and only 14.81% factories are at an experienced level. No factory has become an expert yet to practice data-driven services. Besides, 8.89% factories are still at the beginner stage. This is another category where majority of the factories are lagging behind. After 'smart operation', this category holds the highest number of factories at an intermediate level of readiness.

Table 31: Industry 4.0 readiness assessment: Data-driven services

Readiness level	Frequency	Percent
Beginner	12	8.89
Intermediate	103	76.30
Experienced	20	14.81
Expert	0	0
Total	**135**	**100**

Category 6: Employees

According to Table 32, more than half of the factories (55.56%) have a workforce with experienced level of preparedness to embrace Industry 4.0. In fact, 20.74% factories have expert-level employees to operate the highly complex systems and processes of IR 4.0. Besides, 20% of factories are at an intermediate level, and a mere 3.7% of factories are at beginner stage. The figures of this category seem to be the most impressive out of the six important pillars of foundation of IR 4.0. This is because the majority of the factories have experienced workforce, and the largest expertise in terms of any of the categories, is also found among employees.

Table 32: Industry 4.0 readiness assessment: Employees

Readiness level	**Frequency**	**Percent**
Beginner	5	3.70
Intermediate	27	20.00
Experienced	75	55.56
Expert	28	20.74
Total	**135**	**100**

5.2.2 Industry 4.0 readiness assessment by factory size (using weights)

Small factories

Table 33 shows that majority of the small factories are at an intermediate level of readiness to adopt Industry 4.0. What is more striking is that none of the small factories has displayed experienced readiness, and in fact, nearly one third of them are at beginner level of preparedness for implementing IR 4.0. These figures give the impression that small factories have a long way to go for adopting IR 4.0, and are most likely to find it challenging to reach an expert level of readiness in any of the six aforementioned categories.

Table 33: Industry 4.0 readiness assessment: Small factories

Readiness level	**Freq.**	**Percent**
Beginner	8	27.59
Intermediate	21	72.41
Experienced	0	0
Total	**29**	**100**

Medium factories

Although it is generally presumed that medium factories will be more prepared to implement Industry 4.0, Table 34 shows that it is not the case. Their stance on IR 4.0 is in fact exactly the same as that of small factories; nearly one third of medium factories are at beginner level, and the rest are at an intermediate level of readiness. This is quite an unfortunate finding in the sense that small and medium factories are large in numbers, constitute the majority of the sample of this study as well, and they are not ready at all to embrace IR 4.0.

Table 34: Industry 4.0 readiness assessment: Medium factories

Readiness level	Frequency	Percent
Beginner	19	27.94
Intermediate	49	72.06
Experienced	0	0
Total	**68**	**100**

Large factories

According to Table 35, more than half of large factories (57.89%) are at an intermediate level of readiness for the installation and practice of IR 4.0, and the remaining ones are merely at beginner level. Counterintuitive it may seem, but the large factories are not gearing up for IR 4.0 either; in fact, their proportion of intermediate level of readiness is small than that of small or medium factories. Moreover, the large segment of large factories who are still at beginner level, is a major concern, similarly, the fact that no large factory has been found to be experienced enough for IR 4.0.

Table 35: Industry 4.0 readiness assessment: Large factories

Readiness level	Frequency	Percent
Beginner	16	42.11
Intermediate	22	57.89
Experienced	0	0
Total	**38**	**100**

5.2.3 Industry 4.0 readiness for sampled factories

According to the overall weighted score, a little more than 50% of factories are at intermediate level of readiness for IR 4.0, implying that the apparel sector of Bangladesh can still not be considered well prepared to embrace the highly sophisticated and complex phenomenon of the fourth industrial revolution.

The overall weighted score is 52 which stands at the **Intermediate level**

5.2.3.1 IR 4.0 Readiness at Intermediate Level – Explanation

The survey data from this study were fitted in to the VDMA model and shows that the RMG factories in Bangladesh are currently at intermediate level in terms of Industry 4.0 adaptation. This means that most of the factories are in the process of developing strategy to implement industry 4.0 technologies.

The factories are either now starting to invest in the newer automatic technologies or have started investment very recently like within two years. Data are collected from the production level are at very limited scale and use of the data are limited. The current employees are relatively skilled to take the new steps towards 4.0 upgradation. The infrastructure that is available at the factories are not suitable for the future technologies. Most importantly the score arrived from the model is 52 which is only a bit higher than the beginner level. It implies that a good number of factories are at a transition phase from beginner to intermediate in terms of industry 4.0 adaptation.

There must be other parameters, other challenges present within the sector that need to be addressed before undertaking a transition to IR 4.0. This also calls for more research in this field, and attention from the policymakers to establish a sustainable support system that enables the Apparel industry to adopt automation and IoT and keep up with the growing international competitiveness.

5.3 Research Question Findings

However, many companies are only willing to make some necessary changes to prepare for the Industry 4.0 revolution. Results showed that productivity increases, cost reductions, consumer demand, and the need to keep up with technological changes were the most common reasons for adopting new technology (Ali, 2021). With more than 80% of the country having decent coverage on 4G and 3G networks, India is at the forefront of the industry 4.0 ecosystem. India is a leader in IT, and its top textile companies are already using some industry 4.0 applications with the help of new, high-tech textile machines (A.T.E. Enterprises Private Limited, 2019). Lack of product diversification, reliance on a small number of large-scale industries, a shortage of skilled workers, low productivity among the existing workforce, and large wage gaps when compared to competitors in countries like Cambodia, Vietnam, the Caribbean, and sub-Saharan Africa, are all problems facing Sri Lanka's apparel industry (Lakmali, 2020). The 4 IR Policy Landscape says that Cambodia must still have a full strategy for 4 IR. According to a study by the International Labor Organization (ILO) in 2017, the biggest problem with updating technology in Cambodia is the high fixed capital costs. This is compounded by a shortage of competent technology operators (ADB, 2021).

The term "Industry 4.0 readiness" describes a company's preparedness to use Industry 4.0 tools. In other words, it indicates how digitally prepared a company is to use Industry 4.0 tools. Digital transformation has impacted the hardware and software of businesses. Hanafiah et al. (2020) say that finding these examples of getting ready for Industry 4.0 is a very important part of the digital transformation process that could lead to organizational change. This study divides getting ready for Industry 4.0 into three steps: operational, organizational, and customer.

5.3.1 Findings of Research Question 1 – Level of Apparel Factories (large, medium and small) in Bangladesh in terms of IR 4.0 Readiness

Table 36 illustrates the IR 4.0 maturity levels of all the sampled factories concerning the VDMA analysis categories of organizational strategy, organizational infrastructure, smart operation, smart products, data-driven services, and employees.

Table 36: Percentage of factories according to various level of IR 4.0 and categories

IR 4.0 Levels	Organisational strategy	Organisational Infrastructure	Smart Operation	Smart Products	Data Driven Services	Employees
Beginner	2.96%	8.89%	9.63%	14.07%	8.89%	3.70%
Intermediate	52.59%	53.33%	81.48%	37.78%	76.30%	20.00%

IR 4.0 Levels	Organisational strategy	Organisational Infrastructure	Smart Operation	Smart Products	Data Driven Services	Employees
Experienced	43.70%	37.78%	8.89%	35.56%	14.81%	55.56%
Expert	0.74%	0.00%	0.00%	12.59%	0.00%	20.74%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

In terms of organisational strategy 52.59% factories were found to be at 'intermediate' phase of IR 4.0 readiness and another 43.7% factories were found to be in 'experience' level, according to the survey. This tells that most of the factories have developed their strategy and many of them also started implementing those strategies. 53.33% factories were found be in 'intermediate' level when it comes to organisational infrastructure category of IR 4.0. Also 37.78% factories were found to be in 'experience' level under the same category. Based on this information it can be said that the most surveyed factories are developing infrastructure for IR 4.0 operation.

Smart Operation is where the operations maintained automatically. In this category, 81.48% factories were found to be in 'intermediate' level and second most (9.63%) were in the 'beginner' level. In terms of smart products, 37.78% factories were in 'intermediate level' and 35.56% were in 'experience' level. The factories are in the process of making their products smarter as to their requirements. Data is most important in the process of IR 4.0. There should be adequate services that are data driven connecting backward and forward linkages. In this category, 76.30% factories were at 'beginner' phase and 14.81% were at 'experience' phase. Finally, employees of the surveyed factories were found to be smarter. In terms of employees, 55.56% factories were at 'experience' phase and another 20.74% factories were at 'expert' phase suggesting that employees have the capacities to adapt IR 4.0 faster.

Even while Bangladesh has been making great strides toward IR 4.0 preparedness, other nations are developing even more rapidly. India's manufacturing sector may one day be competitive with the likes of China, Bangladesh, Vietnam, and Sri Lanka, but only if the country jumps on the Textile 4.0 bandwagon sooner rather than later. The Textile Association of India has held two international conferences on Textile 4.0 in the last year in light of the significant paradigm change necessary for the textile sector (A.T.E. Enterprises Private Limited, 2019).

In the same way, it looks like more and more Vietnamese clothing brands have been showing up at technical trade shows in Saigon over the past two years. The Vietnam National Textile and Garment Group and Institutes surveyed more than 300 Vietnamese clothing companies and found that the top companies are trying to adapt to Industry 4.0. Many Vietnamese businesses place a premium on increasing efficiency, decreasing manufacturing costs and labor, and embracing cutting-edge technology (Apparel Resources, 2019).

According to the evaluation, Pakistan's strategic and organizational segmentation is at an advanced beginner level. Most industries are allocating resources to building their workforces and introducing cutting-edge practices. As a result, everyone in every division works together toward the same goal: increased output (Ali, 2021).

However, several national plans and strategy documents show that different governments want to improve their abilities to put IR 4.0 into place. The Cambodia Trade Integration Strategy 2019–2023 is the first national plan to comprehensively outline preparations for the Fourth Industrial Revolution. An interministerial task team worked with the United Nations Development Program, the United Nations Conference on Trade and Development, and the World Trade Organization to make it. Second, "readiness for the digital economy and the Fourth Industrial Revolution" is one of the four goals for economic diversification and new sources of growth established in Rectangular Strategy Phase IV, which lays out the country's socioeconomic vision. A third, "digitalization", is recognized as one of the four pillars of industrial policy in the Industrial Development Policy 2015-2025. Fourth, the National Technical and Vocational Education and Training Policy 2017-2025, supported financially by the Asian Development Bank (ADB), directs national skills' development strategies, with a focus on enhancing trainer quality, pedagogical practices, and the acquisition of resources that are compatible with the ongoing technological development. As a final point, MEF's Garment and Footwear Sector Development Strategy 2019-2025 (now in preparation) will begin transforming the sector to higher-skill and value-added operations through adopting new technology and up-skilling the workforce (ADB, 2021). In the following sections, research questions are answered based on the survey findings and testing the hypothesis using ANOVA tool.

Findings of Research Question 1a: Readiness in Terms of Organisational Strategy

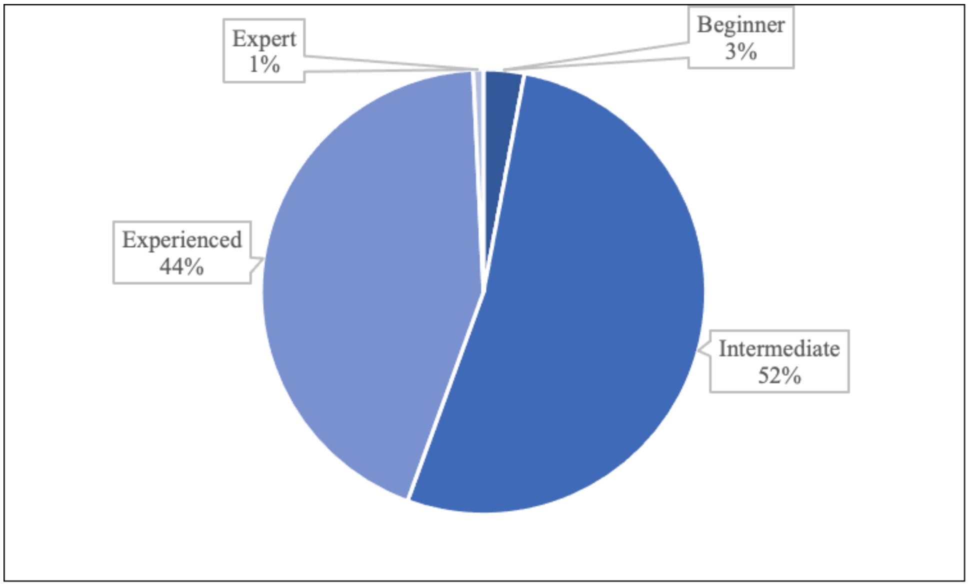
The organisational plan is subdivided into the following areas: systematic technology and innovation management, organisational investments, and implementing an Industry 4.0 strategy (table 37). Indicators under this heading include how the strategy is put into action, how well it fits with other strategies and investment plans, and how technology and innovation are managed. Indicators are linked to their respective subcategories in the following table.

Table 37: Industry 4.0 readiness assessment indicators - Organisational Strategy

Category	Sub-category	Indicators
Organisational strategy	Industry 4.0 strategy implementation	▪ Strategy implementation status ▪ Strategy compatibility with overall organisational strategy
	Organisational investments	▪ Number of distinct areas with investments or plans to invest in Industry 4.0
	Systematic technology and innovation management	▪ Number of distinct areas with systematic technology and innovation management

In the sampled industries, it has been found that most (52%) of the industries that adopted an organisational strategy were in the intermediate level (Figure 21). After adoption of Industry 4.0 in the organisational level, the strategies will need to be re-revised and change the key influential factors in the industry's performance regarding automation (Hanahfia, 2020).

Figure 21: Factory levels based on Organisational Strategy



To test whether there is any relation between the different factory sizes and the adopting an organizational strategy ANOVA tool was used and the result is given below.

ANOVA 1 - Relation between factory size and organisational strategy

H_0: There is no significant relationship between the factory sizes and organizational strategy for industry 4.0

Analysis of Variance

Source	SS	df	MS	F	Prob > F
Between groups	13.5833487	2	6.79167437	0.22	0.7989
Within groups	3986.54813	132	30.2011222		
Total	4000.13148	134	29.8517275		

Bartlett's test for equal variances: chi2(2) = 8.0790 Prob>chi2 = 0.018

Note: Factory sizes (small, medium and large) was considered as groups.
Score for each factory regarding organizational strategy using VDMA analysis has been used in the ANOVA.

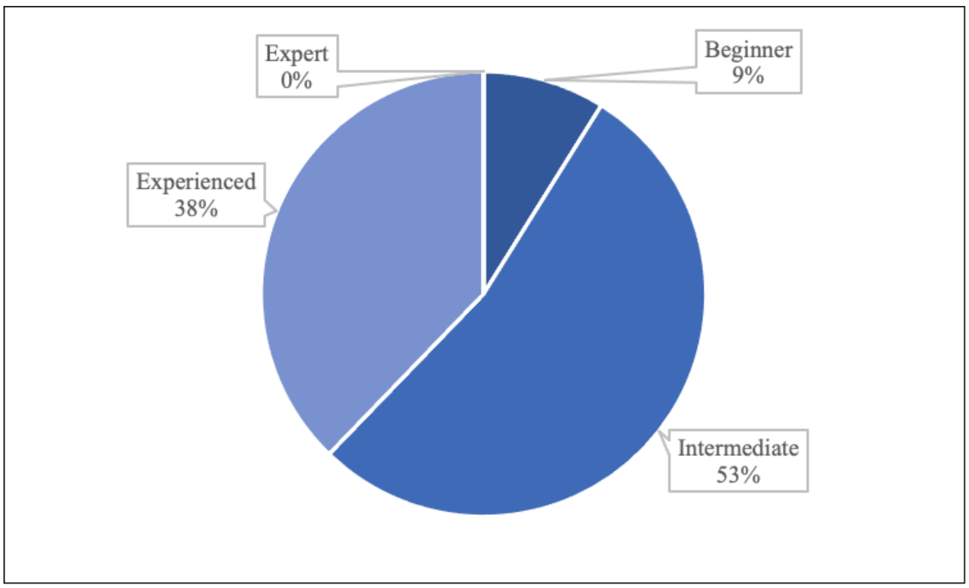
Considering the p-value (0.799), the result is not significant at $p<0.05$. Hence, H_0 cannot be rejected.

From the above analysis, it is evident that in terms of organizational strategy the factories are in the '**Intermediate**' level of Industry 4.0 readiness and from the ANOVA findings it can be said that **factory sizes do not play a role** in developing an organizational strategy for a factory with regards to industry 4.0 readiness.

Findings of Research Question 1b: Readiness in Terms of Organisational Infrastructure

As per the rapidly changing demand regarding IR 4.0, the industries need to cope up with their infrastructure level, which in turn, requires the establishment of world class technology organization and effective use of the resources (Reksoatmodjo et al., 2012). In the factory survey, 53% factories were found to be in 'intermediate' level and 38% were in 'experience' level.

Figure 22: Factory levels based on Organisational Infrastructure



To adapt to Industry 4.0, several nations have started building up their production infrastructure. Many modern textile machines in India are connected to the Internet, digitalized, and capable of artificial intelligence. Many of the leading textile machinery manufacturers have introduced complete production process monitoring systems through the Internet of things (IoT), which can give various analytical reports in real-time, which is very useful in reorienting the production and quality processes for better results.

The ring frame in many Indian spinning mills is equipped with a spindle monitoring system. It provides real-time information that may be utilized to boost efficiency and output. Even in the art of weaving, many factories now use Loomdata and similar Internet monitoring tools to keep tabs on how efficient their weaving sheds are (A.T.E. Enterprises Private Limited, 2019).

Organisational Infrastructure is broken down into four subcategories: equipment functionalities, equipment flexibility, digital modeling and systems, and link to industry-standard platforms. The table below displays many indications for each of these sub-types.

Table 38: Industry 4.0 readiness assessment indicators - Organizational Infrastructure

Category	Sub-category	Indicator
Organisational infrastructure	Equipment functionalities	▪ Level of use of IT to control machine systems ▪ Level of use of Machine-to-Machine communication ▪ Level of machines' interoperability
	Equipment functionalities' adaptability	▪ Level of use of M2M communication ▪ Level of machines' interoperability
	Digital modeling	▪ Machine data collection and processing
	Systems, and interface to leading system	▪ Number of systems in use ▪ Number of systems in use with leading interface

To test whether there is any relation between the different factory sizes and their organizational infrastructure ANOVA tool was used and the result is given below.

ANOVA 2 - Relation between factory size and organisational infrastructure

H_0: There is no significant relationship between the factory sizes and organizational infrastructure for industry 4.0

Source	SS	df	MS	F	Prob > F
Between groups	66.7736583	2	33.3868291	2.85	0.0612
Within groups	1544.40063	132	11.7000047		
Total	1611.17428	134	12.0236887		

Analysis of Variance

Bartlett's test for equal variances: chi2(2) = 2.6978 Prob>chi2 = 0.260

Note: Factory sizes (small, medium and large) was considered as groups.
Score for each factory regarding organizational strategy using VDMA analysis has been used in the ANOVA.

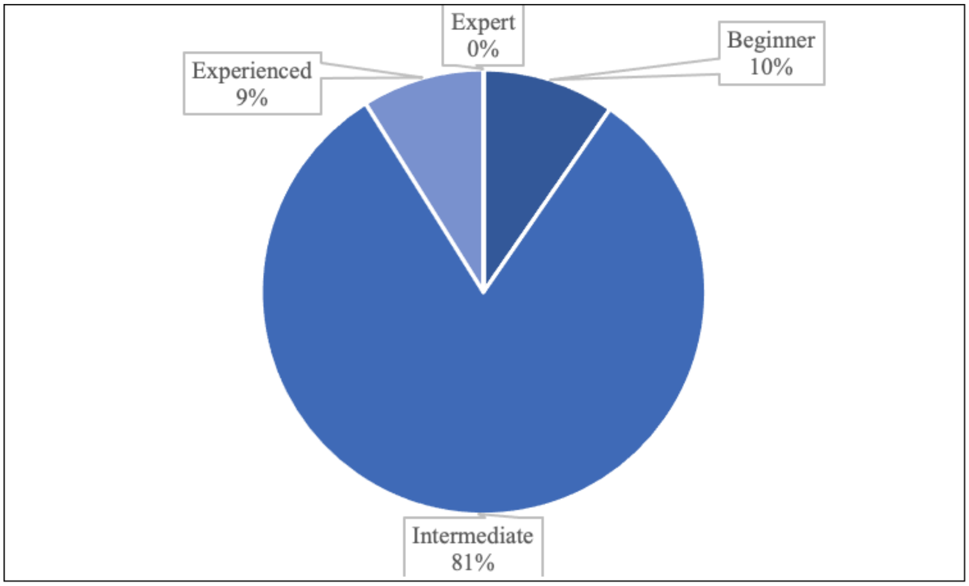
Considering the p-value (0.06), the result is not significant at $p<0.05$. Hence, H_0 cannot be rejected.

From the above analysis, it is evident that in terms of organizational infrastructure the factories are in the '**Intermediate**' level of Industry 4.0 readiness and from the ANOVA findings it can be said that **factory sizes do not play a role** in having organizational infrastructure for a factory with regards to industry 4.0 readiness.

Findings of Research Question 1c: Readiness in Terms of Smart Operations

To increase the global competitiveness, the industries need to embrace the new strategies regarding new technology (Lawrie et al., 2016). New technology tends to redefine the global market; therefore, the organizations have empowered themselves to create new business value (O'Connor et al., 2007). In this study, all the sampled industries have positioned in the intermediate level in terms of smart operations (81%), then beginner (10%) and experienced (9%).

Figure 23: Factory levels based on Smart Operation



Many breakthroughs might be gleaned from how factories in other nations are run. According to a study commissioned by Vietnam's Ministry of Industry and Trade (MOCI) and done by the Institute for Strategic Studies, the country's garment industry has recently started using a lot of cutting-edge technology, especially software used in product design and production (which costs about 20% of all such costs). 70% of the gear in use is medium-tech, whereas 10% is low-tech (Vietnam Credit, 2020).

Training and development should get better at the same time that automation, understanding, and use of leaner manufacturing processes improve. It is only found a handful of articles published in Sri Lanka that fit this category.

Smart Operations can be divided into three parts: sharing data between departments, functions that work independently, and IT solutions. The following table displays a few indications used to evaluate the category.

Table 39: Industry 4.0 readiness assessment indicators - Smart Operations

Category	Sub-category	Indicator
Smart operations	Cross-departmental information sharing	▪ Number of departments with internal integrated cross-departmental information sharing ▪ Number of departments with external integrated cross-departmental information sharing
	Autonomous functionality	▪ Availability of autonomous work piece guides ▪ Availability of autonomous production process response in real time
	IT solutions	▪ IT organization ▪ Security solutions implementation level ▪ Use of cloud services

Most cutting-edge equipment in India is Internet of Things-enabled and has automation, access to the cloud, digitalization, and data analysis for decision-making. Several Indian textile manufacturers use BMS Vision's MES. Some factories monitor production and quality online using specialist software like T-Data (Truetzschler), Spiderweb (Rieter), and Spinconnect (LMW). Robotics and AI are gradually making their way into India's textile sector. In addition, many textile production facilities will use smart factory practices shortly. To their credit, Indian textile firms are also beginning to move in the direction of Textile 4.0. Slower progress has been made since the necessary ecosystem, which includes IT infrastructure and a specifically trained workforce, still needs to be at the level needed (A.T.E. Enterprises Private Limited, 2019).

Despite being in the infancy stage, industry 4.0 in Pakistan is intriguing because of its real-time monitoring and scheduling benefits to all sectors. A weak business model results from the garment industry's lack of data-driven decision-making, and 80% of enterprises lack adequate information technology assistance (Ali, 2021).

Cobots (Collaborative Robots) are widely utilized in the textile industries of China and Sri Lanka. They are also being used in the production of jeans at Bangladesh's textile innovation centres. In this context, as large corporations establish concentrated capacity, the introduction of Cobots into India's clothing industry is imminent (A.T.E. Enterprises Private Limited, 2019).

To test whether there is any relation between the different factory sizes and their smart operation ANOVA tool was used and the result is given below.

ANOVA 3 - Relation between factory size and smart operations

H_0: There is no significant relationship between the factory sizes and smart operations for industry 4.0

Analysis of Variance

Source	SS	df	MS	F	Prob > F
Between groups	.5951679	2	.29758395	0.66	0.5161
Within groups	59.0858689	132	.447620219		
Total	59.6810368	134	.445380871		

Bartlett's test for equal variances: chi2(2) = 1.9099 Prob>chi2 = 0.385

Note: Factory sizes (small, medium and large) was considered as groups.
Score for each factory regarding organizational strategy using VDMA analysis has been used in the ANOVA.

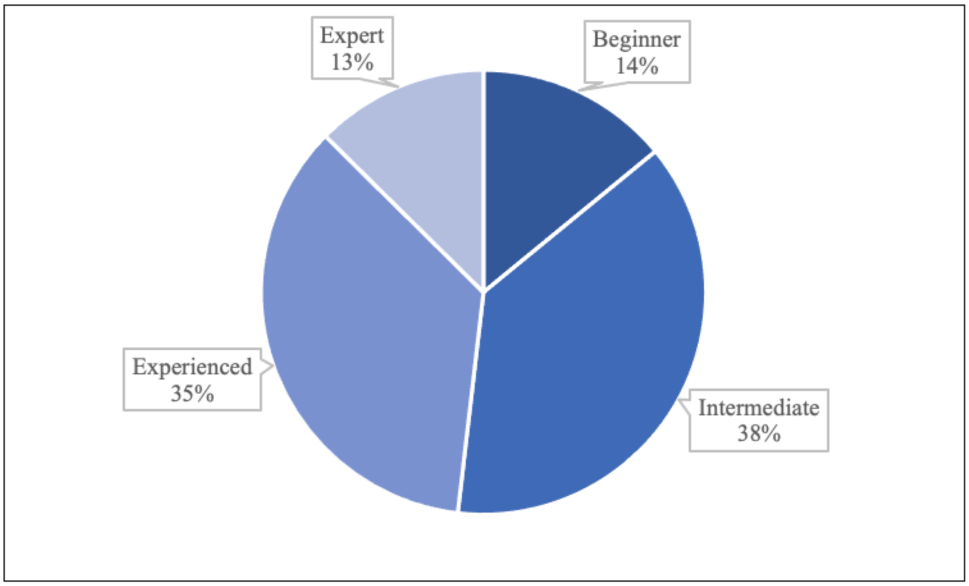
Considering the p-value (0.52), the result is not significant at $p<0.05$. Hence, H_0 cannot be rejected.

From the above analysis, it is evident that in terms of smart operation the factories are in the '**Intermediate**' level of Industry 4.0 readiness and from the ANOVA findings it can be said that **factory sizes do not play a role** in having smart operations in a factory with regards to industry 4.0 readiness.

Findings of Research Question 1d: Readiness in Terms of Smart Products

A mixed response was received from the surveyed factories with regard to smart products. Based on the assessment, among these factories 38% can be labeled as 'intermediate', 35% as 'experienced', 14% as 'beginner' and 13% as expert. It is evident that about half of the factories can be stated as experienced or expert and the other half can be said beginner or intermediate.

Figure 24: Factory levels based on Smart Products



In terms of smart operation, Vietnamese Garco 10 has adopted modern technology in production by putting simply one worker to control two machines. Consequently, the production time of a product has reduced from 1,980 seconds to 1,200 seconds, and to simply 690 seconds per item (Apparel Resources, 2019).

In the textile sector, majority of the knitting equipment is of medium quality, and to make matters worse, the technology used in knitting is further below par. In the factories of the Vietnam Textile and Garment Group, more than 50% of the knitting machines have been operating for more than 15 years, and needless to say, these machines now perform way less efficiently while consuming way more power because of the degradation in quality. More than half of all knitting machines in Vietnam are made from domestic equipment, and yet, the circular knitting machines for weaving is not adequate, with only 6% being available, that too, old ones, for weaving fabrics for the domestic market (Vietnam Credit, 2020).

Table 40 mentions the sub-category that was considered to assess this category. Usually, the number of add-on functionality comes as a determining factor for this category.

Table 40: Industry 4.0 readiness assessment indicators - Smart Products

Category	Sub-category	Indicator
Smart products	Products functionality based on ICT	▪ Number of add-on functionalities

To test whether there is any relation between the different factory sizes and their smart products ANOVA tool was used and the result is given below.

ANOVA 4 - Relation between factory size and smart products

H_0: There is no significant relationship between the factory sizes and smart products for industry 4.0

```
                        Analysis of Variance
    Source              SS          df       MS              F      Prob > F
------------------------------------------------------------------------
Between groups      28.3951304       2    14.1975652       3.72      0.0269
 Within groups      504.101253     132    3.81894889
------------------------------------------------------------------------
    Total           532.496383     134    3.97385361

Bartlett's test for equal variances:  chi2(2) =   3.4640  Prob>chi2 = 0.177
```

Note: Factory sizes (small, medium and large) was considered as groups.
Score for each factory regarding organizational strategy using VDMA analysis has been used in the ANOVA.

Considering the p-value (0.03), the result is significant at $p<0.05$. Hence, H_0 can be rejected.

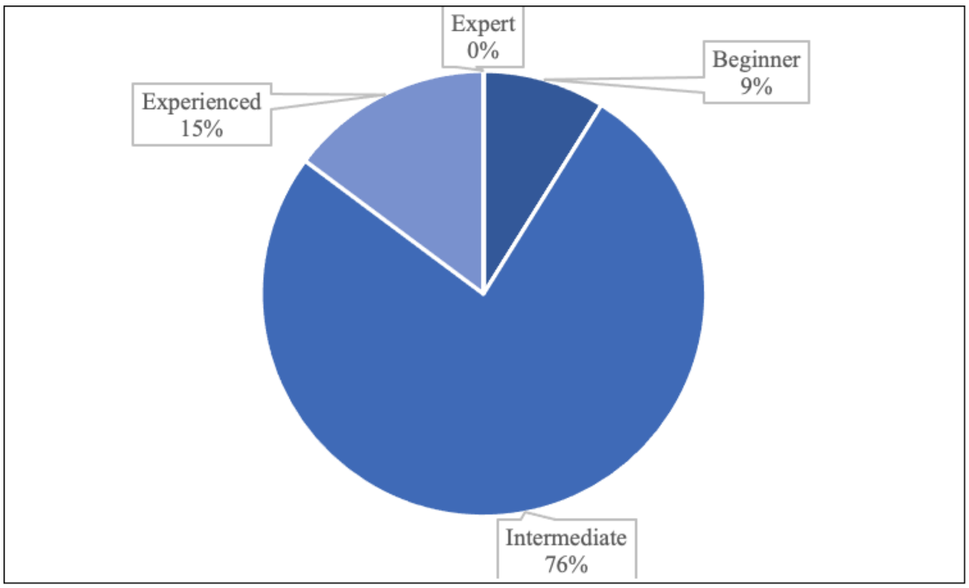
From the above analysis, it can be said that in terms of smart operation the factories are in between the '**Intermediate**' and '**Experienced**' level of Industry 4.0 readiness and from the

ANOVA findings it can be said that **factory sizes play a role** in having smart products in a factory with regards to industry 4.0 readiness.

Findings of Research Question 1e: Readiness in Terms of Data-Driven Services

Based on the replies supplied by the manufacturers and the following readiness assessment, it was found that 76% of the factories fell in the 'intermediate' level of Industry 4.0 preparedness, with services powered by data being the integrating component of the concept. There are 15% "experienced" manufacturers and 9% "beginning" factories (Figure 25).

Figure 25: Factory levels based on Data-driven Services



Businesses are focusing on using real-time data to monitor and enhance their overall business planning. In Pakistan, manufacturing processes are just at the beginning stage. However, according to findings, this feature holds the second-lowest degree of preparedness. Since there is no facility for data processing, most of the products are produced in broad batch quantities with little distinction, and thereby, not contributing to sales (Ali, 2021).

Under the Data-driven Services category there is another sub-category – Data Usage and Analysis. In this sub-category the assessment covers the use of data and process data to enable new services as well as use of data analytics (Table 41).

Table 41: Industry 4.0 readiness assessment indicators - Data-Driven Services

Category	Sub-category	Indicator
Data-driven services	Data usage and analysis	▪ Use of data and process data to enable new services ▪ Use of data analytics

To test whether there is any relation between the different factory sizes and their data-driven services ANOVA tool was used and the result is given below.

ANOVA 5 - Relation between factory size and data-driven services

H_0: There is no significant relationship between the factory sizes and data-driven services for industry 4.0

```
                        Analysis of Variance
    Source              SS          df       MS            F     Prob > F
------------------------------------------------------------------------
Between groups      .190389224       2    .095194612      1.32     0.2702
 Within groups      9.50711026     132    .072023563
------------------------------------------------------------------------
    Total           9.69749948     134    .072369399

Bartlett's test for equal variances:  chi2(2) =   1.7147  Prob>chi2 = 0.424
```

Note: Factory sizes (small, medium and large) was considered as groups.
Score for each factory regarding organizational strategy using VDMA analysis has been used in the ANOVA.

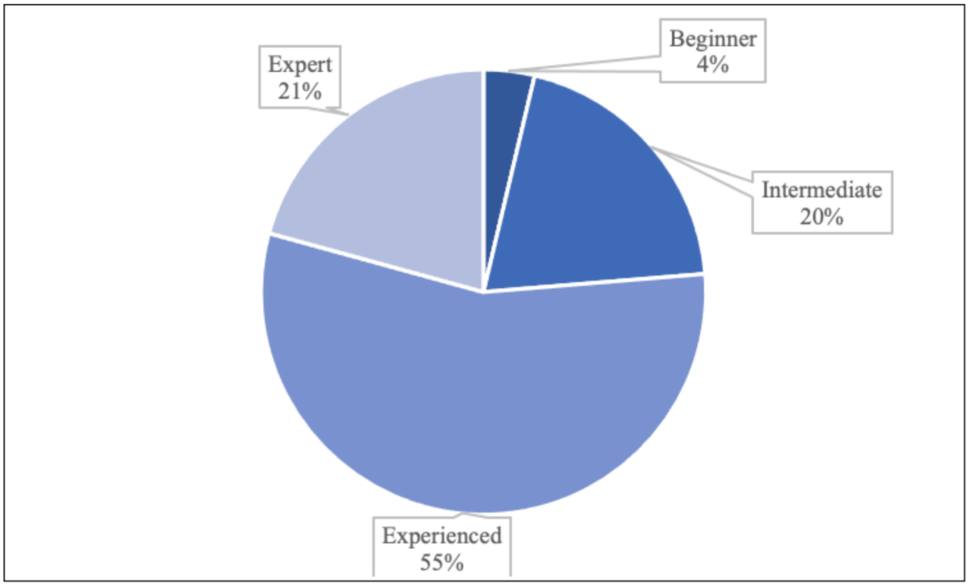
Considering the p-value (0.27), the result is not significant at $p<0.05$. Hence, H_0 cannot be rejected.

From the above analysis, it is evident that in terms of data-driven services the factories are in the '**Intermediate**' level of Industry 4.0 readiness and from the ANOVA findings it can be said that **factory sizes do not play a role** in having data-driven services in a factory with regards to industry 4.0 readiness.

Findings of Research Question 1f: Readiness in Terms of Employees

According to the survey data, factories are very much in an advance level in terms of their employee readiness to Industry 4.0. Based on the assessment, 21% of the factories can be labeled as 'expert', then 55% as 'experienced', 20% as 'intermediate' and only 4% as beginner (Figure 26). The factories and its employees ensured to have the level of capacities to understand and utilise newer technologies that come with Industry 4.0.

Figure 26: Factory levels based on Employees



ILO reveals that nearly three-fifth of employment in Cambodia is vulnerable in the face of automation. There, too, exists concerns regarding gender equity; for instance, women are 1.5 times more likely to occupy a high-risk, automated job than their male counterparts. (ADB, 2021)

While Cambodia's vision for the Fourth Industrial Revolution (4IR) is crystal clear, the plan must be fully integrated with the country's skills strategy. Concerns that IR 4.0 will lead to widespread joblessness stem from two sources: first, the obvious fact that machines can replace humans, and second, the existence of workers who lack the training necessary to take advantage of IR 4.0's cutting-edge technologies or to transition into the sector's emerging occupations. Analysis of the garment manufacturing industry shows that only 28% of employers have a good understanding of 4IR technology. By 2030, 4IR technologies may reduce workers' time on mundane physical chores by more than 20%, and between 57% and 77% of new 4IR-related training modules would need to be taught in the workplace (ADB, 2021).

The main way to figure out how ready an employee is for Industry 4.0 is to look at how much they already know about it (Table 42). Based on what employees said, it was thought that they had the skills to use the new technologies that come with Industry 4.0.

Table 42: Industry 4.0 readiness assessment indicators - Employees

Category	Sub-category	Indicator
Employees	Industry 4.0 skills	▪ Level of existing skills

As a side note, increasing worker and factory output is a top priority for Sri Lanka's top clothing producers (Lakmali, 2020). Female employees can be better prepared for the automation of garment manufacturing in the era of IR 4.0 if they get upskilling through TVET (technical and vocational education and training) and STEM (science, technology, engineering, and mathematics) education. Most fields will need workers with enhanced analytical and problem-solving abilities shortly. It is essential to retrain workers in new skills before implementing 4IR technology. Women need more encouragement to pursue academic or professional fields traditionally associated with men.

In Sri Lanka, for instance, the Vocational Training Authority of Sri Lanka and the innovative course provider Brandix Lanka Ltd have worked together to establish a national vocational qualification (NVQ) for textile technologists at the Level 5 equivalent (Development Asia, 2020).

Sixty-five per cent of Cambodia's training institutes agree that establishing reliable quality certification processes is critical, but only eight per cent are utilizing online learning platforms. Furthermore, 59 per cent of training institutes believe that graduates are adequately prepared for entry-level positions, while only 10 to 21 per cent of employers share this opinion (ADB, 2021).

The following table presents the results of an ANOVA test conducted to determine whether or not there is a correlation between the size of the plant and the level of preparedness of its workers.

ANOVA 6 - Relation between factory size and employees

H_0: There is no significant relationship between the factory sizes and employees for industry 4.0

Analysis of Variance

Source	SS	df	MS	F	Prob > F
Between groups	2.48168519	2	1.24084259	1.09	0.3405
Within groups	150.80055	132	1.14242841		
Total	153.282235	134	1.14389728		

Bartlett's test for equal variances: chi2(2) = 4.7392 Prob>chi2 = 0.094

Note: Factory sizes (small, medium and large) was considered as groups.
Score for each factory regarding organizational strategy using VDMA analysis has been used in the ANOVA.

Considering the p-value (0.34), the result is not significant at $p<0.05$. Hence, H_0 cannot be rejected.

From the above analysis, it is evident that in terms of employees the factories are in the '**Experienced**' level of Industry 4.0 readiness and from the ANOVA findings it can be said that **factory sizes do not play a role** in employee readiness in a factory with regards to industry 4.0 readiness.

5.3.2 Findings of Research Question 2: Is the size of the apparel factories the important determinant for the IR 4.0 readiness?

Apparel industries in Bangladesh have factories of various sizes in terms of the number of workers. Large factories have made more progress adapting to new technologies in the past two decades than medium and small factories. Hence, this is an interesting research question to find if size is an important determinant factor to adapting Industry 4.0. Table 43 shows the summary among the small, medium and large factories regarding the preparedness IR 4.0.

Table 43: IR 4.0 attainment according to factory sizes

IR 4.0 Levels	Small (%)	Medium (%)	Large (%)
Level 1: Beginner	27.59	27.94	42.11
Level 2: Intermediate	72.41	72.06	57.89
Level 3: Experienced	0.00	0.00	0.00
Total	**100**	**100**	**100**

Above table shows that rather small (72.41%) and medium (72.06%) factories are more to be found at intermediate level than the large factories (57.89%). However, it does not provide much evidence to say conclusively the impact of factory size in adapting Industry 4.0.

To find robust evidence an ANOVA has been conducted to see whether factory size is a determinant factor for adapting Industry 4.0. The results of the ANOVA table is shown below.

ANOVA 7 - Relation between factory size and employees

H_0: There is no significant relationship between the groups for industry 4.0

```
                        Analysis of Variance
    Source              SS         df       MS              F     Prob > F
------------------------------------------------------------------------
Between groups      390.61465       2   195.307325       1.85     0.1612
 Within groups      13930.878     132   105.536954
------------------------------------------------------------------------
    Total           14321.4926    134   106.876811

Bartlett's test for equal variances:  chi2(2) =   4.5677  Prob>chi2 = 0.102
```

Note: Factory sizes (small, medium and large) was considered as groups.
Score for each factory regarding organizational strategy using VDMA analysis has been used in the ANOVA.

Considering the p-value (0.16), the result is not significant at $p<0.05$. Hence, H_0 cannot be rejected. This ANOVA analysis suggests that, **factory sizes do not play a role** in having skilled employees in a factory with regards to industry 4.0 readiness.

5.3.3 Findings of Research Question 3: What are areas where apparel industry in Bangladesh need to prepare themselves to adopt and implement IR.4.0?

According to the survey results, Production/manufacturing, Marketing and IT are the main business segments within the company where there is very or great potential for industry 4.0.

These segments are likely to be benefitted from the digital transformation to IR 4.0. On the contrary, the other areas like Sales, Services, Warehousing/logistics, and Procurement/purchasing have fewer possibilities of reaping fruits out of the revolution.

Table 44: Potential areas for industry 4.0

Areas	Very or great potential
Research and development	74.50%
Production/manufacturing	83.40%
Procurement/purchasing	79.10%
Warehousing/logistics	70.10%
Marketing	83.00%
Sales	57.10%
Services	60.20%
IT	**83.60%**

In table 44, 83.6% of responses have been recorded in the IT section suggesting section having the high potential where industry 4.0 can be implemented. The second and third highest being the production/manufacturing and marketing sections. The other segments such as procurement, logistics, marketing, sales have lower potential segments comparing to the other segments mentioned previously regarding the implementation of industry 4.0.

Table 45: Transformation made in the recent past

Areas	Moderate to strong transformation
Research and development	60.70%
Production/manufacturing	74.80%
Procurement/purchasing	57.10%
Warehousing/logistics	41.50%
Marketing	54.30%
Sales	40.70%
Services	41.60%
IT	**59.20%**

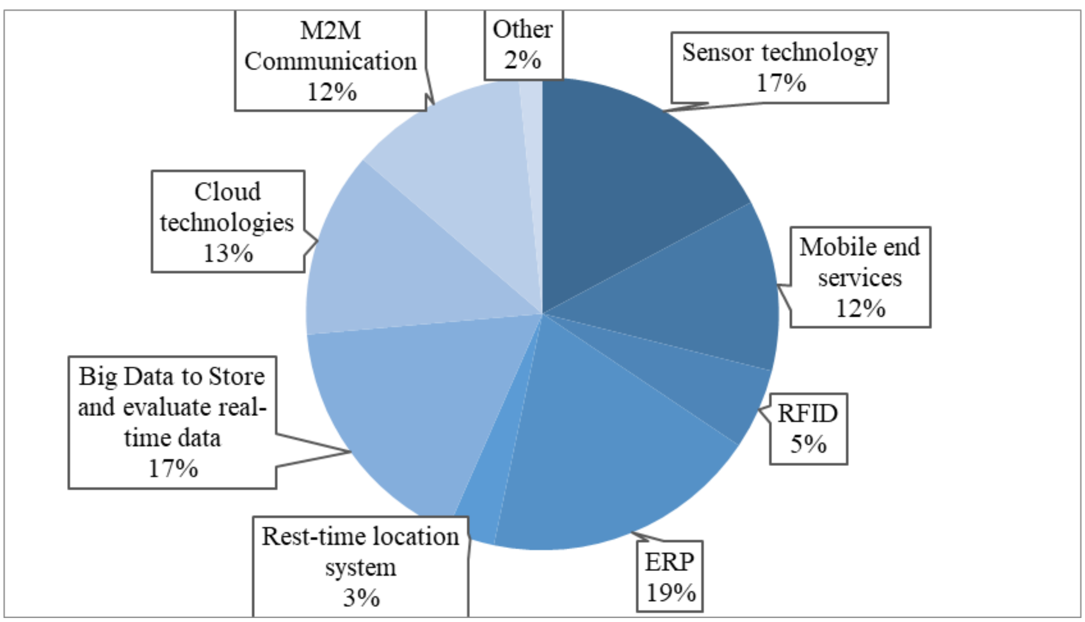
Based on the above table, research and development, production/manufacturing, and IT (60.7%, 74.8%, and 59.2% respectively) are indicating strong transformation to embrace the latest manufacturing technologies in their companies. However, the other segments such as warehousing/logistics, marketing, sales, and service has lower potential segments regarding the implementation of industry 4.0.

Table 46: Investment made in last two years

Areas	Made investment
Research and development	96.20%
Production/manufacturing	96.40%
Procurement/purchasing	93.70%
Warehousing/logistics	93.80%
Marketing	56.30%
Sales	80.10%
Services	81.40%
IT	94.60%

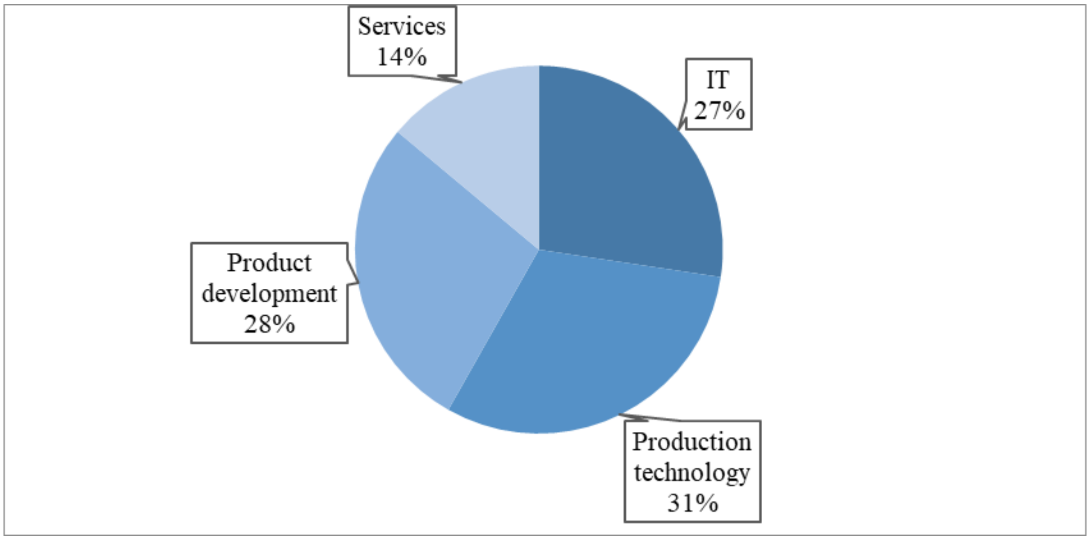
From the survey it was found (table 46) that companies are investing mostly in IT, production/ manufacturing, research and development, procurement/purchasing, warehousing/ logistics areas to digitizing essential operational functions in the past two years. The other segments receive lower level of investment for the implementation of Industry 4.0.

Figure 27: Technologies require to enhance competitiveness



The above chart (figure 27) shows the technologies that companies need to enhance their business competitiveness. It has been observed that ERP (almost 19%), Big Data (17%), Cloud (13%) and M2M Communication (12%) have been mentioned as the most technologies essential for the companies to enhance business.

Figure 28: Systematic technology and innovation management



The chart shows the areas where the responding companies consider to have systematic technology and innovation management. The main areas for the implementation of Industry 4.0 are Production technology (31%), product development (28%), and IT (27%). While for Thailand-based companies the core areas are Production technology, IT, and product development (P. Koomsap et al, 2019).

5.3.4 Findings of Research Question 4: What are the challenges and opportunities for apparel industry in Bangladesh to implement Industry 4.0?

5.3.4.1 Industry 4.0 Challenges for Apparel Industry

Adapting industry 4.0 fully to the apparel industry of Bangladesh will have to face a few challenges and hurdles in the coming days. Several are necessary to create an enabling environment to be upgraded to industry 4.0. In this part, these challenges will be discussed in terms of enabling the environment for IR 4.0. This part will describe and explain the challenges of adapting IR 4.0 to the apparel industry of Bangladesh which are derived from the FGD, case studies, and knowledge-sharing meetings conducted for this study. The challenges are mentioned below:

Initial investment cost:

Cyber-physical systems, robotics, virtual reality, 3D product design, wireless sensor networks, big data infrastructures, and their amalgamations are expensive. To make matters worse, most apparel companies tend to be small-and-medium-sized enterprises, which are bound to find it challenging to afford such costs. Therefore, a thorough cost-benefit analysis of embracing IR 4.0 is duly required for the companies to smoothen their journey into the fourth industrial revolution rather than impulsively rushing into the hype.

Privacy and security:

Many works of fiction have shown worries about the privacy and security of digital data, which is understandable since hackers often get into information. For the factory's safety, a smart factory's digital data must also be kept secret. Hence, rigorous protocols must be established between the communication among smart devices, among themselves, and humans, basically the entire virtual system involved, to protect information.

Technology Adaptation:

Most of the proposed innovations in the extent of IR 4.0 are generally new advances, meaning there is a severe scarcity of experienced workers who could operate these technologies. Therefore, public strategies ought to be created and upheld to build the amount of experienced labor. It is crucial to have a favourable/conducive environment for adapting to technological changes. By favourable environment, it is meant the whole set of capabilities to roll out and maintain new technology. There is a set of factors that determines the ability to an adaptation to technology. These factors include infrastructure, technical knowledge, skilled manpower, innovation, internet penetration, cost of doing business, and many more.

Lack of a global standard:

As seen already, with multiple definitions, theories, and discourses associated with IR 4.0, it is easy to get bewildered for any apparel company which is interested in adopting the fourth industrial revolution. There is still an absence of a globally accepted/standardised Industry 4.0 maturity model, despite the introduction of the term a decade ago, and this gap needs to be filled to properly guide the aspiring firms and practitioners toward IR 4.0 (Gökalp, Şener, & Eren, 2017).

Social difficulties and Skilled Manpower:

Naturally, with the emergence of IR 4.0, companies will be inclined to recruit more high-skilled labour who could operate complex machines, with rapt attention and efficiency, and this poses a significant social problem – unemployment, especially in the low or semi-skilled workforce. World Economic Forum predicted a loss of jobs for 5 million people in 15 developed countries by the year 2021 due to the introduction of Industry 4.0 (World Economic Forum, 2016). Henceforth, a thorough guideline is essentially required to prepare the existing labour force for arising technologies (Gökalp, Şener, & Eren, 2017).

Because of the fourth industrial revolution, indeed, many conventional jobs will be rendered obsolete by new skills and forms of jobs, and companies' regular tasks are likely to be performed by machines rather than humans. However, the digital transformation in the apparel sector could boost Bangladesh's global competitiveness. Moreover, the transparency of the apparel companies can be readily enhanced when the factory has customer access to the integrated production processes and real-time report generation regarding the production system.

For any country, having skilled manpower is a blessing to adapt to any technological changes and maintain them. Unfortunately, we don't have plenty of skilled manpower to implement technological changes. Still, in 2018 we have to depend on foreign expertise to implement and maintain most of our development projects. Bangladesh has a huge population of approximately160 million, it lacks in having manpower with digital skills which is very important when talking about the capability of adapting new technologies because new technologies usually require more digitally skilled manpower to produce goods and services using the most sophisticated production processes. The number of technical training institutions and the quality of technical training is not up to the mark, which needs to be addressed.

Technological progress, at any time frame, is bound to raise concerns regarding the future of human labour for their potential replacement by machines and robots; however, the major findings of this study reveal that IR 4.0 do not pose any threats to human labour, provided the workforce has been enabled to adapt to new advancements, and governments set up policies, and also follow them strictly, that protect the vulnerable labour population from any unprecedented and unwanted ramifications of technological progress. Routine jobs which require less communicative and cognitive skills, the likes of office work, or construction and manufacturing, are most subjected to automation. But occupations like instructing, nursing, and taking care of the elderly, where multiple tasks have to be performed and require adaptability, genuine inventiveness, and social knowledge, are hard to be automated. Thus, it is safe to say that a new technological revolution is not likely to substitute all of the human workforce with machines and robots (Evanthika, 2019).

Internet Penetration:

The Internet is like a one-stop solution for every problem. There is no area where the internet can't help. We are living in the era of the internet and information technology. The whole business model has changed and been changed by the online business model. The Internet has made business much easier and reached out to people living all over the world. Internet users ranking is a very good tool to evaluate the capability of adaptation to technological change. To enjoy the benefit of IR 4.0 the access of internet base needs to be increased and it is time to grasp the 5G network.

Innovation Capability:

The more innovative a country is the more likely it is to adapt to new technology quickly and efficiently. The capacity to innovate leads the industry to a higher position with a higher return. Bangladesh has been lacking this capacity since the beginning. Then again, to be innovative people, need to be educated properly and need to have the right skill. Education is an essential indicator of having skilled and innovative manpower to cope with any kind of technological change. While assessing this indicator, quality is much more important than quantity. In our country, we have a literacy rate of 72.76, which does not provide the actual scenario. Though our universities are providing a good number of fresh graduates they lack innovative ideas and digital skills. We are producing Business graduates with BBA and MBA but they are not coming up with innovative ideas or starting a new business or developing new business models rather we are creating stereotypical employees who can only follow orders and that is something which is making the difference between us and other rapidly growing economies like India and Malaysia.

Policy Implementation:

To escalate the pace of industrialization in Bangladesh, its government proclaimed the 'National Industrial Policy-2016'. The major and fundamental objectives of the Industrial Policy (NIP)

2016 include sustainable and comprehensive industrial growth through making of dynamic employment to produce new entrepreneurs, mainstreaming women in the industrialization process, and international market linkage. However, policies like NIP-2016, export and import policies (2018-2021), and the five-year plan didn't lean light the challenges of the 4th industrial revolution and other issues. Though we have National Strategy for Artificial Intelligence of Bangladesh (2019) either we have to include IR 4.0 in our Industrial Policy, or we have to generate other strategies or policies which will uphold IR 4.0 as a whole.

5.3.4.2 Industry 4.0 Opportunities for Apparel Industry

Industry 4.0 entails several opportunities which have been illustrated in the following diagram. Eventually, the new industrial revolution will assist businesses in becoming smarter and more efficient.

Figure 29: Industry 4.0 opportunities

Source: LightCastle (2021)

New technology and inventions contribute to the betterment of industries and human lives during each industrial revolution. The fourth industrial revolution (4IR) is currently altering how people work and live. The 4IR is revolutionizing traditional operational procedures in the apparel sector with automation, artificial intelligence, 3D printing and knitting, robotics and intelligent manufacturing, augmented reality, and other technologies. Simultaneously, it is transforming the sector by bringing new consumer trends. As the RMG sector becomes more competitive with the adoption of 4IR technology, Bangladesh must accept and utilize technical benefits to maintain a greater piece of the pie of global garment exports. The following prospects have been revealed during Case Studies and KIIs.

High Productivity Worker

Until recently, global fashion garment procurement followed a cost-cutting paradigm. This is why ready-made clothing took off in Bangladesh: the country was able to supply adequate quality apparel at a low cost due to cheap labour. Every year, approximately 37 public and private institutions in Bangladesh graduate textile students, adding to the skilled workforce accessible labour that will lead to modern technology use in the apparel sector by the skilled graduates.

The transition from the Cost-Based Model to the Fast Fashion Model

As previously indicated, global garment sourcing has been following a cost-effective trend for some time. Changes in the fashion business have had an impact on the sourcing paradigm, which has converted into a trend known as 'fast fashion.' Fast fashion refers to affordable and trendy clothing that is manufactured and sold in record time. The concept of fast fashion is to develop, manufacture, and produce large quantities of apparel to replicate any existing trend and frequently update retail store shelves. The key causes for the emergence of fast fashion are lower garment production costs, streamlined operations, and increased consumer spending. So being cost-effective is no longer the only necessity. To remain competitive, faster production and shorter lead times are required. To keep up with the ever-changing market, the ready-made clothes business must embrace digitalization and automation. A photo-realistic virtual simulation of design concepts, for example, can replace the time-consuming design conceptualization, sample creation, and prototype process. The requirements of quick fashion can be satisfied by utilizing technology in automating various manufacturing procedures.

Transforming 'Fast Fashion' to 'Precise Fashion'

As previously stated, quick fashion has risen due to low-wage production. This fast-fashion paradigm is now becoming dubbed 'correct fashion,' thanks to the overnight creation of ever-changing customer wants. Precise fashion refers to correctly matching the fashion industry's ever-changing trends. It entails paying attention to all the subtleties of consumer wants and creating attire that perfectly suits the nuances and trends. For example, global sporting events like the Olympics or big fashion events like the Met Gala can influence accurate fashion. Undoubtedly, flexibility is essential to match precision, as the demand for garments may be affected by factors such as the outcome of a football game. Another effect of this trend is that the average production lead time has decreased from 120 to 90 days. This new precise fashion model has spawned at least four distinct trends:

- near-shoring
- automated production
- mechanical designs that replace manual labour
- less time spent on shipping items
- a nuanced, precise supply of garments

Inclusive Opportunities in Bangladesh's Context

While the risk of unemployment looms large over the apparel sector of Bangladesh in the face of the fourth industrial revolution, the opportunities that also come along with this transition are immensely lucrative and are essential for the survival of the industry to a large extent, as also opined by the former president of the BGMEA, Rubana Huq: "It makes no sense for us to slow down and not automate" (Emont, 2018). Thanks to the practice of fast fashion, the global apparel market is heading towards IR 4.0, which puts tremendous pressure on the lead time of Bangladesh's apparel industry, which only comes second to China, the world's leading garment exporter. Though cheap labour has kept the nation competitive for decades, without adopting innovations and technologies, that position can be vulnerable (Fahim, Chyon, Suman, & Islam, 2020). However, by embracing IR 4.0, Bangladesh can turn things around by minimizing lead time and increasing customer responsiveness, that too within budget – or to put simply, become more internationally competitive, hold a strong foothold on the global market by making optimum use of resources.

Moreover, Bangladesh must cash into the "China Plus" opportunity through the help of innovation. China's dominance over the global apparel market is overwhelming. However, with increasing labour costs and other materials, Chinese manufacturers are now considering an investment in other countries, such as Vietnam and Ethiopia, to further their position in apparel sourcing and produce on a greater scale overseas. In addition, China is shifting focus to digitization and automation for their 'Made in China 2025' initiative. So, the biggest garments exporter is creating spaces for other countries to pitch in and promote technological advancement, and Bangladesh must note that. An earlier report published by World Bank in 2016 showed that a 1% rise in apparel prices in China would lead to a 1.36% additional demand for Bangladeshi garments in the USA. A 1% rise in expected wages in China would increase the odds of women entering the labour force by 30.6% in Bangladesh (The Financial Express, 2016). These figures clearly show that any changes put forth by China are bound to impact the apparel industry of Bangladesh, and they must be made accordingly. More importantly, for Bangladesh to enjoy more jobs and a rise in exports, there must be productivity improvements, which, as lauded by all experts, is the key outcome of adopting IR 4.0.

Experts have predicted that businesses will be able to ramp up their productivity by around 30% with the realization of the fourth industrial revolution (Bari, Habib, & Akash, 2021). The various elements of IR 4.0, the likes as automation, simulation, big data analysis, internet of things, will make the manufacturing systems more flexible, thereby allowing industries to meet individualized customer requirements or to inaugurate new products in a shorter time without putting much strain on costs, since with automation comes greater control over the entire value chain of the production process (Bari, Habib, & Akash, 2021). For instance, by utilizing blockchain technology, shipments of apparel can be recorded, tracked, and traced, without the help of a bookkeeper, ensuring rapid and anonymous transactions. This will, in turn, enable customers to be aware of the sourcing of products and the corresponding compliance with safety and human rights. At the same time, producers can earn more because, with such transparency, consumers will be willing to spend more on the products (Shibli, 2022). Furthermore, history suggests that the fear of losing jobs due to automation is not justified. This is because between 1980 and 2017, China, Bangladesh, Pakistan, and Indonesia witnessed a prominent growth in textile and apparel industry employment, despite the upsurge of robotics and automation that took place during this timeline (Manchanda, Schlorke, & Schmitt, 2020). Therefore, be it for survival or for becoming a stronger candidate in the global apparel market, the opportunities that the new technologies and innovations of IR 4.0 offer need to be meticulously observed by policymakers, manufacturers, academicians, and other relevant stakeholders.

5.4 Findings from Case Studies

For the assessment of the readiness level of factories in terms of embracing IR 4.0, it was crucial to acquire insights from some of the long running factories/industries of Bangladesh, and understand what they think are the challenges, the benefits, and the potential pockets of implementing the much-coveted 4th industrial revolution. In this regard, four factories/industries were approached in this regard, and their useful understanding of IR 4.0 is presented below.

5.4.1 Beximco Textile & Apparel Division

Beximco Textile & Apparel Division or more popularly known as Bextex Limited commenced its journey way back in 1995. Located at the Beximco Industrial Park in Kashimpur, Gazipur, the company specializes on multiple fronts, with its woven division producing 12 million woven labels per month with its state-of-the-art facilities, its knit fabric production mill catering to the demands of high-quality knit garments exporters of the country, and its cotton and polyester-blended yarn-spinning mill proudly standing as one of the largest spinning mills of Bangladesh with 122,000 spindles. Bextex, with its 40,000 talented and hardworking employees and full vertical infrastructure, enjoys an annual turnover of roughly US$ 500 million, and can thus be considered as a top level/big industry itself. As one of the leading textile and apparel makers of the country, the company has established a clientele spectrum all over the world, including big names such as Amazon, Zara, Target, Marks & Spencer, and so on (Bextex Ltd., n.d.).

In the light of the industrial revolution, despite the unprecedented Covid-19 global pandemic, Beximco has championed in its usage of “smart fabrics”, which are basically fabrics that can be engineered to amalgamate features such as thermal management, rapid drying, additional durability, antimicrobial, odour free, or UV protection. The organization also makes use of 3D design technology to exhibit its samples to the respective clients, and its Group Chairman, A.S.F Rahman claims that they have “taken a proactive approach to the implementation of production technologies and processes that have the greatest impact on efficiency and product quality” (Forbes, 2021).

According to Bextex though, it is much more difficult for small factories to adopt and sustain automation compared to mid and top tier ones. The company pointed out the departments where automation can be easily instilled: accounts and finance, store, cutting, sewing and finishing. To be more precise, for woven, the organization recommended automation in the making of back placket, five pockets, loop loin, packing and folding, and for a polo shirt, the intricate work of sleeve joints could also be handed over to the machines. The two obvious benefits of realizing the various tools of IR 4.0 are a rise in production capacity and a boost in productivity, as mentioned by Bextex. However, the company is afraid that to fully reap the benefits of 4th industrial revolution, skilled manpower will be a concern, along with the perception of people regarding the narrative "machines replacing humans", and thereby, leading towards unemployment.

5.4.2 Metro Knitting & Dyeing Mills Limited

As a concern of Panam group, Metro Knitting & Dyeing Mills Limited was established in 2000, and over the past two decades, with an exponential growth in export, registering over US$ 150 million in 2020, has become an iconic figure in the composite knitwear manufacturing sector in Bangladesh. The approximate 20,000 employees and high-quality machinery of the company enables it to achieve a garments production capacity of 6.4 million pieces per month, knitting capacity of 2,125 tonnes a month, and a dyeing capacity of 2,400 tonnes each month. Starting from Calvin Klein to H&M to Tommy Hilfiger, several clients around the world, with vast majority in Europe, purchase the wide range of products offered by Metro (Metro knitting and Dyeing Mills Ltd, n.d.). The six premises of the company, each with a different name and specialization, are all part of the Panam group, and located in and around Narayanganj.

Various means of technology and innovation could be seen within the organization for instance, as an attempt to be globally competitive in the era of fast fashion, thanks to the investment of Panam Group on Coast Digital's FastReactPlan solution, which is a production planning solution, the company has been able to foresee its plan 12 months ahead rather than 3 months (Knitting Industry, 2020). Besides, Metro utilizes software-based technology in cutting fabrics, which according to Atiqul Islam, general manager of the company, "saves fabric, time and money, and improves quality by ensuring accuracy in measurements during the cutting" (Dhaka Tribune, 2017). The organization, though believe, that adopting the latest technology or IR 4.0 must not be limited to cutting only, rather it can be exercised in sewing and finishing, transportation as well, in folding machines and elastic joints. Besides benefitting production capacity and productivity, Metro reckons that the fourth industrial revolution will greatly improve data accuracy, which is crucial to the development of an industry.

5.4.3 Esquire Knit Composite Limited

Esquire Knit Composite Limited was formed in 2001 and is now widely recognized as a world-class garment manufacturer, and versatile too for its array of facilities, starting from yarn dyeing, knitting, fabric dyeing, and finishing, to printing, embroidery, garments dyeing and washing to the actual making of garments. The organization, comprising of over 8,000 employees, have two plants, one located in Kanchpur, Narayangonj, and another in Jamiredia, Mymensigh. Currently, it has a garments production capacity of more than 2 million pieces a month, and in the fiscal year 2020-2021, it produced a whopping 34,690,032 pieces of apparels and 6,088,892 kgs of textiles, with a production efficiency of 69.49% and 75.83% respectively. Esquire's market coverage spans across European and American chain stores, fashion brands and supermarkets.

A company which seems to be only growing over the years, considers the introduction of auto spreader and auto cutter, as part of adopting IR 4.0. It also states the importance of providing automation to skilled workforce to maximize the benefits of the fourth industrial revolution; supply chain management is another aspect of the entire production that could be automated and made better, according to Esquire.

5.4.4 Shanta Industries Limited

Established in 1998, and located in Savar, Shanta Industries Limited belongs to the Cut and Sew Apparel Manufacturing Industry and has a production capacity of 390,000 (Yearly in dozen) (BGMEA, n.d.). With specialization in woven, and utilizing 735 machines, its principal exportable products are shirts, pants and shortalls.

According to the company, automation may be included in storing, cutting, sewing and finishing, and to be more precise, for woven products, in five pockets, pocket setting, loop setter, and pocket rolling, under the purview of IR 4.0. The company also recommends standardizing Standard Minute Value (SMV) for different types of products, for instance, with the use of GSD software. Shanta Industries Limited also considers data accuracy to be a significant positive outcome of adopting IR 4.0, besides the increment in production capacity and overall productivity.

5.4.5 KIIs/Knowledge Sharing Meeting

A total of 15 factory representatives at the management level were present at a knowledge-sharing meeting (A list of the participants is presented in Appendix IV). The idea was to understand their perception of adopting industry 4.0 in their factories. During the discussion, the lion's share of recommendations was about different kinds of training, including lean six sigma, supply chain management and logistics training, machine maintenance training, technician development training for automation, ergonomics-related training, adapting to changes over time training, and mid-level supervisor training – all of which are meant to equip the respective workforce with adequate IR 4.0 skills. So, it seemed bad that there was low skilled labour to take advantage of the fourth industrial revolution. Whether there will be the desired return on investment or not for instilling IR 4.0 or whether the unemployed people due to automation will get another job or not – these are questions that still need to be addressed before considering the transition, as stated by the respondents. However, everyone seems to unanimously believe that IR 4.0 will increase production capacity, productivity, and data accuracy to a great extent, along with provision for higher quality products, better planning, better information system, and an overall improvement in accountability and enormous financial support is needed to implement IR 4.0 in this sector.

6. Chapter Six: Recommendations, Future Scope of Research and Conclusion

6.1 Recommendations

The implementation of 4IR requires considerable changes in Knowledge Skills, and Attitudes (KSAs) in hiring, and training, both for Employers and employees, and adopting new technologies into their industries. For successful adoption of IR 4.0 technology and implementation of it in the apparel industries the flowing measures can be recommended:

1. *Developing New Leadership Capabilities for the 4IR:*

   Have to develop positive and modern thinking leadership capabilities of people in the apparel sector considering technology and innovation. The industries have to come out of the old-traditional manufacturing process. They should adopt the right technology and build new innovative people strategies for future work.

2. *Skill Disruption:*

   The demand for skillful workers in IT technologies will rise for extensive use of software, robotics, and data analytics. There is no room for the traditional workforce or low-skilled people. The risk of losing old-aged people's jobs will also increase. Hence, industry owners should create training facilities for their existing workforce within the IR4.0 technology adoption purview.

3. *Managing the Integration of Technology in the Workplace:*

   The latest technology could alter job responsibilities between humans and robots and algorithms, which can create consequences of job displacement. The human resource may introduce concepts of reskilling, redeployment, and job reinvention.

   - <u>Reskilling:</u> refers to the search for employees with "adjacent skills," It gives workers a lateral learning opportunity.
   - <u>Redeployment:</u> is when employees are re-positioned within the company to avoid redundancy.
   - <u>Reinvention:</u> it's vital to remember that automation affects tasks rather than jobs. Therefore, it is necessary to rethink and restructured or redefined the job.

4. *Enhancing the Employee Experience*

The core of the employee experience is employee engagement. Without having the right set of skills and knowledge (KSAs), it is hard for employees to engage in work as they did before the fourth industrial revolution. As technology is altering how employees work in various ways, and as a result, it has an increasingly created positive or negative impact on Employee Experience. It has to ensure that all the employees continuously engage in work through technology.

5. *Building an Agile and Personalized Learning Culture*

The concept of agile learning is a method of training and development that emphasizes speed, collaboration, and flexibility of employee learning. By implementing agile and personalized learning culture, organizations can ensure that employees have enough time and facilities for training as needed.

6. *Reforming TVET (Technical and Vocational Education Training):*

In the Technical and Vocational Education Training institutes of Bangladesh the total courseware-Competency Standard (CS), Competency-based learning material (CBLM), and Assessment tool should be redesigned based on the concept of automation and new technology related to the fourth industrial revolution.

7. *Funding for Human resource development and new technology adoption:*

To have a skilled workforce for accelerated growth in Bangladesh National Human Resource Development Fund (NHRDF) has been established in 2018. It is time to activate NHRDF for helping the youth prepare themselves for market-responsive demand for work in the manufacturing sectors. At the same time, the government should give some financial support to the manufacturing industries especially the apparel Industries to adopt new technology in supply chain management and logistics, machine maintenance, technician development for implementing automation and IR 4.0. More specifically in the department of accounts and financing, store, cutting, sewing and finishing, designing, real-time data collection, research and development financial support might be extended from the government side. Furthermore, financial cost benefit analysis to embrace IoT, Cyberphysical System, 3D printing, Robotics virtual reality, sensor network, big data infrastructure is required and based on this case to case financial support from government side and from the manufacturers side are needed.

8. *Shifting from a 4G network to a 5G network:*

4G network coverage in Bangladesh is still not up to the mark. For smooth operation of IR 4.0 adoption, it is necessary to enter 5G network coverage that provides faster download speeds, more capacity to connect many more devices, and low latency. Furthermore, IT security service is a pressing need to implement IR 4.0 and to increase the base of internet penetration and 5G utilisation.

9. Policy formulation for IR 4.0:

Since Bangladesh has National Strategy for Artificial Intelligence 2019 it is an urgent need to formulate a policy on IR 4.0 that will help adoption in different manufacturing agencies in the proper way without difficulties.

6.2 Future Scope of Research

There are plenty of areas where more research could be conducted in future with regard to IR 4.0 in the apparel industry of Bangladesh. A list of such areas of research is given below –

I. There is a need for productivity analysis of the apparel industry comparing the various level such as beginner, intermediate and experience levels of industry 4.0.
II. Finding appropriate policy measures to support small level factories to adapt industry 4.0 will be an important research scope for the near future.
III. Factories will require to improve the organisational strategy of the factories through research in order to accelerate their industry 4.0 goals.
IV. It will be essential to identify the skill gaps of the future RMG workers with regard to experiencing industry 4.0.
V. A comprehensive exercise is required for identifying the needs and steps for creating enabling environment for industry 4.0.

VI. Comparative studies are required to assess country’s status in view of the competitive countries such as Vietnam, Sri Lanka, Cambodia, India etc.

VII. There could be a well-developed comprehensive tool for assessing industry 4.0 level for the factories. This will help the buyers to assess factories and their capacities.

6.3 Conclusion

Though IR 4.0 is a fairly new movement, many nations have begun to adopt it. Bangladesh is also considering engaging in the revolution, and rightly so, I believe. The spotlight is on the apparel sector, or the RMG industry, in the case of Bangladesh, because of its massive contribution to the economy and the numerous prospects of IR 4.0 in the manufacturing industry. The thesis explains the different parts of the revolution and how they changed the global clothing market. It also breaks down the theories and concepts related to IR 4.0 and how they can be practised or realized in the garment sector. Nevertheless, the thesis stands out because it is the first evaluation of how ready Bangladesh's clothing industry is to use IR 4.0. This evaluation is important because IR 4.0 is not just a step toward more automation. However, it comprises highly complex technologies and ideas, which cannot be effectively utilized without figuring out the question: "Are we ready for it?". Other nations followed a similar approach before embracing the revolution and taking leaves out of their books, their readiness index. This thesis reveals the current standing of the RMG factories in Bangladesh and that finding alone is significant for policymakers, the industry, and academicians. After a thorough evaluation, the thesis finds that most RMG factories are only at an intermediate level of readiness for IR 4.0. This means that Bangladesh's clothing industry still needs to get ready for the fourth industrial revolution, which is a very complicated and advanced change. In every aspect of Industry 4.0, there remains a lot to be done before our RMG industry can implement it, let alone enjoy the facilities. In this way, the thesis explores readiness, the challenges and opportunities about adopting IR 4.0 in our strong clothing industry and then makes suggestions. For us to remain mighty and thrive internationally in the future internationally, it is quite evident that we have to adopt IR 4.0 eventually; given that, more such readiness assessment needs to be conducted so that our progress gradually heads in the right direction.

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8. Appendices

Appendix I: Terminology

Industry 4.0: Industry 4.0 or fourth industrial revolution is characterized by a much more ubiquitous and mobile internet, by smaller and more powerful sensors that have become cheaper, and by artificial intelligence and machine learning. It is not only about smart and connected machines and systems. Its scope is much wider. Occurring simultaneously are waves of further breakthroughs in areas ranging from gene sequencing to nanotechnology, from renewables to quantum computing. It is the fusion of these technologies and their interaction across the physical, digital and biological domains that make the fourth industrial revolution fundamentally different from previous revolutions (Schwab. K., 2016).

Sensor technology: Many recent advances in the sensor technology become mainly possible by means of micro technologies. These new technologies offer high-volume manufacturable systems with small dimensions, lower power consumption, and higher re-liability. Thereby, realized micro systems integrate sensors, actuators, mechanical, and electronic units. They provide low-cost solutions that were not realizable with microelectronic systems. Their development involves special challenges for device modeling, micro fabrication, material, and pack-aging technologies (Kanoun, O., & Trankler, H. R., 2004).

Mobile end devices: End devices are either the source or destination of data transmitted over the network. In order to distinguish one end device from another, each end device on a network is identified by an address. When an end device initiates communication, it uses the address of the destination end device to specify where the message should be sent.

RFID: RFID means Radio frequency identification i.e. the technology that uses radio waves to automatically identify individual items. The objective of any RFID system is to carry data in suitable transponders, generally known as tags and to retrieve data, by machine readable means, at a suitable time and place and to satisfy particular application needs RFID is one of the most technologies being adopted by both industry and academic world (Mahajan, K. D., Pandey, P., & Pandher, B. K., 2010). The RFID readers then pass the data over a network to a computer for processing. Unlike bar codes, RFID tags do not need line-of-sight contact to be read. The

RFID tag is electronically programmed with information that can uniquely identify an item plus other information about the item, such as its location, where and when it was made, or its status during production. Embedded in the tag is a microchip for storing the data. The rest of the tag is an antenna that transmits data to the reader (Laudon, K. C., 2007).

ERP: Enterprise resource planning (ERP) systems are business that integrated and streamline data across the company into one complete system that supports the needs of the entire enterprise. ERP systems are designed to enhance all aspects of key operation, such as purchasing, accounting, manufacturing, and sales, by taking processes and functions that were previously disjointed and supported by various legacy system, or older, standalone, disparate business systems, and seamlessly integrating and coordinating them (Bradford, M., 2014). Enterprise Resources Planning (ERP) to provide a single financial view, for as many departments as possible, of internal and external transactions that either add value or transform the status or location of a product, part or asset. ERP is often disguised as a new more fashionable acronym (Evans, M., 2001).

Real-time location systems: Real-time location systems (RTLS), are used to track and identify the location of objects in real time using “nodes” or “tags” attached to, or embedded in the objects tracked, and “readers” that receive and process the wireless signals from these tags to determine their locations (H. W., & High, M. M. H., 2009).

Big data analytics: Big data analytics is the often-complex process of examining big data to uncover information -- such as hidden patterns, correlations, market trends and customer preferences -- that can help organizations make informed business decisions (Chai, W., Labbe, M., & Stedman, C., 2021).

Real-time Evaluation: A real-time evaluation (RTE) is an evaluation in which the primary objective is to provide feedback in a participatory way in real time (i.e., during the evaluation fieldwork) to those executing and managing the humanitarian response. RTEs are potentially most effective at the early stages of a response, as this is the phase when they can have the greatest influence on operations. Early stage RTEs can also capture the experience of those dealing with the initial part of a response (Cosgrave, J., Ramalingam, B., & Beck, T., 2009).

Cloud technologies as scalable IT infrastructure: Cloud computing provides the facility to access shared resources and common infrastructure, offering services on demand over the network to perform operations that meet changing business needs. The location of physical resources and devices being accessed are typically not known to the end user. The best Example of cloud computing is Google Apps where any application can be accessed using a browser and it can be deployed on thousands of computers through the Internet. (Kulkarni, G., 2012).

M2M communications: Machine-to-machine, or M2M, is a broad label that can be used to describe any technology that enables networked devices to exchange information and perform actions without the manual assistance of humans. Artificial intelligence (AI) and machine learning (ML) facilitate the communication between systems, allowing them to make their own autonomous choices. The main purpose of machine-to-machine technology is to tap into sensor data and transmit it to a network. (Shea, S., 2019).

Sensors: A sensor is a device which receives signals as well as responding to a signal or stimulus. The stimulus signals can be defined by the measure, property, or state which is sensed. A sensor has many forms of input properties and electrical output properties. If there is small change in the sensed quantity, it will cause a small change in the electrical output and the changes can be detected with their measuring capabilities. All the sensors are categorized on the basis of their uses, applications, material used and some production technologies. Some sensors are classified also by their characteristics such as cost, accuracy or range of sensor. There are two main types of sensors: passive sensor and active sensor (Patel, B. C., Sinha, G. R., & Goel, N).

IoT connection: The Internet of Things (IoT) is rapidly becoming a reality that surrounds us and intersects with many aspects of our lives. Pervasive connectivity and advances in ICT technologies have made possible the connection of more and more devices to the Internet. This is leading to a new wave of applications that have the potential to dramatically improve the way people live, learn, work, and entertain themselves. The success of IOT will be driven by applications that deliver tangible improvements to people's everyday lives (McGrath, M. J., Ni Scanaill, C., & Nafus, D., 2013).

IT infrastructure: Information technology is one of many tools managers use to cope with change. Computer hardware is the physical equipment used for input, processing, and output activities in an information system. It consists of the following: computers of various sizes and shapes (including mobile handheld devices); various input, output, and storage devices; and telecommunications devices that link computers together. Computer software consists of the detailed, preprogrammed instructions that control and coordinate the computer hardware components in an information system. Data management technology consists of the software governing the organization of data on physical storage media. All of these technologies, along with the people required to run and manage them, represent resources that can be shared throughout the organization and constitute the firm's information technology (IT) infrastructure. The IT infrastructure provides the foundation, or platform, on which the firm can build its specific information systems. Each organization must carefully design and manage its IT infrastructure so that it has the set of technology services it needs for the work it wants to accomplish with information systems (Laudon, K. C., 2007).

Automation technology: Automation technology is a crossover discipline that uses knowledge and scientific methods from numerous other technical sciences. According to DIN 19223, an automatic machine is an artificial system that makes decisions based on the linking of inputs with the respective states of the system; these decisions then produce very specific desired outputs. Three components are needed to realise modern automatic processes- sensors to detect the system states; actuators to output the control commands and controllers for the program flow and to make decisions (Ebel, F., Idler, S., Prede, G., & Scholz, D., 2008).

IT: Information technology (IT)- All the hardware and software technologies a firm needs to achieve its business objectives (Laudon, K. C., 2007).

3D printing: Uses machines to make solid objects, layer by layer, from specifications in a digital file. Also known as additive manufacturing (Laudon, K. C., 2007).

Overall equipment effectiveness (OEE): Overall equipment effectiveness (OEE) is a term used to evaluate how efficiently a manufacturer's operation is being used. In other words, overall equipment effectiveness helps you notice a problem in your operations, identify which percentage of manufacturing time is actually productive and fix it while giving you a standardized gauge for tracking progress. The goal for measuring your OEE is continuous improvement (Trout, J., 2019).

Product Lifecycle Management (PLM): Product Lifecycle Management (PLM) is a concept often promoted for product development to address innovation. PLM is a strategic concept for product development structured according to the four dimensions: organization, processes, methods and IT. It is a strategic business approach potentially providing a basis for an engineering environment, as it, in a comprehensive understanding, also comprises the same four dimensions as the engineering environment (Bitzer, M., & Vielhaber, M., 2011).

Product Data Management (PDM): PDM (Product Data Management) includes all organization-based tasks for the identification, the supply and the archival storage of product related data during the product development. PDM helps to organize the data and information flow throughout the development process. The management of the entire flow of data, processes and documents during the development or modification of products across the products lifecycle states the basis for an efficient virtual product generation. Complex product structures or product variations create numerous product parameter and information. A powerful PDM system supports the interaction of the data transfer between different phases of the development. (Hirz, M., 2008).

Production Data Acquisition (PDA): Production data acquisition (PDA), also called BDE or PDC, data collection about a company’s processes. It is the deliberate monitoring, tracking, and collection of production or operating data in ways that make it useful and relevant in attaining macro production or productivity goals in an organization. PDA’s purpose is to collect data that helps make the production process leaner, more flexible, and sustainably more profitable. Although the past half-century has witnessed incremental innovations that have allowed manufacturers to reduce waste and variability while dramatically improving quality and yield, there is still some way to go. Variability in the manufacturing process remains a fact of life in several industries, such as mining, pharmaceuticals, and chemicals (FORCAM, 2022).

Computer-aided design (CAD): CAD – computer-aided design- Information system that automates the creation and revision of designs using sophisticated graphics software. (Laudon, K. C., 2007). CAD involves any type of design activity, which makes use of the computer to develop, analyze or modify an engineering design. Modern CAD systems are based on interactive computer graphics (ICG). Interactive computer graphics denotes a user-oriented system in which the computer is employed to create, transform and display data in the form of pictures or symbols (Sarcar, M. M. M., Rao, K. M., & Narayan, K. L., 2008)

Supply Chain Management (SCM): Abbreviation for "supply-chain management." Systems for the management and monitoring of the global supply chain of a company. SCM systems manage both external and internal supply chains. One example of a partly external, partly internal supply chain is the provision of the material for the first work process of a product (Meyer, H., 2009).

Vertical and horizontal integration: Horizontal integration refers to the integration of IT systems for and across the various production and business planning processes. Between these various processes, there are flows of materials, energy and information. They concern internal and external partners, suppliers, customers and other ecosystem members, from logistics to innovation, and stakeholders. In other words, horizontal integration requires digitization across the full value and supply chain with an emphasis on data exchanges and connected information systems. This can be difficult, because many organizations still have disconnected IT systems.

Whereas horizontal integration is about IT systems and flows in the supply or value chain and the various processes happening across it, vertical integration has a hierarchical level component. In other words, it is about the integration of IT systems at various hierarchical production and manufacturing levels into one comprehensive solution. These hierarchical levels are: the field level interfaces with the production process via sensors and actuators; the control level regulates both machines and systems; the process line level or actual production process level needs to be monitored and controlled; the operations level includes production planning, quality management and so on; the enterprise planning level includes order management and processing, bigger overall production planning and so on (Pascual, D. G., Daponte, P., & Kumar, U., 2019).

Cloud-based software: Cloud-based software and the data it uses are hosted on powerful servers in massive data centers, and can be accessed with an Internet connection and standard Web browser. In addition to free or low-cost tools for individuals and small businesses provided by Google or Yahoo, enterprise software and other complex business functions are available as services from the major commercial software vendors. Instead of buying and installing software programs, subscribing companies rent the same functions from these services, with users paying either on a subscription or per-transaction basis (Laudon, K. C., 2007).

Data analysis: Data analysis can refer to a variety of specific procedures and methods. However, the data analysis involves goals; relationships; decision making; and ideas, in addition to working with the actual data itself. Simply put, data analysis includes ways of working with information (data) to support the work, goals and plans of your program or agency. From this perspective, we present a data analysis process that includes the following key components are- Purpose; Questions; Data Collection; Data Analysis; Procedures and Methods; Interpretation/Identification of Findings; Writing, Reporting, and Dissemination; and Evaluation (Start, S. H., 2006).

Appendix II: Apparel Industry Size by Employment

Small	Medium	Large
The factories have less than 500 workers	The factories have workers between 500-1000	The factories have more than1000 workers

Source: Asia Centre for Development (2021)

Appendix III: Apparel Industries' Profile that were taken as case studies in this research

Beximco Textile & Apparel Division

9. Bextex Ltd. was incorporated in Bangladesh on March 8, 1994 as a public limited company with limited liabilities. The company commenced its commercial operations in 1995, and in the same year it went into public issue of shares and debentures. Bextex Ltd. is the most modern composite mill in the region. It has an installed capacity of 288 high-speed air-jet looms in its weaving section, as well as a high-tech dyeing and finishing section with a capacity of 100,000 yards of finished fabric per day. The company is located at the BEXIMCO Industrial Park. Bextex Ltd. has a state-of-the-art composite knit fabric production mill, which serves the growing needs of high-quality knit garments exporters in Bangladesh. The project was set up as an ultra-modern knit fabric knitting, dyeing and finishing facility. Beximco is making major **new investments in new technologies** to become one of the most capable, fastest-reacting and most sustainable fashion vendors despite Covid-19. Such as:

- **US$ 25M** Fabric Technologies invested in setting up a large-scale Vertical PPE Park (Beximco Health) on 20 Acres of land.
- **$20M** investment to upgrade South Asia`s most sustainable and advanced washing plant for denims, garment dyeing, and special finishing of woven and knits.
- **$16M** in new Japanese state-of-the-art looms, sizing & warping to speedy manufacturing of innovative fabrics that are constantly in-demand by the world's biggest fashion brands.
- **$9M** on building a new denim garment manufacturing plant. This plant will be highly computerized with next-gen technologies. Operational May 2021.

Company Overview

40,000 Employees

Annual Turnover US$ 500 Million

Full Vertical Infrastructure

Global Footprints for Services & Manufacturing Collaborations

Innovation & Speed for Multi-Product Categories

Strong Design Support

Metro Knitting & Dyeing Mills Limited

Founded in 2000, Metro knitting and Dyeing Mills Ltd (concern of Panam group) has quickly risen the ranks and established itself as one of the i**ndustry leaders in the composite knitwear manufacturing sector of Bangladesh.** They believe that as a company they must consistently evolve with the market in order to best serve their clients. Therefore, they have equipped their plants with state-of-the-art types of machinery and highly experienced employees, to match the quality & shipment standards set by their clients. Further, they believe that their employees are the heartbeat of our organization and therefore, they continuously put their best efforts into maintaining their welfare and adhering to their development. Consequently, over the years through their collaborative efforts, they have cultivated a great trustworthy relationship with all their stakeholders. These relationships are the building blocks of the company and they look forward to harmoniously growing together in the years to come.

Company Overview

22 years in Business

20000 Employees

Garments Production 6.4 million Pcs/Month

Garments Sewing Lines 186

Knitting Capacity 2400 Ton/Month

Garments Dyeing Capacity 2830 Ton/Month

Yarn Dyeing Capacity 360 Ton/Month

Garments Dye Capacity 0.4 million Pcs/Month

Garments Wash Capacity 0.8 million Pcs/Month

The product includes T-Shirts, Shorts, Jackets, Hoodies & Sweatshirts Fleece Jackets, Dress & Skirts Blouse, Infant/Toddler Clothing Knit Shirt, Organic Apparels, Modal Products Viscose Garments, Grey & Finished Knit Fabric, Under Garments.

Esquire Knit Composite Limited

Esquire Knit Composite Limited was established in 2001. Having the industrial knowledge over 16 years from its sister concern companies namely, Esquire Dyeing Industries, Esquire Knitwear Ltd and Synthia Multi Fiber Ltd, Esquire Knit Composite Limited has focused on its business and successfully established the name as a world-class Garment Manufacturer under one roof having a composite facility of Yarn dyeing, Knitting, Fabric dyeing, and finishing; printing, embroidery, garments dyeing & washing up to Garments making. One stop solution of the company makes things much more convenient for their customers. Using state-of-the-art technology, focused business policies, and maintaining business ethics over the years helped us successfully establish the name as a world-class garment manufacturer in the knit garments arena. The group currently serving customers in European & American Chain stores, Fashion Brands and Super markets.

It keeps improving the quality of its products and services and looking forward to introducing a wider range of products to its customers to meet their needs. Given the strength of its leading position in the global market, with a comprehensive product portfolio, sound & strong customer base, its aim is to unveil its position as one of the unique garments manufacturers in the world. The company constantly is focusing on strengthening the business substances to ensure a strong podium on which it can rely to explore new business opportunities for the development of core business, widen its revenue base, upsurge the growth potential and consequently improve customer satisfaction.

Company Overview

10000 employees

Production capacity 2.0 million pieces of garments per month

100% Export oriented Knit Garments Factory having a composite facility of Knitting, Fabric Dyeing, Yarn Dyeing, Cutting, Sewing, Industrial Laundry, Embroidery, Printing, and Washing.

Fully automated State of art eco-friendly machinery and own design studio.

Lab accredited by NABL, ESPRIT, C&A, NEXT.

Shanta Industries Limited

Shanta Group is a conglomerate of Shanta Garments Ltd, Shanta Apparel Ltd,Shanta Industries Limited, Shanta Denims Limited, Shanta Washworks Limited. is one of the esteemed compliant garment group of Bangladesh. Group extended in health care with Apollo Hospital Ltd,in chemicals with GDS chemicals ltd, in education with ISD, DPS school, in real estate with SPL that manufacturing export oriented finest products for American Eagle Outfitters, Mark & Spencer, Gymboree, Polo, Chaps, Tommy Hilfiger, Mexx and S.Oliver. It produces 34500pcs RMG per day from 34 lines with special finishes like blasting, Scrapping, Whiskering,PP Spray, Resin, Grinding, Punching, Crunching, Oven Curing, Brushing, Center Crease and advanced dyeing & wash effects.

Company Overview

Employees 5001-10,000

23,000 m^2 of manufacturing space

150,000 units produced per week

All washing, dry processes & specialised finishing.

Experts in denim wet and dry processing

Extensive garment dyeing: reactive, direct, pigment

Excellent reputation for quality and on time delivery

Appendix IV: Machine Used in RMG

Here are lists of machines used in the RMG industry shown in comparison that used to be in 1980s and at present.

Table 47: Sewing Machines

Topics	1980	Present
Operation	Manually operated	Power Driven
Productivity	Low	High
Energy consumption	More because use classical motor	Less because use Servo motor in 1992 then now use direct driver motor where not use belt
Trimmer	Manual Thread trimming	Auto thread trimming
Production monitoring	Not possible	Possible because use IOT system /technology

Table 48: Cutting Machines

Topics	1980	Present
Cutting System	Before 1980 use Hand scissor then in 1980 use rotary cutter (Manual cutting)	Use software based cutting ie CAD, CAM is used.
Productivity	Low. By Hand scissor cutting only one layer of fabric.	Productivity more
Fabric consumption	Fabric consumption more	Low
Fabric wastage	More	Low
Fabric Spreading	Manual	Semi-automatic & automatic
Cost	Initial investment is less but overall cost is high	Initial investment is high but overall cost is less

Table 49: Knitting Machines

Topics	Conventional Knitting Machine (1980 - 2000)	Modern Knitting (2000- present)
Productivity	Low – As machine RPM is low	High - As machine RPM is low
Fault Detection	No Automatic fault detection system.	Automatic fault detection system.
Yarn Breakage	No Automatic Yarn Breakage detection system.	Automatic Yarn Breakage detection system.
Design Verity	Very limited fabric design verity	Higher design verity
Yarn Feeder	Only one yarn can feed in a single feeder.	More than one yarn can be feed in a single feeder because of more than eyelet.

Table 50: Dyeing Machines

Topics	**Conventional Dyeing Machine (1980 - 2000)**	**Modern Dyeing Machine (2000-present)**
Productivity	Low – As loading capacity 60% - 70% of design Capacity	High - As loading capacity 90% - 110% of design Capacity
Dyeing Time	Average dyeing timer per Batch is around 12hrs.	Average dyeing timer per Batch is around 8hrs.
Machine size	Machine size is big as required additional hot water reservoir.	Machine size is small as required no additional hot water reservoir.
Water Consumption	Higher – As liquor ratio 1:8 to 1:10	Lower- As liquor ratio 1:3 to 1:3
Chemical Consumption	High	Lower up to 40%.
Energy Consumption	High	Lower up to 50%.
Effluent Generation	High – As liquor ratio is high	Low- As liquor ratio is low
ETP Cost	High –As chemical consumption is high.	Low –As chemical consumption is low.
Environmental Impact	Not environment friendly	More environment friendly

Appendix V: Participants of Knowledge Sharing Meeting

Sl	Name & Designation	Institute Name	Cell & E-mail
1	A A Kabir Chy DGM	BEXIMCO	01713274300 kabirchy@beximtex.com
2	Shahinuzzama GM, IE	Shanta Industries Ltd.	01716508809
3	G. A. Anik Manager (HR)	Graphics Textiles Ltd.	01988885534 g.anik@graphics.com.bd
4	Joynal Abedin Manager (HR & Compliance)	Esquire Knit Composite Ltd.	01708464460 Joynal.hr@esquire.com.bd
5	Uttam Sarker AGM, Technical	Metro Knitting & Dyeing Mills Ltd.	01717609475 uttam@metrokd.com
6	Subrata Das Gupta AGM (Admin & HR)	Metro Knitting & Dyeing Mills Ltd. (Factory-02)	01730785566 Subrata.u2@metrokd.com
7	Prasenjeet Dey Sr. Trainer	Dea-Con Knitwear Ltd. (Factory-02)	01916838101 onlyjony@gmail.com
8	Md. Afzal Hossain Manager (HR, Admin & Comp.)	NRG Knit Composite	01730375947 afzal@nrgroup-bd.com
9	Resma Akter Asst. Manager (Welfare & IR)	Bendo Eco Apparels Ltd.	01865296945 welfare@teamtexgroup.com
10	Md. Sabbir Hossain Manager, HRD	Fakir Fashion Ltd.	01818244574 sabbirhr@fakirfashion.com
11	Md. Faisal Asst. Manager	Fatullah Apparels	01913535332 Hr.fatullah88@gmail.com
12	Md. Asaduzzaman	Fatullah Apparels	01711687801 asad.fatullah@gmail.com
13	Syed Shoriful Islam Sr. Executive	Knit Asia Ltd. (Factory-02)	01708801766 ie.ratanpur@knitasia.com
14	Md. Omar Hamdu Executive	Multifabs Ltd.	01717251265 Omarhamdu67@gmail.com
15	Md. Abbas Ali In-Charge	Multifabs Ltd.	01998017006 hr.abbas@multifabs.com

Appendix VI: Results from Reliability Test of the Instruments

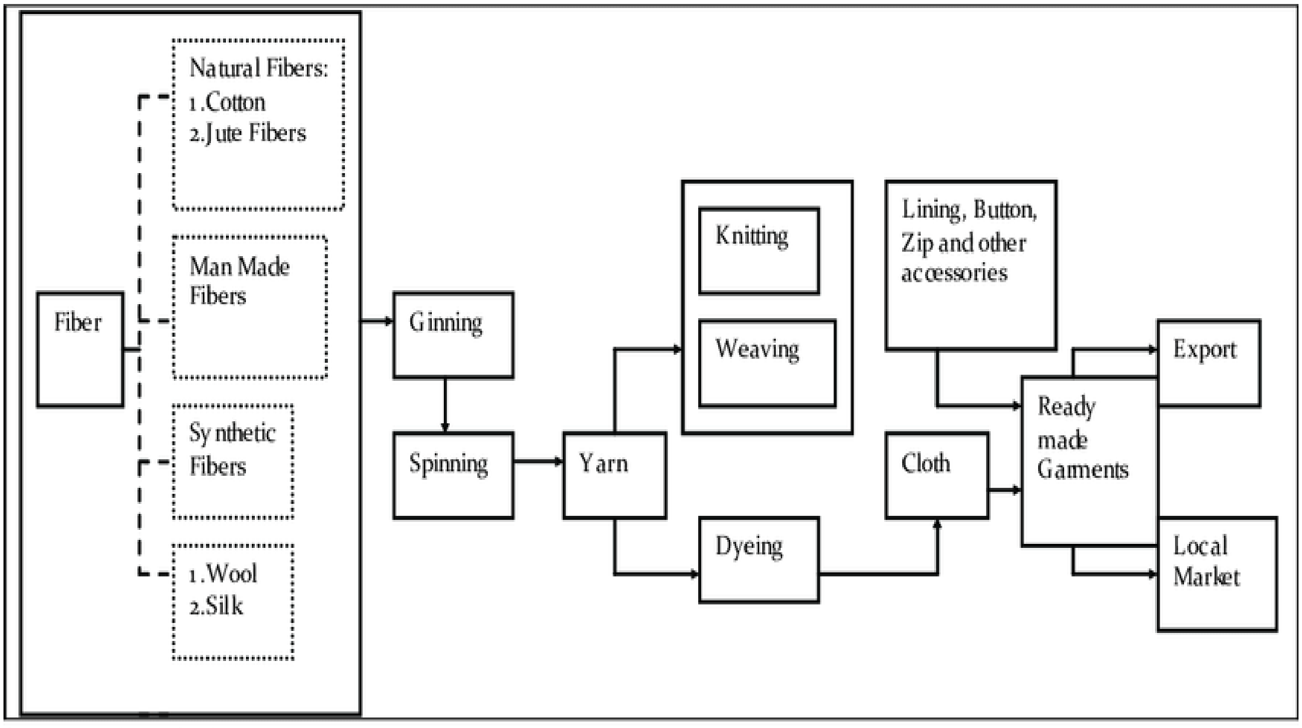
Questions	Obtained value (Pearson's correlation)
q2.1.1 Do you believe that the digital transformation to industry 4.0 in apparel sector could boost Bangladesh's global competitiveness?	.291**
q2.1.2 How strongly is your company feeling the impact of the digital transformation to industry 4.0?	.215*
q2.1.5_1 Which business segments within your company have the greatest potential to benefit from the digital transformation to industry 4.0 ? (Research and development)	.462**
q2.1.5_2 Which business segments within your company have the greatest potential to benefit from the digital transformation to industry 4.0 ? (Production/manufacturing)	.393**
q2.1.5_3 Which business segments within your company have the greatest potential to benefit from the digital transformation to industry 4.0 ? (Procurement/purchasing)	.652**
q2.1.5_4 Which business segments within your company have the greatest potential to benefit from the digital transformation to industry 4.0 ? (Warehousing/logistics)	.684**
q2.1.5_5 Which business segments within your company have the greatest potential to benefit from the digital transformation to industry 4.0 ? (Marketing)	.542**
q2.1.5_6 Which business segments within your company have the greatest potential to benefit from the digital transformation to industry 4.0 ? (Sales)	.706**
q2.1.5_7 Which business segments within your company have the greatest potential to benefit from the digital transformation to industry 4.0 ? (Services)	.721**
q2.1.5_8 Which business segments within your company have the greatest potential to benefit from the digital transformation to industry 4.0 ? (IT)	.475**
q2.1.6_1 Which business segments within your company have undergone the most and the least transformation as part of Industry 4.0? (Research and development)	.582**
q2.1.6_2 Which business segments within your company have undergone the most and the least transformation as part of Industry 4.0? (Production/manufacturing)	.688**
q2.1.6_3 Which business segments within your company have undergone the most and the least transformation as part of Industry 4.0? (Procurement & purchasing)	.698**
q2.1.6_4 Which business segments within your company have undergone the most and the least transformation as part of Industry 4.0? (Warehousing & logistics)	.734**
q2.1.6_5 Which business segments within your company have undergone the most and the least transformation as part of Industry 4.0? (Marketing)	.730**
q2.1.6_6 Which business segments within your company have undergone the most and the least transformation as part of Industry 4.0? (Sales)	.700**
q2.1.6_7 Which business segments within your company have undergone the most and the least transformation as part of Industry 4.0? (Services)	.720**
q2.1.6_8 Which business segments within your company have undergone	.690**

Questions	Obtained value (Pearson's correlation)
the most and the least transformation as part of Industry 4.0? (IT)	
q3.2a.5 How intensely your company already making use of the opportunities that 3D printing technology offers development and production processes?	.423**
q4.2_1 Lack of unified leadership that makes cross-unit coordination difficult within the company	.272*
q4.2_2 Lack of courage to launch the radical digitalisation	.238*
q4.2_3 Lack of in-house talent to support the development and deployment of Industry 4.0 Initiatives	.211*
q4.2_4 Difficulties with integrating data from various sources to enable initial connectivity	.172
q4.2_5 RowData ownership concerns when choosing third-party vendors for hosting and operationalising company data	.279**
q4.2_6 Lack of knowledge about technologies, vendors and IT outsourcing partners that could help executive the core initiative	.285**
q4.2_7 Expensive	.230**
q4.3_1 Revenue Gains	.772**
q4.3_2 Increased efficiency and productivity	.690**
q4.3_3 Machine downtime reductions	.591**
q4.3_4 Improved supply /Demand matching	.698**
q4.3_5 Quality	.714**
q4.3_6 Lower Cost	.735**
q4.3_7 Safety	.735**
q4.3_8 Sustainability	.772**

**. Correlation is significant at the 0.01 level (2-tailed).

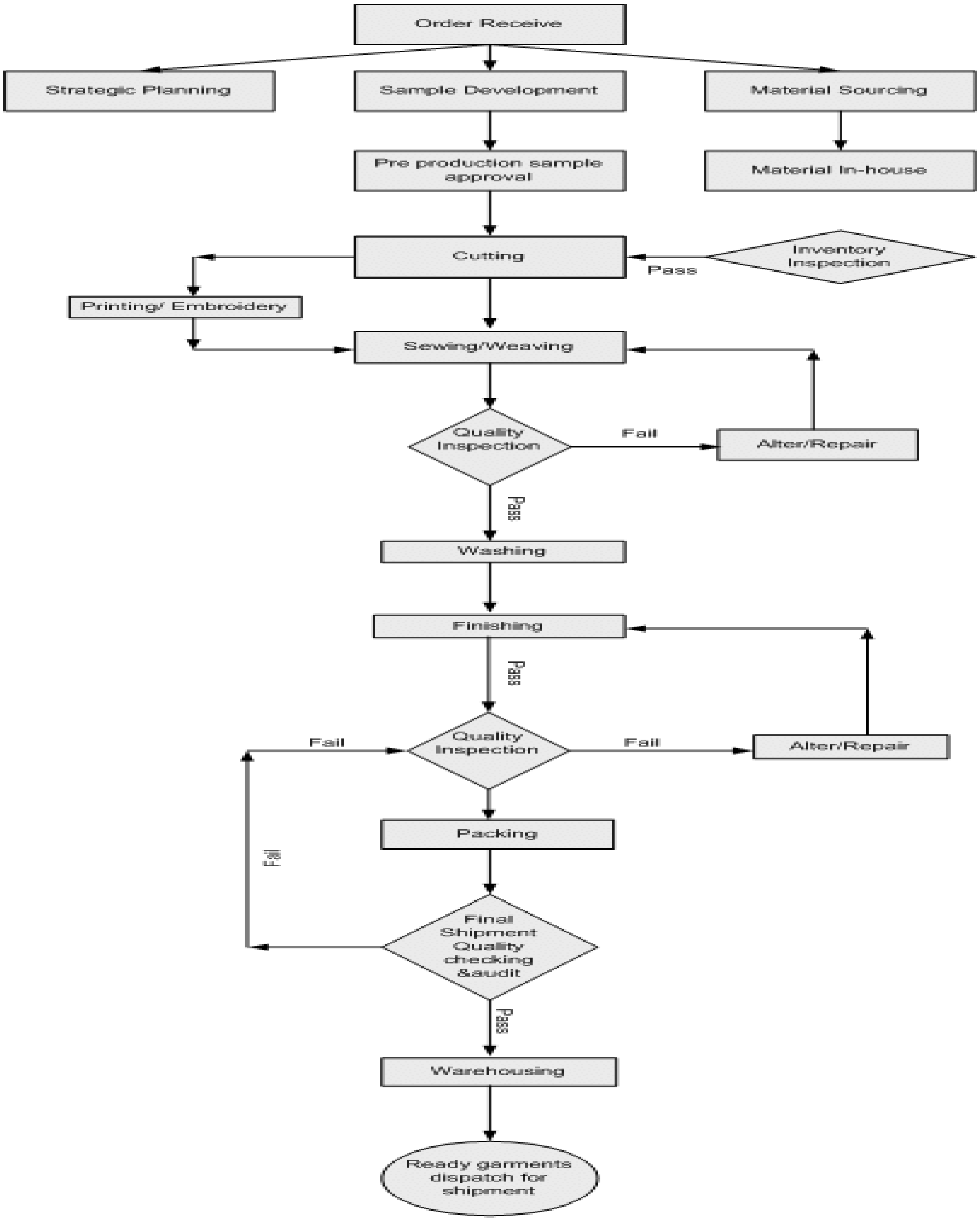
*. Correlation is significant at the 0.05 level (2-tailed).

Appendix VII: Supply Chain of RMG in Bangladesh



Source: Fakir Fashion, Naranganj

Appendix VIII: Production flow chart of RMG



Source: Md. Farhan Shahriar (2014) A Research Framework of Supply Chain Management in Ready Made Garments Industry of Bangladesh

Appendix IX: Questionnaire

Doctoral of Business Administration
RESEARCH QUESTIONNAIRE

Topic: The 4th Industrial Revolution in Apparel Sector: Challenges and opportunities for Bangladesh

This research is conducted by a DBA fellow of the Department of Management of the University of Dhaka). The topic of the research is ***The 4th Industrial Revolution in Apparel Industry: opportunities and Challenges for Bangladesh****. This research is conducted for study purpose only. Your identity would be confidential and you also do not need to provide your identification while answering this questionnaire. The research is intended to use this questionnaire for gathering inputs from people who are working with apparel manufacturer industries in Bangladesh. You may need 25 to 30 minutes for responding to this questionnaire.*

Respondent Information

Name:

Company Name:

Cell Phone Number:

E-mail Address:

Designation:

Part 1: Basic Information

1.1What category of apparel manufacturer you are currently working with?

a)☐ Women's apparel   b)☐ Men's apparel   c)☐ Children's apparel   d)☐ Other………………….

1.2 What is the level of your position in your current organization?

a)☐ Managing Director/Chairman   b)☐ Senior-level management   c)☐ Mid-level   d) ☐Other (please specify)_________________

1.3 What's your gender?

a)☐Male b)☐Female c)☐Transgender d)☐Prefer not to answer

1.4 What's your highest level of education?

a)☐ Master or above b)☐ Bachelor c)☐ Below tertiary d)☐ Prefer not to answer

1.5 Your duration of professional experience in Apparel/Garment sector?

☐ 15 years or above ☐ 10 to 15 years ☐ 5 to 10 years ☐ Less than 5 years

Part 2: Strategy Level

2.1 Strategy and organization

Q2.1.1 Do you believe that the digital transformation to industry 4.0 in apparel sector could boost Bangladesh's global competitiveness?

Completely disagree	1	2	3 Neutral	4	5	Completely agree
	❍	❍	❍	❍	❍	

Q2.1.2 How strongly is your company feeling the impact of the digital transformation to industry 4.0?

No impact	1	2	3 Neutral	4	5	Very substantial impact
	❍	❍	❍	❍	❍	

Q2.1.3 How would you describe the implementation status of your Industry 4.0 strategy?

☐No strategy exists
☐Pilot initiatives launched
☐Strategy in development
☐Strategy formulated
☐Strategy in implementation
☐Strategy implemented

Q2.1.4 Do you use indicators to track the implementation status of your Industry 4.0 strategy?

☐Yes, we have a system of indicators that we consider appropriate
☐Yes, we have a system of indicators that gives us some orientation
☐No, our approach is not yet that clearly defined

Q2.1.4a Which technologies do you need in your company to enhance business competitiveness? (Can answer more than 1)

□Sensor technology
□Mobile end devices
□RFID
□ERP
□Real-time location systems
□Big data to store and evaluate real-time data
□Cloud technologies as scalable IT infrastructure
□Embedded IT systems
□M2M communications
□Other (please mention): IOT System

Q2.1.4b Which technologies do you currently using in your company?(Can answer more than 1)

□Sensor technology
□Mobile end devices
□RFID
□Realtime location systems
□Big data to store and evaluate real-time data
□Cloud technologies as scalable IT infrastructure
□Embedded IT systems
□M2M communications
□Other (please mention):

Q2.1.5 Which business segments within your company have the greatest potential to benefit from the digital transformation to industry 4.0 ?

	No potential 1	Potential 2	Neutral 3	Great potential 4	Very great potential 5
Research and development	❍	❍	❍	❍	❍
Production /Manufacturing	❍	❍	❍	❍	❍
Procurement & Purchasing	❍	❍	❍	❍	❍
Warehousing & Logistics	❍	❍	❍	❍	❍
Marketing	❍	❍	❍	❍	❍
Sales	❍	❍	❍	❍	❍
Services	❍	❍	❍	❍	❍
IT	❍	❍	❍	❍	❍

Q2.1.6 Which business segments in your company have undergone the most and the least transformation as part of Industry 4.0?

	No transformation 1	Transformation 2	Neutral 3	Strong transformation 4	Very strong transformation 5
Research and development	❍	❍	❍	❍	❍
Production /Manufacturing	❍	❍	❍	❍	❍
Procurement & Purchasing	❍	❍	❍	❍	❍
Warehousing & Logistics	❍	❍	❍	❍	❍
Marketing	❍	❍	❍	❍	❍
Sales	❍	❍	❍	❍	❍
Services	❍	❍	❍	❍	❍
IT	❍	❍	❍	❍	❍

Q2.1.7 In which parts of your company have you invested in the implementation of Industry 4.0 in the past two years, and what are your plans for the future?

	Investments in the past 2 years				Investments in the next 5 years			
	Large	Medium	Small	None	Large	Medium	Small	None
Research and development	❍	❍	❍	❍	❍	❍	❍	❍
Production /Manufacturing	❍	❍	❍	❍	❍	❍	❍	❍
Procurement & Purchasing	❍	❍	❍	❍	❍	❍	❍	❍
Warehousing & Logistics	❍	❍	❍	❍	❍	❍	❍	❍
Marketing	❍	❍	❍	❍	❍	❍	❍	❍
Sales	❍	❍	❍	❍	❍	❍	❍	❍
Services	❍	❍	❍	❍	❍	❍	❍	❍
IT	❍	❍	❍	❍	❍	❍	❍	❍

Q2.1.8 In which areas does your company have systematic technology and innovation management? (Can answer more than 1)

□IT
□Production technology
□Product development
□Services
□Marketing
□Centralized, in integrative management
□Do not have

2.2 To Enhance Business Models, Product & Service

Q2.2.1a What is the level of contribution of Industry4.0 that your organization need in order to increase the competitiveness, overall value creation of your products & service?

□1 (Industry4.0 is **not** relevance to business and we are not need to adopt it in next 5 years)
□2 (Industry4.0 is **somewhat** relevance to business and we will need to adopt it in next 3 years)
□3 (Industry4.0 is relevance to business and we are will need to adopt it in next 3 years)
□4 (Industry4.0 is **very** relevance to business and we will need to adopt since past 3 years)
□5 (Industry4.0 is **strongly** relevance to business and we are need to adopt it since past 5 years)

Q2.2.1b What is the actual level of Industry4.0 that your organization is currently employing?

□1 (We are not currently employing any of Industry4.0 because it is **not** relevance to business)
□2 (We have adopted part of Industry4.0 because it is **somewhat** relevance to business)
□3 (We have adopted part of Industry4.0 in the past 2 years because it is relevance to business)
□4 (We have using Industry4.0 in the past 3 years because it is **very** relevance to business)
□5 (We have fully employing Industry4.0 in the past 5 years because it is **strongly** relevance to business)

Q2.2.2 To which degree is the average product in your portfolio digitized (e.g. RFID for identification, sensors, IoT connection, smart products etc.)?

□1 (All our product and services are completely digitized and our portfolio is **never** based solely on digitized serviced/product)
□2 (at least 25% of our product and services are digitized and our portfolio is **somewhat** based on digitized serviced/product)
□3 (at least 50% of our product and services are digitized and our portfolio is based on digitized serviced/product)
□4 (at least 75% of our product and services are digitized and our portfolio is **strongly** based on digitized serviced/product)
□5 (All our product and services are **completely** digitized and our portfolio is **completely** based on digitized serviced/product)

Q2.2.3 To which degree can your customers individualize the products they order?

□1 (All our product and services are standardized mass production, cannot be defined by customer via configuration tools)
□2 (at least 25% of our product and services can be defined by customer via configuration tools depending on lot size)
□3 (at least 50% of our product and services can be defined by customer via configuration tools but cannot have lot size of 1)

□4 (at least 75% of our product and services are defined by customer via configuration tools for customers, can have lot size of 1)
□5 (All our product and services are **completely** defined by customer via configuration tools for customers, can have lot size of 1)

Q2.2.4 To which degree are the life cycle phases of your products digitized (digitization and integration of design, planning, engineering, production, services & recycling)?

□1 (No digitization & integration – None of any phases are digitized or using any IoT/IT as our basis operation
□2 (Low digitization & integration – Only some phases such as design, planning, engineering are partly digitized for basis operation (e.g., using IT and software designed specifically for company operation)
□3 (Medium digitization & integration – Only design, planning, engineering phases are digitized (e.g., producibility can directly be evaluated via virtual prototyping, virtual design)
□4 (High digitization & integration – All phases in the product life cycle are **mostly** digitized from design, planning, engineering, production, services & recycling (e.g., producibility can directly be tested during product development via virtual prototyping)
□5 (Complete digitization & integration - All phases in the product life cycle are completely digitized from design, planning, engineering, production, services & recycling (e.g., Quality, Producibility, Productivity can directly be tested during product development via virtual prototyping, virtual process)

Q2.2.5 How important is the usage and analysis of data (customer data, product or machine generated data) for your business model?
□1 (No data analytics are relevant or leveraged to our business model. Customer data, product or machine data are not relevance to our operation. We plan to analyze and monitor those data in the next 3-5 years)
□2 (Customer data, product or machine generated data is **somewhat** relevance to business, can be value driver of the business model and we will analyzed and monitored these generated data in the next 1-3 years)
□3 (Customer data, product or machine generated data is relevance to business, the value driver of the business model and we have analyzed and monitored these generated data in the past 1-3 years)
□4 (All customer data, product or machine generated data is **very** relevance to business, the main value driver of the business model and we have analyzed and monitored these generated data in the past 2-3 years)
□5 (Crucial - Data is the main value driver of the business model. All customer data, product or machine generated data is **strongly** relevance to business and we are continuously analyzing and monitoring these generated data in the past 3-5 years)

Q2.2.6 How intense is your collaboration with partners, suppliers and clients for development of products and services?

□1 (No Collaboration - Product development is done completely in-house without any exchange of information with partners, suppliers or customers)

□2 (Low - collaboration - Collaborative development of products together with partners are low in our supply chain networks, can be communicated but cannot be integrated)
□3 (Medium - collaboration - Collaborative development of products together with partners has been employed our supply chain networks, but are not integrated, transparent for the customers)
4 (High - collaboration - Collaborative development of products together with partners has been employed throughout our supply chain networks, and are transparent for the customers in the past 1-3 years)
□5 (Crucial - collaboration - Collaborative development of products together with partners has been employed throughout our supply chain networks, and are transparent for the customers in the past 3-5 years)

2.3 Transversal & Domain related competences: Employees

Employees help companies realize their digital transformation and are the ones most affected by the changes of the digital workplace. Their direct working environment is altered, requiring them to acquire new skills and qualifications. This makes it more and more critical that companies prepare their employees for these changes through appropriate training and continuing education.

Q2.3.1 Do you have skilled workers/talents/employees to implement industry 4.0 in your organization/company?

□ has the skilled workers/talents/employees as needed
□ has the skilled workers/talents/employees in certain areas
□ Completely lacked the necessary skilled workers/talents/employees
□ Other (please mention):

Q2.3.2 Does your company have adequate talents to run the digitally sophisticated factory?
□Yes □ No □ Partly

Q2.3.3 How do you assess the skills of your employees when it comes to the future requirements under Industry 4.0?

	Not relevant	Non-existent	Existent, but inadequate	Adequate
IT infrastructure	❍	❍	❍	❍
Automation technology	❍	❍	❍	❍
Data analytics	❍	❍	❍	❍
Data security / communications security	❍	❍	❍	❍
Development or application of assistance systems	❍	❍	❍	❍
Collaboration software	❍	❍	❍	❍
Non-technical skills such as systems thinking and process understanding	❍	❍	❍	❍

Q2.3.4 In which areas does your company need to have to attain Industry4.0?
(Can answer more than 1)

□IT
□Production technology

□Product development
□Services
□Centralized, in integrative management
□Do not have

Q2.3.5 What kind and level of competence that your company will need for new employees when it comes to the Industry 4.0?

	Low	Medium	Strong	Very Strong
IT infrastructure	❍	❍	❍	❍
Automation technology	❍	❍	❍	❍
Data analytics	❍	❍	❍	❍
Data security / communications security	❍	❍	❍	❍
Development or application of assistance systems	❍	❍	❍	❍
Collaboration software	❍	❍	❍	❍
Non-technical skills such as systems thinking and process understanding	❍	❍	❍	❍

Part 3: Adoption Level

3.1 Smart products - Co-created Design concepts

Q3.1.1 Does your company allow the customer to co- design the product or service experience to suit their context? If yes mention %

	No	25%	25%-50%	51%-75%	More than 76%
Product	❍	❍	❍	❍	❍
Service	❍	❍	❍	❍	❍
Product/Service Integration	❍	❍	❍	❍	❍

Q3.1.2 Does your company allowing the customer to co-construct the product or service experience to suit their context? If yes mention %

	No	25%	25%-50%	51%-75%	More than 76%
Product	❍	❍	❍	❍	❍
Service	❍	❍	❍	❍	❍
Product/Service Integration	❍	❍	❍	❍	❍

Q3.1.3 Does your company offer products equipped with the following add-on functionalities based on information and communications technology?

	No	25%	25%-50%	51%-75%	More than 76%
Product memory	❍	❍	❍	❍	❍
Self-reporting	❍	❍	❍	❍	❍
Integration	❍	❍	❍	❍	❍
Localization	❍	❍	❍	❍	❍
Assistance systems	❍	❍	❍	❍	❍
Monitoring	❍	❍	❍	❍	❍
Object information	❍	❍	❍	❍	❍
Automatic identification	❍	❍	❍	❍	❍

3.2 **Smart factory -Intelligence Manufacturing System**

3.2a Equipment infrastructure

Q3.2a.1 How would you evaluate your equipment infrastructure when it comes to the following functionalities?

	No	Yes but 25%-50%	Yes but 51%-75%	Yes but 76%+
Machines/systems can be controlled through IT	❍	❍	❍	❍
M2M: machine-to-machine communications	❍	❍	❍	❍
Interoperability: integration and collaboration with other machines/systems possible	❍	❍	❍	❍

Q3.2a.2 How would you evaluate your adaptability of your equipment infrastructure when it comes to the following functionalities?

	Not relevant	Relevant, but not upgradable	Upgradable	High, because functionality already available
M2M: machine-to-machine communications	❍	❍	❍	❍
Interoperability: integration and collaboration with other machines/systems possible	❍	❍	❍	❍

Q3.2a.3 Does your company invest in 3D printing?

☐Yes ☐No ☐Partly

Q3.2a.4 Does your company has plan to invest in 3D printing in future?

□Yes □No □Partly □ already exist

Q3.2a.5 How intensely your company already making use of the opportunities that 3D printing technology offers development and production processes?

Not at all	1	2	3	4	5	Very strongly
	❍	❍	❍	❍	❍	

3.3 Digital model of factory

Q3.3.1 The digitization of factories makes it possible to create a digital model of the factory. Are you already collecting machine and process data during production?

No	Yes but below 25%	Yes but 25%-50%	Yes but 51%-75%	More than 75%
❍	❍	❍	❍	❍

Q3.3.2 How is the data you collect used? (Can answer more than 1)

□Predictive maintenance
□Optimization of logistics and production processes
□Creation of transparency across production process
□Quality management
□Automatic production control through use of real-time data
□Optimization of resource consumption (material, energy)

Q3.3.3a Which data about your machinery, processes, and products as well as malfunctions and their causes is collected during production, and how is it collected?

	Yes, manually but below 25%	Yes, manually but below 25%-50%	Yes, manually but below 51%-75%	Yes, manually more than 76%	No
Inventory data	❍	❍	❍	❍	❍
Manufacturing throughput times	❍	❍	❍	❍	❍
Equipment capacity utilization	❍	❍	❍	❍	❍
Production residues/waste/WIP	❍	❍	❍	❍	❍
Quality MGMT	❍	❍	❍	❍	❍

Employee utilization	❍	❍	❍	❍	❍
Quality Control data	❍	❍	❍	❍	❍
Data about processing, process condition	❍	❍	❍	❍	❍
Production times	❍	❍	❍	❍	❍
Overall equipment effectiveness (OEE)	❍	❍	❍	❍	❍
Other	❍	❍	❍	❍	❍

Q3.3.3b Which data about your machinery, processes, and products as well as malfunctions and their causes are collected during production, and how is it collected?

	Yes, automatically but below 25%	Yes, automatically but below 25%-50%	Yes, automaticall y but below 51%-75%	Yes, automaticall y more than 76%	No
Inventory data	❍	❍	❍	❍	❍
Manufacturing throughput times	❍	❍	❍	❍	❍
Equipment capacity utilization	❍	❍	❍	❍	❍
Production residues/waste/WIP	❍	❍	❍	❍	❍
Quality MGMT	❍	❍	❍	❍	❍
Employee utilization	❍	❍	❍	❍	❍
Quality Control data	❍	❍	❍	❍	❍
Data about processing, process condition	❍	❍	❍	❍	❍
Production times	❍	❍	❍	❍	❍
Overall equipment effectiveness (OEE)	❍	❍	❍	❍	❍
Other	❍	❍	❍	❍	❍

Q3.3.4 Which of the following systems do you use? Does the system have an interface to the leading system?

	In use		Interface to leading system	
	Yes	No	Yes	No
MES – manufacturing execution system	❍	❍	❍	❍
ERP – enterprise resource planning	❍	❍	❍	❍
PLM – product lifecycle management	❍	❍	❍	❍
PDM – product data management	❍	❍	❍	❍

PPS – production planning system	❍	❍	❍	❍
PDA – production data acquisition	❍	❍	❍	❍
MDC – machine data collection	❍	❍	❍	❍
CAD – computer-aided design	❍	❍	❍	❍
SCM – supply chain management	❍	❍	❍	❍
3D Printing	❍	❍	❍	❍

3.4 Smart operations - Controlling, Adjusting & Monitoring Process Real Time Vertical and horizontal integration

Q3.4.1 Where have you integrated cross-departmental information sharing into your system? Distinguish between enterprise-wide (internal) and cross-enterprise (external) information sharing.

	Internally between departments		Externally with customers and/or suppliers	
	Yes	No	Yes	No
Research and development	❍	❍	❍	❍
Production/manufacturing	❍	❍	❍	❍
Purchasing	❍	❍	❍	❍
Logistics	❍	❍	❍	❍
Sales	❍	❍	❍	❍
Finance/accounting	❍	❍	❍	❍
Service	❍	❍	❍	❍
IT	❍	❍	❍	❍
Nowhere	❍	❍	❍	❍

3.5 Distributed control

Q3.5.1 The vision of Industry 4.0 is a work piece that guides itself autonomously through production. Does your company already have use cases in which the work piece guides itself autonomously through production?

□Yes, cross-enterprise
□Yes, but only in selected areas
□Yes, but only in the test and pilot phase
□No

Q3.5.2 Does your company have production processes that respond autonomously/automatically in real time to changes in production conditions?

□Yes, cross-enterprise
□Yes, but only in selected areas
□Yes, but only in the test and pilot phase
□No

3.6 Data and communications security

Q3.6.1 How is your IT organized?

□No in-house IT department (service provider used)
□Central IT department
□Local IT departments in each area (production, product development, etc.)
□IT experts attached to each department

Q3.6.2 How far along are you with your IT security solutions?

	Solution implemented	Solution in progress	Solution planned	Not relevant for us
Security in internal data storage	❍	❍	❍	❍
Security of data through cloud services	❍	❍	❍	❍
Security of communications for in-house data exchange	❍	❍	❍	❍
Security of communications for data exchange with business partners	❍	❍	❍	❍

Q3.6.3 Are you already using cloud services?

	Yes	No, but we're planning to	No
Cloud-based software	❍	❍	❍
For data analysis	❍	❍	❍
For data storage	❍	❍	❍

Q3.6.4 How advanced is the digitization of your production equipment (sensors, IoT connection; digital monitoring, control, optimization & automation)?

□1 (Purely physical factory – Production equipment is entirely cut off from IT systems and no real-time information can be gathered)
□2 (Low digitized factory – Interconnected production equipment allows for IT-access and information is fed into some machine in the factory)
□3 (Medium digitized factory – Interconnected production equipment allows for IT-access and information is fed for some part of the production in the factory)
□4 (High digitized factory – Interconnected production equipment allows for IT-access and information is fed into a virtual representation only for the main productions of factory)
□5 (Fully digitized factory – Interconnected production equipment allows for IT-access and information is fed into a virtual representation of the factory)

Q3.6.5 How would you rate the degree of digitization of your horizontal value chain (from customer order over supplier, production and logistic to service)?

□1 (No digitization at all – No automated exchange of information along the horizontal value chain, e.g. no connection to supplier's IT)
□2 (Low digitized factory – some automated exchange of information to supplier's IT or customer's IT)
□3 (Medium digitization–data flow along the horizontal value chain with integration of logistic)
□4 (High digitization–Continuous data flow along the horizontal value chain with integration of logistic)
□5 (Complete digitization–Continuous data flow along the horizontal value chain with integration of logistic service into internal IT)

3.7. Data-driven services-Integrated Business and Operational Data Management

Q3.7.1 The process data gathered in production and in the usage phase enable new services. Do you offer such services?

□Yes, and we are integrated with our customers
□Yes, but without integration with our customers
□No
Q3.7.2 What share of your revenues come from these new data-driven services??
Often, data that is collected is just stored and then not used any further. What share of the data you collect are you already using?

□0%
□0% to 20%
□21% to 50%
□Over 50%

Q3.7.3 Do you analyze the data you collect from the usage phase?

□Yes
□No – we collect the data but do not analyze it
□No – we do not collect data in the usage phase

Q3.7.4 To which extent do you use multiple integrated sales channels to sell your products to your customers?

□1 (One channel - Traditional sales force approach, e.g. local sales force)
□2 (One Channel – Integration of digital and non-digital sales)
□3 (Several Channel –various digital and non-digital sales channels, e.g., sales force, web-shop, sales platforms)
□4 (Multi Channel – Integration of various digital and non-digital sales channels, e.g., sales force, web-shop, sales platforms)
□5 (Multi/ Omni-Channel – Integration of various digital and non-digital sales channels, e.g. store, sales force, web-shop, sales platforms)

Q3.7.5 How far do you integrate multiple channels (website, blogs, forums, social media platforms etc.) into your customer interactions for communicating news, receiving feedback, managing claims etc.?

□1 (One-way communication – Usage of traditional communication channels for information purposes only (e.g. corporate website, newsletters)
□2 (One-way communication – Usage of traditional communication channels to response to customer from e.g. corporate website)
□3 (Reactive communication – Usage of digital channels to response to customer, e.g. use previous information from customers to product development)
□4 (Proactive communication – Usage of digital channels to acquires customer interaction, e.g. some integrating customers into product development)
□5 (Interactive communication – Usage of multiple digital channels to foster customer interaction, e.g. integrating customers into product development via social media platforms)

Q3.7.6 How advanced is the digital enablement of your sales force (mobile devices, access to all relevant system anywhere and anytime, full sales process possible at client site)?

□1 (Traditional sales approach - Sales force works 'offline' without access to relevant systems, e.g. using centrally distributed paper documents)
□2 (Connected sales approach - Sales force works 'online' with access to relevant systems, e.g. using centrally digitized document)
□3 (Digital sales approach - Sales force is supported by digital devices and distribute to all relevant processes and systems using centrally integrated IT)
□4 (High Digital sales approach - Sales force is supported by digital devices and access to all relevant processes and systems to customer and product data using horizontally integrated IT with customers and suppliers)
□5 (Digital sales approach - Sales force is supported by digital devices and access to all relevant processes and systems at real-time access to customer and product data, possibility to configure personalized products & dynamically create orders etc)

Q3.7.7 To which extent do you analyze customer data to increase customer insight (e. g. personalized offers to customers based on their personal situation, preferences, location, credit score; consideration of usage data for design & engineering etc.)?

□1 (Trivial data usage - Information is kept decentralized and in an unsystematic way by single units and is not analyzed further for, e.g. sales orders in excel sheets)
□2 (Non trivial data usage – Some Information is kept centralized and in an systematic way by single units and is analyzed further for, e.g. sales orders in both files and excel sheets)
□3 (Medium data usage - Main data collection are kept centralized and in an systematic way by single units and is analyzed further for, e.g. sales orders)
□4 (High data usage – Most data collection are kept centralized in integrated systems to review products, sales and customer experience)
□5 (Substantial data usage - Extensive data collection at all touch points that is fed into integrated systems to monitor, review and optimize products, sales and customer experience)

Q3.7.8 How far do you want to collaborate with partners regarding your approach of accessing customers (exchange of customer insights, coordination of marketing activities etc.)?

□1 (Not at all - No collaboration with partners in approaching customers, e.g. separate customer databases and no coordination of marketing or sales activities)
□2 (Somewhat – Some collaboration with partners in approaching customers for coordination of marketing or sales activities)
□3 (Medium - Some collaboration with partners in approaching customers databases for some coordination of marketing or sales activities and production activities)
□4 (Somewhat Unified approach – Customer access approach is partly backed up along with the partner network, e.g. common customer ID with partners and use of partner data)
□5 (Unified approach – Customer access approach is completely backed up along with the partner network, e.g. common customer ID with partners and use of partner data)

Part 4: Challenges & Opportunities

Q4.1 In most Bangladeshi apparel manufacturing companies, the IT infrastructure is not wholly to ready to support the digital transformation to industry 4.0—do you agree?

□Yes □ Partly □ No

Q4.2 What are the challenges, adopting of adoption IR 4.0 in your factory? (Can answer more than one)

	Not at all	Slightly	Neutral	Considerably	Very Considerably
Lack of unified leadership that makes cross-unit coordination difficult within the company	❍	❍	❍	❍	❍
Lack of courage to launch the radical digitalization	❍	❍	❍	❍	❍
Lack of in-house talent to support the development and deployment of Industry 4.0 initiatives	❍	❍	❍	❍	❍
Difficulties with integrating data from various sources to enable initial connectivity	❍	❍	❍	❍	❍
Data ownership concerns when choosing third-party vendors for hosting and operationalizing company data	❍	❍	❍	❍	❍
Lack of knowledge about technologies, vendors and IT outsourcing partners that could help execute the core initiative	❍	❍	❍	❍	❍
Expensive	❍	❍	❍	❍	❍

Q4.3 What are the business benefits of industry 4.0 adoption in your factory? (can answer more than one)

	Not at all	Slightly	Neutral	Considerably	Very Considerably
Revenue gains	❍	❍	❍	❍	❍
Increased efficiency and productivity	❍	❍	❍	❍	❍
Machine downtime reductions	❍	❍	❍	❍	❍
Improved supply/demand matching	❍	❍	❍	❍	❍
Quality	❍	❍	❍	❍	❍
Lower cost	❍	❍	❍	❍	❍
Safety	❍	❍	❍	❍	❍
Sustainability	❍	❍	❍	❍	❍

Q4.4 Do you think the digital transformation to industry 4.0 could further increase cyber risk for manufacturing companies?

Not at all	Slightly	Neutral	Considerably	Very Considerably
❍	❍	❍	❍	❍

Q4.5 Do you think with the help of big data analytics, a company can gain a deeper understanding of customer needs and that helps your company's product development?

☐Yes ☐ No ☐ Partly