Journal of Business Studies, University of Rajshahi 1
JBS-ISSN 2303-9884
Volume 14, No. 1, pp. 1-35 (Published in December 2024)

Revolutionizing Production: The Impact of 4IR on Factory Management of Ready-Made Garment Industry in Bangladesh

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Abstract

This study aims to provide insights into the impacts of the Fourth Industrial Revolution (4IR) on the factory management of the Ready-Made Garment (RMG) industry in Bangladesh. The researchers employed a qualitative field research approach to collect data from 18 respondents selected through purposive sampling from stakeholders within the RMG industry of Bangladesh. A semi-structured questionnaire was utilized to ascertain the impacts of the 4IR on factory management within the study's scope. Subsequently, the data interpretation is obtained through a rigorous thematic analysis. The study reveals the significant impacts of the 4IR on the RMG industry of Bangladesh, marked by the widespread adoption of digital industrial technologies and automation in factory management processes. Automation, propelled by 4IR, has resulted in improved precision and efficiency in production processes. This automation not only minimizes human intervention but also contributes to cost reduction, while simultaneously yielding social benefits and addressing ethical imperatives. The findings underscore the importance of proactive policy interventions to address the challenges and opportunities associated with 4IR adoption. Strategies focusing on education, skills development, and supportive policies are essential for facilitating a smooth transition toward digitalized factory management while ensuring equitable benefits for all stakeholders.

Keywords: Industrial revolution; industry 4.0; internet of things; production management; Ready-made garments (RMG).

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JBS-ISSN 2303-9884
Volume 14, No. 1, pp. 1-17 (Published in December 2024)

1. Introduction

The 4IR has emerged as a pervasive term, yet many individuals remain unaware of its profound implications on their daily lives within this new digital landscape. Across various sectors, the integration of automation, biological sciences, blockchain, artificial intelligence (AI), augmented reality (AR), 3D printing, and the Internet of Things (IoT) is progressively displacing human labor (Park, 2018). However, the effectiveness of these contemporary technologies varies significantly based on a nation's cultural, societal, political, and economic contexts. The concept of the 'Fourth Industrial Revolution', often synonymous with 'Industry 4.0', originates from Germany's initiative between 2011 and 2015, focusing on digital technology's role in production (García & García, 2019; Kagermann et al., 2013). 4IR holds tremendous promise, encompassing customer satisfaction, enhanced adaptability, streamlined decision-making, improved worker efficiency, novel service creation, and addressing social challenges such as work-life balance and demographic shifts. Following previous industrial revolutions, 4IR marks a pivotal shift toward digital integration across the entire value chain, horizontal networking within the value network, and vertical integration within manufacturing systems (Rüßmann et al., 2015). This paradigmatic transformation is propelled by foundational technological advancements, amalgamating technologies, business processes, and data processing into a novel industrial framework (Bordeleau et al., 2018).

The 4IR aspirations extend beyond efficiency gains to foster innovation, address social issues, and cater to evolving consumer demands while maintaining competitiveness in a globalized market. Achieving these objectives necessitates the seamless integration of vertical and horizontal processes, transforming industrial production to accommodate personalized products without sacrificing economies of scale. The ongoing evolution from mass manufacturing to personalized production entails a series of incremental steps, with data analytics, artificial intelligence, additive manufacturing, and simulation playing pivotal roles (Brettel et al., 2014). Consequently, 4IR not only revolutionizes production processes but also redefines the relationship between humans, machines, and tasks, emphasizing flexibility and adaptability.

The potential for revolutionizing manufacturing and industrial management is enormous with the Fourth Industrial Revolution (4IR). Some of the key benefits of

4IR are increased customer satisfaction, flexibility, simpler decision-making, increased worker productivity, creative service creation, and addressing social challenges like work-life balance and demographic shifts (George, 2024; David et al., 2022; Explainers, 2022). In contrast to other industrial revolutions, 4IR is characterized by vertical integration inside production systems, horizontal networking within the value chain, and widespread digital transformation throughout the entire value chain (Castelo-Branco, 2022). Fundamental technological developments that combine business procedures, data processing, and technology into a new industrial framework are what contribute to this paradigm shift.

In addition to increasing efficiency, the 4IR seeks to fulfill changing customer demands, promote innovation, and solve social issues all while being competitive in a globalized market. The smooth integration of vertical and horizontal processes is necessary to achieve these aims, changing industrial production to allow customized goods without sacrificing economies of scale (Bhuiyan, 2020). A number of incremental steps are required to make the shift from mass manufacturing to customized production, and simulation, artificial intelligence, data analytics, and additive manufacturing are all important components (Castelo-Branco, 2022).

In the context of the RMG industry in Bangladesh, automation adoption is seen as crucial for maintaining efficiency and competitiveness (Farhana et al., 2022). However, the sector's reliance on manual labor and concerns about job loss necessitates careful consideration and strategic planning. The Bangladesh Garment Manufacturers and Exporters Association (BGMEA) faces the challenge of leveraging the latest technological developments to enhance competitiveness while addressing socio-economic concerns such as job displacement and gender disparities in RMG. Collaborative efforts between the Bangladesh Government and BGMEA are necessary to modernize infrastructure and establish a digital ecosystem to promote sustainable growth of this industry. Moreover, the integration of innovative frameworks and technologies is essential for the RMG sector in Bangladesh to remain competitive in the global market (Rahman &Maniam, 2022).In light of these challenges and opportunities, this study raises the research question: What are the impacts that the RMG industry of Bangladesh might encounter in its factory management as a result of 4IR? To address this question, this study aims to provide insights into the impacts of 4IR on the factory

management of the RMG industry in Bangladesh. This paper is further organized including a literature review, methodology, demographic discussion of the respondent, findings, and discussion of the themes, implications, limitations, and future research agenda.

2. Literature Review

Professor Klaus Schwab, the founder and executive chairman of the "World Economic Forum," describes the 4IR as a major worry and a topic of discussion around the world, including Bangladesh. Experts predict that the 4IR will be marked by major industrial advancement with developing technologies such as robots, AI, 5G, nanotechnology, fully automated cars, and so on, similar to the third industrial revolution. To showcase a manufacturing revolution, 4IRis referred to in a variety of ways; for example, in the United States, it is referred to as the Manufacturing Renaissance, but in China, it is referred to as Made in China 2025 (MAPI Foundation, 2015; BDI, 2016).However, Germany's progress is considerably more noticeable than that of other countries; for example, German experts say that they are already at level 3.8 and that reaching 100 percent and4IR production will take a decade, if not less. This is due to the fact that a corporation cannot migrate from 3.0 to 4.0 in a single day or step, as the process takes time and involves several stages. Even though 4IR is well-known and in use in several Western nations, the term is foreign to many important strategists and managers across a wide range of nations(Leiden et al., 2018; Cleverism, 2018). 4IR, on the other hand, is critical for manufacturing-dependent countries that are seeing rapid economic growth as a result of their exports.

Industry 4.0 transforms industrial management through the smooth integration of interconnected systems and the use of data science, machine learning, and artificial intelligence to improve decision-making, optimize operations, and provide a workforce with the necessary skills to use cutting-edge technologies. By seamlessly combining the Internet of Things (IoT), sophisticated connectivity, and cyber-physical systems, Industry 4.0 transforms plant management and can result in significant cost savings and improved operational efficiency (Orellana & Torres, 2019).

Industry 4.0 revolutionizes industrial management through the integration of cutting-edge systems that optimize operations and decision-making by enabling intelligent control, real-time data interchange, and seamless connectivity between machines, people, and processes (Zhong et al., 2017). According to Constantinescu

et al. (2014), the fourth industrial revolution improves factory management by allowing systems to communicate and exchange information. This allows for just-in-time information retrieval to support decision-making and lessen cognitive overload for human stakeholders.

According to Nagpal et. al. (2019), the fourth industrial revolution streamlines production processes by improving factory management through IIoT integration, enabling real-time monitoring, intelligent device communication, and decreased downtime via automated notifications. Moreover, industry 4.0 improves factory management through intelligent manufacturing, increased efficiency, and flexibility. This allows for better process planning and risk management while promoting sustainable business models (Kumar, Zindani, and Davim 2019). Through automation, real-time data analysis, and networked smart devices, the fourth industrial revolution improves factory management and makes it possible for more effective operations, predictive maintenance, and better decision-making (Pagnon, 2017). By allowing for self-organization and self-optimization through dynamic predictive decision-making based on broad data usage, the fourth industrial revolution improves factory management through enhanced flexibility, agility, and efficiency (Ebrahimi, Baboli, & Rother, 2018). By using cutting-edge digital technologies, the Fourth Industrial Revolution improves factory management, resulting in higher productivity and better results both inside and between businesses (Margherita, & Braccini, 2021).

Bangladesh, a nation in the Asia-Pacific area, has one of the fastest-rising economies, with a Gross Domestic Product (GDP) that has been averaging between 6 and 8 percent for the past 20 years. By 2030, Bangladesh is expected to have the twenty-eighth-largest economy in the world (Humphrey, 2019), with export earnings expanding at a significant rate of around 10% percent with occasional variations. Despite facing domestic and international challenges, Bangladesh's economy has achieved robust growth, reduced inflation, increased foreign exchange reserves, and a stable GDP due to prudent macroeconomic policies and structural reforms(Humphrey, 2019). The Fourth Industrial Revolution (4IR) offers significant opportunities for Bangladesh, but realizing these benefits requires concerted action from both the government and private organizations. The manufacturing and service sectors must adopt and implement 4IR technologies, and businesses with substantial investments can accelerate production and drive economic growth by embracing 4IR processes(Moktadir, et al., 2018).

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In the meantime, several obstacles hinder the adoption of 4IR technologies in Bangladesh, including insufficient expertise, worker skills, factory equipment, funding, and application of technology in manufacturing. To fully capitalize on the opportunities presented by the Fourth Industrial Revolution, the government and private sector must collaborate to address these challenges and drive economic growth(Sarkar et al., 2017).

Rapid technological advancements are transforming the apparel and fashion industry, and Bangladesh's RMG sector, a $38.52 billion export, is at the forefront of this transformation. The sector's commitment to sustainability is evident in the construction of 135 environmentally friendly green buildings, the most globally.Hence, the adoption of 4IR technologies is crucial for garment factories to remain competitive in the global market. 4IR aims to revolutionize industrial production through the integration of information and technology.Additionally, the 4IR production system offers greater sophistication and adaptability, allowing businesses to produce customized products more efficiently. This is a game-changer for industrial countries that rely heavily on manufacturing and exports(Benayoune et al., 2021). Consequently, 4IR offers substantial benefits, such as increased efficiency, productivity, and innovation. Automation and digitization can streamline production processes, reduce costs, and facilitate faster decision-making, leading to economic growth.

Despite concerns about job displacement and skill shifts, there is a lack of research examining the specific impacts of 4IR on employment dynamics in Bangladesh. Investigating the sector-specific implications of automation and technological advancements on job creation, job quality, and workforce reskilling would provide a more nuanced understanding of the socio-economic implications of 4IR.To fully understand the implications of 4IR adoption in Bangladesh, it is crucial to research environmental and social sustainability considerations. While there is a focus on economic growth, studies examining the potential environmental risks, resource implications, and social equity considerations would provide valuable insights for policymakers and industry stakeholders.Addressing these research gaps would not only advance scholarly understanding of 4IR in Bangladesh but also provide actionable insights for policymakers, industry practitioners, and other stakeholders navigating technological transformation in the RMG Industry.

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3. Methodology

The researchersemployed a qualitative field research approach to collect data from the RMG industry of Bangladeshto explore the answers to the research questions of this study. Data was collected from 18 respondents. The data was collected from four RMG factories i.e. 1 from Dhaka, 1 from Narayanganj, 1 from Chittagong, and 1 From Ishwardi EPZ.This study employs purposive sampling because, in Bangladesh, very few garment factories have adopted advanced technologies that promote Industry 4.0. Therefore, the researchers purposefully selected the garment factories that have been using advanced technologies and machines in the production system. The prominent objective for selecting purposive sampling was to explore the impact of Industry 4.0 on production management. The face-to-face in-depth interviews were used to further understand and analyze the impacts of 4IR on the factory management of the RMG industry of Bangladesh.After going through an extensive literature review the project directors prepared a semi-structured questionnaire to explore the impact of the fourth industrial revolution on the production management in the garments factories in Bangladesh. The interviews were scheduled at the convenience of the participants. The researchers prepared and maintained a detailed interview protocol before and during the interview session with the respondents. Each interview lasted between 30 minutes and an hour. During the interview, participants were requested to authorize the mobile recorder to capture their voice. Only one of the participants refused to record his interview session. In such a case, essential points were written down as notes. The data analysis of this study started from the very first interview. After finishing the interview sessions with the respondents, the recorded raw data was transcribed accordingly.However, the data analysis follows a rigorous process to generate themes for this study. For example, this study transcribed the raw recorded data and then identified several codes from the transcription. The codes were then further categorized and finally, several themes emerged. The respondents of this study have been selected from different departments in the factory. The respondents are diversified with gender, age, and experience. The details of respondents' demography are given in the following table 1.

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Table 1: Demographic Profile of the Respondents

Sl. No	Code	Gender	Age	Role	Experience	Education	Study Area
1	WRK1	F	35	Worker	10 Years	Under SSC	Narayanganj
2	WRK2	F	36	Worker	9 Years	Under SSC	Chattogram
3	WRK3	M	29	Worker	5 Years	Under HSC	Narayanganj
4	WRK4	F	35	Worker	8 Years	Under HSC	Chattogram
5	WRK5	F	45	Worker	13 Years	Under SSC	Ishwardi EPZ
6	WRK6	M	40	Worker	10 Years	HSC	Narayanganj
7	WRK7	M	37	Worker	10 Years	SSC	Narayanganj
8	WRK8	F	35	Worker	16 Years	Under SSC	Chattogram
9	WRK9	F	48	Worker	25 Years	Under SSC	Ishwardi EPZ
10	WRK10	M	33	Worker	11 Years	Under SSC	Narayanganj
11	ORM 1	M	39	Operations Manager	10 Years	Masters	Narayanganj
12	ORM 2	F	43	Operations Manager	15 Years	Masters	Chattogram
13	ORM 3	M	37	Operations Manager	11 Years	Masters	Ishwardi EPZ
14	LNM1	M	39	Line Manager	12 Years	Bachelor	Narayanganj
15	LNM2	M	48	Line Manager	32 Years	Bachelor	Chattogram
16	LNM3	M	38	Line Manager	11 Years	Bachelor	Ishwardi EPZ
17	FSV1	F	42	Floor Supervisor	14 Years	HSC	Narayanganj
18	FSV1	F	45	Floor Supervisor	15 Years	SSC	Chattogram

Note: WRK: Worker, **ORM:**Operations Manager, **LNM:**Line Manager, **FSV:**Floor Supervisor

4. Findings and Discussion

The study identified several key themes, including organizational perspectives on precision in the production process and social impacts, organizational and social factors such as intervention on humans and economic considerations, and broader societal and household implications like ethical imperatives, emotional intelligence, and social and human concern. These themes are interconnected and highlight the complex interplay between various aspects of the study's focus.

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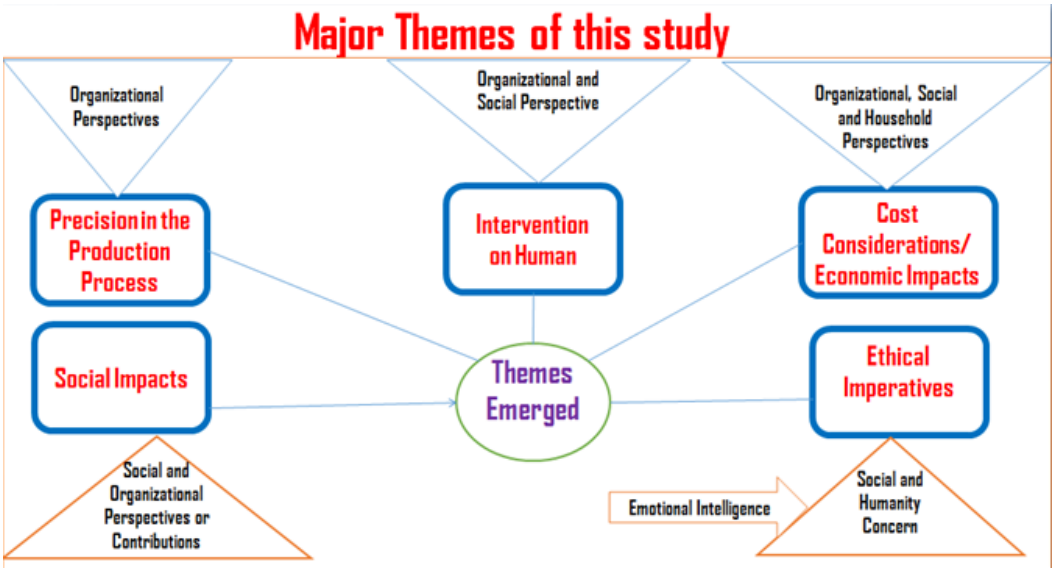

Figure 1: Developed by the Authors

4.1 Discussion of Theme 1: Precision in the Production Process

During the very beginning of the Industrial Revolution, advances in technology spurred tremendous gains in industrial productivity. However, we are currently in the middle of a fourth wave of technical progress.4IRis going to allow the collection and analysis of data across machines, allowing for quicker, more flexible, more efficient processes to manufacture higher-quality items at lower prices. Initially, automation reduces the number of human contacts in any given manufacturing segment. However, it boosts productivity, quality, and cost benefits, resulting in increased growth and employment in apparel businesses. The RMG industry in Bangladesh has been experiencing a change that includes the digitalization of garment production processes. The 4IRproduction system is more adaptable and intelligent, allowing enterprises to produce more customized goods more efficiently. Since the term ‘Industry 4.0’ is frequently used to identify the developing progression in managing production and manufacturing as well as chain production, it is of significant relevance for emerging industrial countries that rely heavily on production and export (Benayoune et al., 2021). Following the discussion and interview, the first theme of this study is precision in the production process and it is further divided into the following categories.

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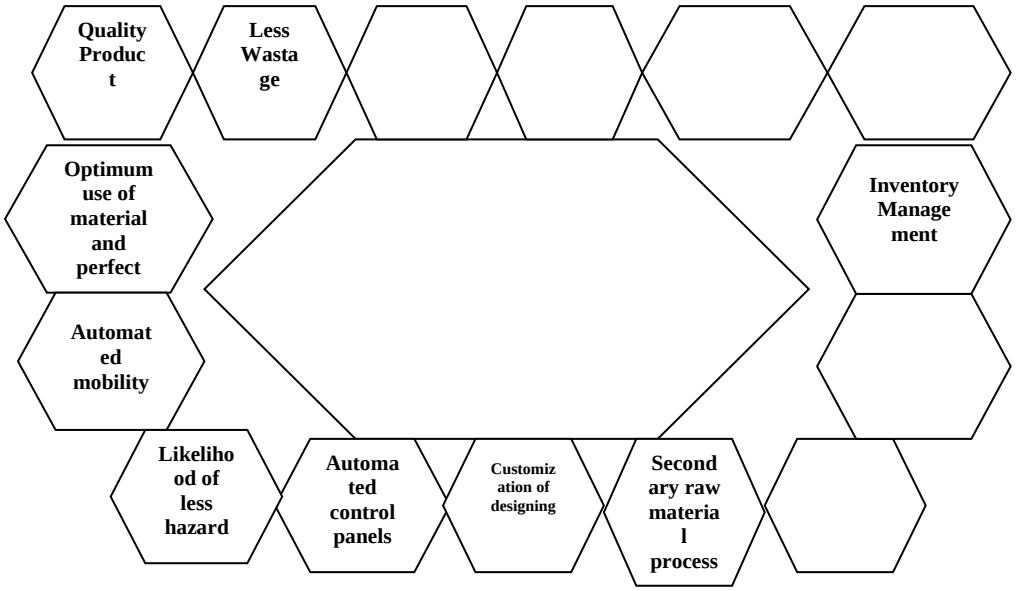

Figure 2: Developed by Authors

The industrial sector has become highly competitive in terms of cost, time, market penetration, and quality. The competition with other countries like China and India in Asia is not only based on productivity but also based on quality (Masud et. al., 2009). That is why it needs continuous monitoring and improvement for mass production. Automation in production systems has caused significant changes in the industry recently.

WRK1 and WRK5 stated

"Product quality is one of the most pressing issues confronting global garment productivity." Quality is determined by characteristics such as fiber qualities, fabric type, weight, thickness, strength, needle count, machine speeds, yarn tension, and stitch per inch. An intelligent system may considerably reduce this issue by detecting future thread breakdowns. In our industry, automation systems have been deployed for continuous quality monitoring and reducing the dominant source of quality loss."

> *In addition to improving accuracy and reducing waste, computer-aided design and manufacturing (CAD/CAM) tools have made it possible for us to compare and contrast designs that have already been done, ideas for designs, and other references. All of these may be combined and analyzed with the use of computers (Sawy, 2016).*

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OM1 discussed that

"Automation brings accuracy. Machines may be designed to consistently create objects or garment parts, resulting in minimal waste. Fabric cutting, for example, is more precise when done by machine because it eliminates the risk of human error that occurs when done by hand. This reduces the possibility of future product recalls, allowing companies to deliver consistent quality to customers."

LNM1 and FSV1 evidence that

"It is true that machines work quicker than humans. Instead of spending hours manually distributing layers of fabric, automated spreading devices can handle up to 90 meters of fabric each minute. As a consequence, lead times are lowered since manufacturers no longer have to wait for manual labor to complete orders."

The genuine leather, fashion accessory, and trim sectors as well as the apparel business are all regarded as components of the worldwide fashion sector (Nayak et al., 2017). The supply chain management (SCM) logistic providers for the apparel and textile industries, retail establishments, and retailers that handle the recycling of used clothing are all regarded as components of the fashionable production process.

ORM2 stated that

"Our industry re-used water in toilets, gardening, and industry by recycling through automation. Wastes are also used in the field for fertilizing the land."

By the statement of FSV1, LM3 and WRK9

"By leveraging automation to consistently hit order deadlines and avoid product defects, manufacturers can increase customer satisfaction, and in turn, their reputation. The greater the reputation, the more customers will flock to a manufacturer with bulk orders."

The labor-intensive nature of textile production is generally accompanied by a high standard of quality. Therefore, in order to meet the high standards for quality, manual operations must be transformed into automated ones. This can be achieved through the use of digital elements, computational tools, and artificial intelligence (AI) (Nayak et al., 2020).

"Linked together to collect and share data, integrated machines are guaranteed to boost factory productivity. By remotely reviewing and collating data such as quality control pass and fail rates, integrated machines help managers make decisions on the go. Managers get to view data for an entire fleet of garment machines at a glance instead of individually, letting them optimize production in a timely fashion" statement by, **W6, W8, and W10**

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Through appropriate inventory management, new technologies may be introduced into the garment production process, resulting in a significant boost in productivity and work quality.

WRK8 and WRK10 ***reveal that***

> *"Automated factories work smarter. Automation affords manufacturers greater control over the entire production process by keeping everything in-house. This enhances factory managers' oversight of production while letting them cut loose from external suppliers that are susceptible to delays."*

The styles and designs of clothing determine the extent of adoption of new technologies and automation in numerous cases. For example, a clothing factory making men's shirts can use automatic equipment for attaching cuffs and collars, which is now commonly accessible at a reasonable price(Nayak & Padhye, 2018).

ORM 2 and LNM2 stated that

> *"As social media increases public awareness of fashion trends, garment manufacturers need to find new ways to keep up. More and more garment manufacturers are looking to manufacturing automation to remain current. For most, the only way to meet demand while cutting costs is to use computerized systems designed to streamline production and handle bulk orders."*

The statement found from WRK3, WRK6, LNM4

> *Machines maintain high productivity levels without tiring the way humans do. Moreover, machines do not require toilet or lunch breaks, sick days, or time for staff handovers at the beginning of a new shift. Machines make products of the same quality even under challenging working conditions, which is impossible for manual workers to achieve. By increasing productivity, heavy-duty automated machines let manufacturers take on bulk orders and enhance overall turnover.*

Automation does not encourage restoring, but it may promote manufacturing site relocation activities at the hubs of global value networks. It boosts productivity, quality, and cost benefits, resulting in increased growth and employment in apparel companies. When automation is successfully implemented in the system, the employment of unskilled personnel is reduced in the long term.

ORM3 stated

> *"We use up-to-date water recycling methods, own electricity supply plan, and produce other supplementary raw materials in one ground."*

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LNM2 and ORM3 evidence that

"Advanced automation systems can also enable textile manufacturers to achieve higher levels of customization, allowing them to produce smaller runs of specialized products quickly and affordably." This is especially critical in an industry where fashion and trends change quickly and organizations must be more sensitive to consumers' wants."

WRK1, WRK3 and WRK5 told the significant of incorporating 4IR that is

"The enhanced uniformity and efficiency of automated technology allows producers to correctly forecast demand and arrange advance orders for raw supplies. Because of advanced planning, manufacturers only buy what they need, eliminating fabric waste from over-ordering."

They also raised the issues of likelihood are less hazardous and stated

"Another significant advantage of automation in the textile sector is safety. Automated machines can do risky jobs such as handling heavy goods or running machinery, lowering the risk of worker harm. Furthermore, automation can assist to decrease the danger of fire and other risks, which is especially significant in textile plants that often employ combustible materials."

Statement by WRK5 and WRK6,

"Automated solutions may accomplish jobs faster, more accurately, and reliably, reducing lead times and speeding up production cycles. As a consequence, Bangladesh's textile industry is able to handle large orders, meet deadlines, and maintain a competitive edge in the worldwide market."

ORM1 given the opinion-

"Integrated machines are sure to increase manufacturing production since they are linked together to gather and share data. Integrated machines assist managers in making choices on the fly by remotely examining and compiling data such as quality control pass and fail rates. Managers may now access data for a full fleet of garment machines at a glance rather than individually, allowing them to improve output in real-time."

4.2 Discussion of Theme 2: Intervention on Human

In a 2016 research, the UN's International Labor Organization warned that as automation increases, some Asian countries could lose over 80% of their jobs in the textile, clothing, and garment industries. Automation is the technique of

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controlling machinery and procedures in industries without the need for human operators by using computerized systems like computers.

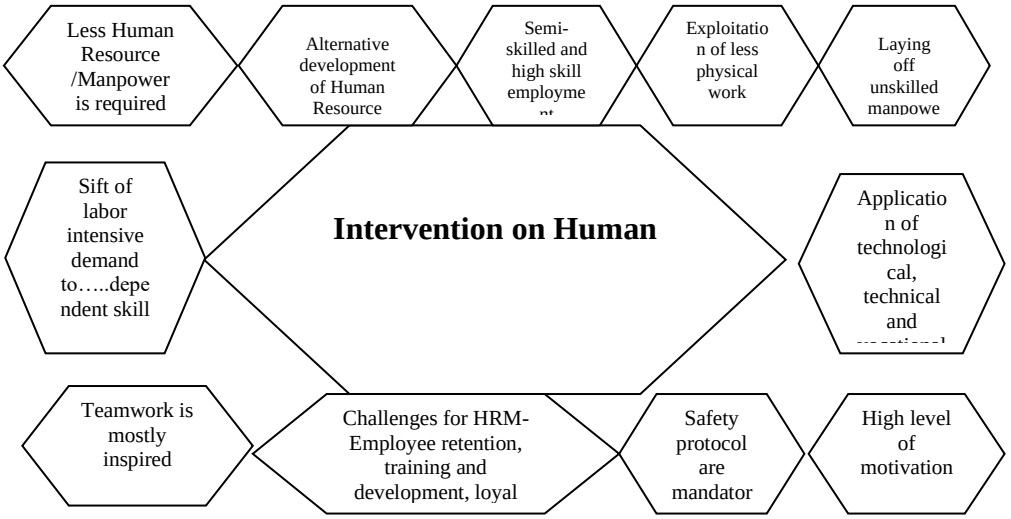

Figure 3: Developed by the Authors

Automation has boosted production while decreasing the need for labor." Many businesses are currently utilizing these technologies. When robot technology transforms into accessible, labor will be further reduced. Many individuals are already seeking new positions in various industries.

LNM1 and ORM 2 discussed

> *"Due to the upfront expenditures of automation adoption, it may want to minimize expenses and shrink its personnel. There are also fears that the speed of automation adoption may outpace the workforce's ability to react, potentially leading to social and economic disparities. Various modern technologies, such as 3D printing, CAD, 3D body scanning, and robotics applications, may require fewer workers."*

Numerous workers are losing their employment as a result of automation. This is considered to be one of the primary causes of the job reduction. Many people do not, however, view it as a threat because; in one way or a different nation this industry employs all of the Bangladeshi workers who are losing their jobs as a result of automation.

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WRK2 stated that

"There is no effective alternative action taken by the factory that gives us fruitful benefits. The lead mental stress"

LNM2 argued that

"We believe that we have limitations but our factory ensureslittle opportunity for the development of employees suffer by the implication of automation. Sometimes we rotated the employees to their suitable place."

"We promote job security by investing in upskilling and reskilling programs that allow their workers to adapt to technological advancements and take on higher-value roles. You combine the strengths of automation with the expertise and creativity of the workforce. There will be some new jobs emerging because of the automation, which will provide employment." As discussed by ***ORM1***

FSV2 and LNM1 evidence shows that

"In our factory, the cutting sector used to employ 150-200 people, but today just 10-12 people utilize automatic cutting equipment. Again, while four people were required to manufacture a rear pocket for jeans, it is now done with one machine. In other words, one operator performs the work of four workers."

Due to continuous automation, several sweater factories had to fire employees because jacquard machines could perform comparable tasks far more effectively and efficiently. Even if only large clothing factories have started adopting AI applications, there is still cause for concern regarding potential job losses in this industry in the future, even though there hasn't been a wide-scale termination of RMG workers yet. Less human labor is needed to operate machines when they are more computerized and automated technology can recognize and (sometimes) resolve problems on its own. This results in unemployment, especially for those who lack skills or knowledge of technology (Akter et al., 2022).

"Many workers may lose their employment as a result of automation, as automated technology may accomplish the work of numerous individuals. As a result, the workers executing the task will be at risk of losing their employment due to automation."

Automation may result in the creation of new jobs in analyzing data, creation of technology, and support.

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ORM1 and LNM2 clearly stated

> *"We predict that this move will widen the gap between those with suitable skills and those who do not, thereby increasing income inequality. While I am not convinced of this, the problem of skills does emphasize the need for increased investment in skills and training as automation increases."*

Interesting ideas are linked to automation. Automation is an autonomous framework of machines that goes beyond the simple technological replacement of human labor. Stone (2016) integrated the idea of automation with a computer-aided system and suggested that drivers will still be needed even with advanced technology.

> *"We know that in the textile industry, fabrics are made from yarn and yarn from fiber. Then dyeing and printing are done to make the fabric more attractive. Every step of it, especially the spinning, weaving, and dyeing process, can be dangerous for anyone. So, automation has created automatic machine equipment to handle most of these processes by securing working conditions for all in the textile industry."* ***Started by WRK4, WRK6, WRK9***

WRK2, WRK4, WRK9 and FSV2 told that

> *"Previously we are working in some critical areas and there is a change of physical damage at any time. By the employment of automation robots automatically did it without any physical damage."*

Supported by ORM2

> *"Automation eliminates or reduces the need for repetitive and physically demanding tasks, improving workplace safety and reducing the risk of injuries associated with manual labour."*

Personnel education and training are essential for success in any endeavor; simply modernizing tech won't produce the desired outcomes (Schumacher, 2001). Organizations 'adaptability, production, competence, safety, and ultimately profit are positively influenced by training (Salas, 2001); the Bangladeshi RMG sector is no exception. Factory owners from this sector realize the importance of training programs; however, to them, in some cases, training is somewhat effective and in others, it does not have any desired impact. A sincere management of compliance might fetch various benefits for the RMG sector, such as minimizing labor unrest, meeting customer demands, obtaining a better quote, decreasing unemployment,

boosting employee morale, raising the quality of the product, enhancing occupational health and safety, making a good impression internationally, and cultivating positive relationships with authorities (Das et al., 2021).

Evidence from ORM 3

> *"We have a number of excellent in-house training facilities in the industry that are used to retain experienced employees in the workplace. Workers are enthusiastic about training and recognize its value in the workplace and at your place of work."*

Leadership in operations and structure is required for automation awareness-raising, gathering resources, and automation. Develop your leadership skills and abilities to keep up with developments and shifts that spur teamwork, and move more quickly than the rate of change (Hensellek, 2020).

WRK3 and LNM3 discussed

> *"automation in the production of garments including fabric inspection, cad & cam, grading, pattern making, fabric spreading and cutting, sewing, pressing, material handling and radio frequency identification (RFID) in a single process. Soteamwork is mostly inspired."*

For the ready-made clothing business to thrive in the global market, automation and factory quality improvement require particular attention. Because automation and a shorter lead time are now essential to the apparel industry's future success. One needs to be up to date on the latest tools and technology to compete. Automation is one such problem at the moment. Thus, the owners of clothing companies have just lately begun utilizing automated equipment in their factories. This Sort of machine-dependent expertise from labor-intensive demand.

> *"The potential for job displacement as machines and robotics replace human workers in repetitive and labour-intensive tasks. This could lead to millions facing unemployment and there would arise a need for deskilling masse so that workers adapt to the changing technological landscape. Technically skilled personnel are required to operate this equipment with modern technology and high quality. So, the demand for skilled textile workers is increasing with automation."* ***As stated by WRK3, FSV1.***

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7.3 Discussion of Theme 3: Cost Consideration/ Economics Impacts

Automation has resulted in cost savings in the apparel industry. By replacing automated technology for labor-intensive operations, the sector has reduced its reliance on physical labor, which may be expensive and sensitive to a variety of labor-related concerns. Automation helps to cut labor expenditures such as wages, benefits, and training expenses. Furthermore, as compared to human work, automated systems consume fewer resources and need less maintenance. As a result of the cost reduction, Bangladeshi apparel makers' profitability has grown.

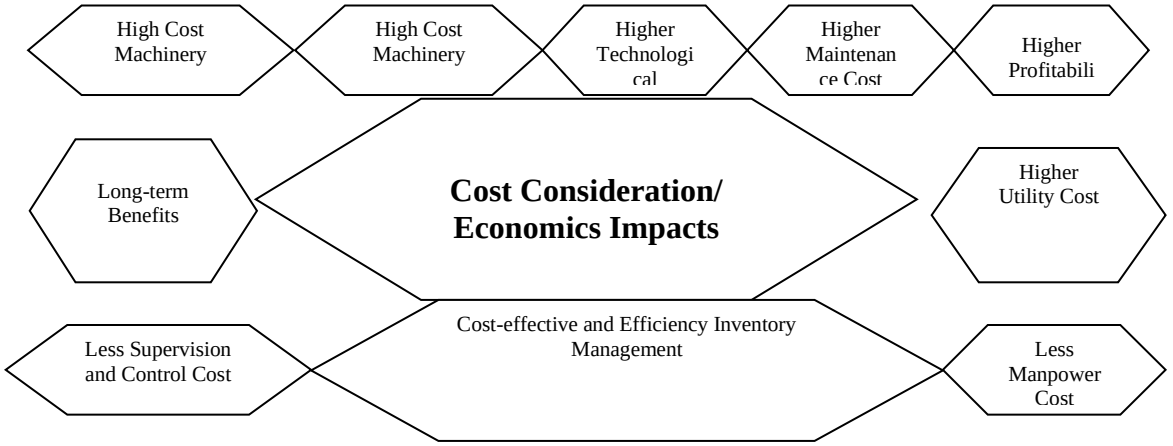

Figure 4: Developed by the Authors

Bangladesh's textile and clothing sector pays less than average wages for labor-intensive occupations that are done by people. But in the case of automation, which calls for expensive apparatus and technology, that is usually the case (Shearer, 2010). Additionally, as more skilled labor is required for the creation of garments with added value, the need for workers will not decrease.

ORM 1 stated that

> *"The initial investment to automate the garment manufacturing process is significant. But, the return on investment in automation technology is very low in the initial days. The net cost savings can be gained in a short period."*

The 4IR is built on nine pillars that aim to reduce costs and delivery time, improve efficiency and productivity, enable customization for customer satisfaction, shift toward environmentally friendly practices to reduce waste and create a sustainable competitive advantage (Sharmin, 2022).

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ORM 3 and LNM 2 discussed

> *"As the current social media-fueled fast fashion trend spreads across the globe, buyers' expected lead time has decreased, creating a significant demand for technology-driven efficiency improvement in the value chain." Sales growth has benefitted industrial players that have used new technologies in their manufacturing processes."*

Labor is a key component of the garment manufacturing process, and the cost of keeping a large number of laborers raises this dependency. The industry occasionally deals with problems related to a lack of workers and high absenteeism. Reducing the demand for human labor in the apparel business can be achieved by implementing automation. Consequently, lower expenses, quicker production, etc.

ORM 3 and LNM 2 discussed

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Thus, the aforementioned Bangladeshi clothing units have seen great benefits from the deployment of these technologies. These industries have seen a decrease in lead times in addition to the enhancement of RMG goods' quality and quantity, which has increased profitability (Hasan et al., 2022).

> ***LNM2 reveals that*** *"we have huge maintenance cost on operating machinery in the floor. The main reason for this cost, most of the machineryis exported from foreign countries and the supplementary equipment is not available at all times. It may hamper regular production."*

Higher Utility Cost 4IRs have made the manufacturing of clothes more efficient, less expensive, more productive, more adaptable, better at predicting trends, and more environmentally friendly. By determining its potential benefits while managing its challenges, such as increased machine and software operation costs (Ahmmed, 2023).

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ORM 1 stated

> *"We considered continuous electrical supply when using technology in our operation. We generate our electricity, which is sometimes more than they need for an unbroken power supply. As a result, we have paid a hefty sum for electricity supplies."*

Manufacturers may now lower labor expenses, improve manufacturing quality and speed, and save production costs thanks to automation. Furthermore, automation has made production processes more adaptable and efficient, enabling businesses to react swiftly to shifting consumer expectations. It is thought that cutting production costs by 30–40% using sophisticated technology also has positive knock-on effects on productivity and lead time.

LNM1 and ORM3 reveal that

> *"We experienced significant improvements in store and cutting system procedures and efficiency after using existing raw materials. Once applied correctly, technology may provide the quickest return on investment (ROI) through greater production, efficiency, and streamlined supply chain management."*

Industries may now make garments more rapidly, effectively, and affordably due to technological advancements. It aids in the generation of less garbage, as RMG is one of the industries in the world that generates the most waste. Excessive manufacturing, driven by great demand for creative patterns, may result in a slew of issues, including increased chemical waste during manufacture and hundreds of tons of garbage from abandoned clothing.

ORM1 stated

> *"Our garment business employs raw materials like textile-related and cuttings, and inventory management can be pricey at times. After technology application, we get inventory management solutions to reduce inventory management costs."*

The garment sector is undergoing a dramatic shift known as the 4IR. This is referred to as Apparel 4.0. It is capable of monitoring businesses using new technologies such as IoT, AI, and cloud computing, as well as delivering services in the manufacturing process with complete neutral delivery. Technology has had a significant influence on the textile and garment industries. A new vista of possibilities has been opened in Bangladesh's garment sector as a result of this revolutionary development (Shabur et al., 2023).

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Statement by FSV2 and LNM3

> *"We recently accompanied new technology that designed an interconnection within multiple technologies, allowing for improved monitoring and coordination with less human interaction. With a single order, automated processes may operate on many parts of fashion design, development, and manufacturing. For that, it saves both money and time in production and operation."*

Since automation takes time, practically every factory has already automated the knitting and washing departments. The swing, the most significant component of RMG, has been used by two-thirds of large companies.

The manual method will be more pleasant for many garment workers. They could have a harder time understanding the procedure when it comes to switching to digital technologies. Therefore, it can lead to lower production in the early going. However, long-term objectives of technology adaptation are far superior to immediate setbacks.

ORM3 told that

> *"We can create patterns using computer software, which saves time and requires very little manpower. Nowadays we are leaning towards computer-aided design (CAD) software, which allows us to easily create patterns of different parts of different garments and save them in computer memory for a long time."*

Supported statement by LNM2

> *"We installed machineries that give us service long time without any major changes. We will usethe previous design by saving data and access information easily."*

4.4 Discussion of Theme 4: Social Impacts

Automation has been transforming the way we work for decades, but recent advances in technology have made it a topic of increasing interest and concern. As machines become more intelligent and capable, they are taking over more jobs and tasks that were once performed by humans. This trend is expected to continue in the coming years, and the impact of automation on society is likely to be profound. On the one hand, automation can lead to increased efficiency, lower costs, and higher productivity. This can benefit companies, consumers, and the economy as a whole. On the other hand, automation can also lead to job displacement, wage stagnation, and growing inequality.

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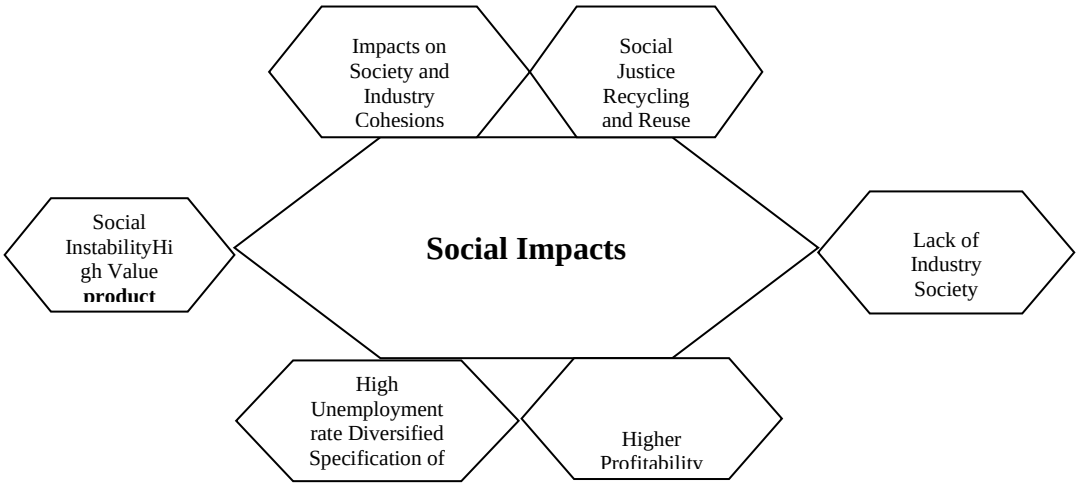

Figure 5: Developed by the Authors

To address automation, it will be important for society to take proactive steps to prepare for the future. This should involve a debate on whether such programs should be implemented at all, and if so, whether proper checks and balances are in place, such as risk, impact, appeal, and accountability procedures (Mann, 2019).This will require a combination of policies, programs, and investments to ensure that workers are equipped with the skills and knowledge needed to succeed.

WRK1 and WRK8 stated that

> *"The nature of work is changing due to automation, and workers will require new technology and skill training. To enable workers to adjust to evolving technologies throughout their careers, this will necessitate investments in education and training programs as well as emerging methods for lifelong learning."*

Added by FSV2

> *"It will be necessary for policymakers to take into account new possibilities for social support and protection. To aid workers who are displaced by automation, this could involve initiatives like income support, pay subsidies, and retraining centers. To ensure that society as a whole shares in the advantages of automation, it might also include new ways of taxation and redistributing."*

The consequences of employing robotic devices to specifically target vulnerable individuals concerning inclusion and social justice. The potential impact of community-driven campaigns and grassroots activity in drawing attention to the

implications automated systems have for people. The community must be included in assessing the social justice and human rights implications of robotic equipment employed in public spaces for public service delivery before its introduction (Mann, 2019).

WRK6 told that

> *"The possible effects of automation on inequality and wages. Machines might be able to carry out jobs that have already been done by higher-paid workers as they develop in capability. As a result, there may be pressure on those workers' wages to decline, and the gap between those who can operate machines and those who can't may widen."*

ORM1 discussed

> *"We know automation displaced all levels of employees. We are trying to ensure that it promotes the well-being of everyone in society, not just the privileged few. We take some policy such as investments in education and training, new approaches to social protection"*

There is no clear consensus on which ideas and practices allow industrial partners and society to develop and sustain mutually beneficial collaborations (Lucietto et al. 2021). Collaboration aids in learning about the effects of autism in society. This should include discussions on whether these sorts of programs should be adopted at all, and if so, if adequate checks and balances, such as risk, impact, appeal, and accountability systems, are put in place.

> *"As workplace automation grows, human employees may need to adapt to new workflows and methods of interacting with automated machinery." Furthermore, the increasing use of technology at work may change the way industry interacts with society." Statement by WRK3*

Pay increases are often seen for workers who can augment new automation and do tasks that robots are not capable of doing.

LNM3 discussed that

> *"Workers who do comparable duties and can be replaced by machines fare badly. In general, automation moves pay away from workers and toward corporate owners, who benefit from increased profits with less labor."*

Automation has the potential to completely transform the way we work and live, but it also comes with several serious hazards and difficulties that need to be

resolved. The loss of jobs is one of the main threats posed by automation. There is a chance that many jobs could be lost as machines and algorithms become more advanced and can carryout tasks that were previously done by humans (Siddiqui &Khurram, 2023)

WRK4 and WRK10 thought that

> *"The majority of owners desire increased productivity at lower costs. Some workers suffer as a result. Especially those who are now forced to compete with the machines after being directly replaced by them. This leads to higher lay off of employees."*

It highlights how the employment of automated technology may assist in perpetuating structural and administrative violence against the socially and economically marginalized (Barbaschow, 2019). Significant social justice challenges are linked with the explicit design of a program utilizing automated technology that targets vulnerable persons experiencing financial difficulties.

WRK5 and WRK6stated by

> *"As a consequence of steadily increasing growth, automation, and control technologies, in particular, have a social influence that is so great that it alters the conventional equilibrium between technology and society and implies new behaviors from both humans and machines."*

Supported by FSV1

> *"Industry initiated automation for their fast production and quality accuracy. This may replace humanswith machines where huge workers are deposed by the industry due lackof advanced technology. It resulted in social unrest but the industry might not be concerned about the issues."*

4.5 Discussion of Theme 5: Ethical Imperatives

Bangladesh has long been recognized for having a large pool of inexpensive labor. Bangladesh's economy has significantly improved due to the contribution of the apparel industry. The industry has reduced the number of people living in poverty, produced a large number of jobs, and supported women's empowerment. One of the main causes of the nation's rise in female labor participation was the apparel industry. On the other side, a significant issue the nation faces is the high percentage of unskilled laborers working in the RMG industry. Because of automation, there is a growing need for skilled labor, which means that unskilled workers are losing out.

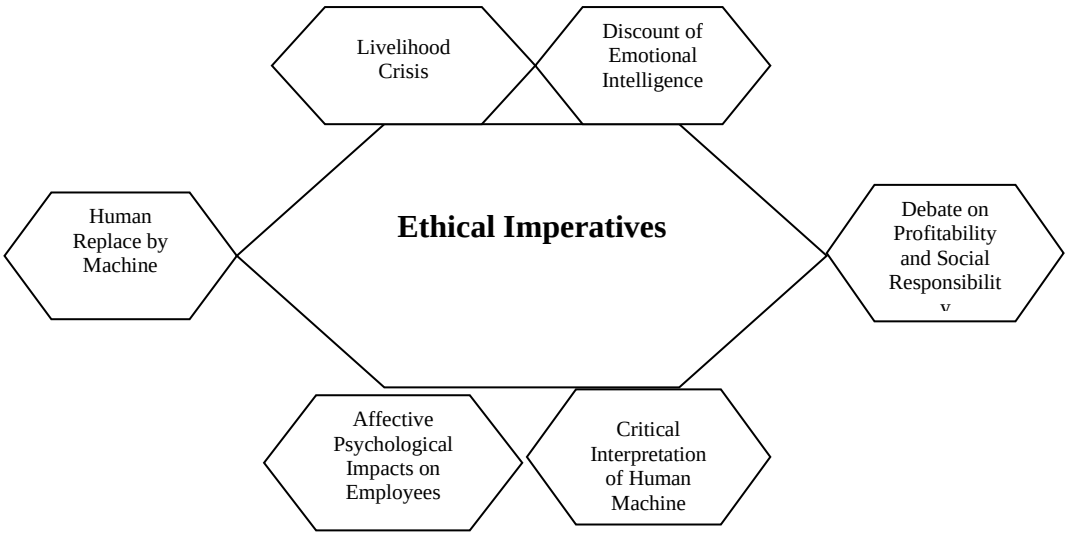

Figure 6: Developed by the Authors

Compliance in the RMG industry is a complex issue influenced by buyer demand, labor regulations, industrial laws, ILO agreements, and worker rights(Ashwin et al., 2020). In Bangladesh, the terms "compliance" and "social compliance" are often used interchangeably, but the former refers to legal frameworks, while the latter emphasizes social accountability. The application of compliance varies significantly in the Bangladeshi RMG industry, as it encompasses both high-quality garments and subcontracts sweatshops, posing unique challenges for ensuring compliance standards are met.

WRK3 stated that

"Youth unemployment and job displacement are issues brought about by automation. Political instability and societal frustration were the results."

Evidence from LNM3

"To guarantee employment retention and help laid-off workers learn new sources of livelihoods, the industry offers training focused on improving and expanding labor market skills."

WRK7andWRK10 discussed

"The displacement is a major consequence of automation. Even while retraining displaced workers for other occupations may have social benefits, the workers whose job has been taken over by a technological device nearly always experience a time of emotional distress"

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Garment compliance difficulties are one of the most serious concerns of foreign purchasers. Typically, reputable international purchasers place orders based on four criteria: quality, price, lead time, and social compliance (Alam et al., 2017). Furthermore, these customers are taking many measures to assure safety compliance and promote supply chain transparency (integrity), including the Accord on Fire and Building Safety and Alliances for Bangladesh Workers Safety. In the context of the Bangladeshi RMG situation, potential human aspects originating from automation are part of the compliance checklist, which is viewed as a coercive force emanating from overseas purchasers.

WRK3 stated that

> *"Automated machinery could operate more quickly and precisely, leading to shorter production cycles and greater output levels. No doubt, this may result in larger profits for companies, which may then help employees by offering better pay and job stability."*

ORM2 argued that

> *"Nothing about this is assured. It's important to keep in mind that Bangladesh's apparel industry contributes significantly to employment there. Because of their ignorance of technology, many fear that automation will result in job losses in Bangladesh's garment sector. Restructuring the educational system and bridging the knowledge gap between it and industry are necessary if we are to reap all of the benefits. To guarantee job retention and help the fired employees locate other sources of income, this would necessitate investments in education and training to improve labor market abilities."*

4IRis critical for manufacturing-dependent countries that are experiencing rapid economic growth as a result of their production of various products and services. As a result, they have been investing in technology that will allow humans to be integrated for the advancement of the production level. Nonetheless, empirical study on the potential of 4IRin Bangladesh has been lacking.

WRK6 discussed that

> *"Automation may also lead to job creation. They said that machines require supervision and wear and tear, necessitating maintenance and repair work. In order to properly use automation, this could lead to the creation of some new jobs."*

Remarkably, a partial automation of the same industry won't end up resulting in a net loss scenario. Mondolo (202) offers an alternate perspective on automation-based job loss, arguing that when all duties of the particular job are outsourced completely, it may lead to a net decline in jobs.

WRK4 worried and said that

> *"Our job may be significantly affected by the introduction of automation and artificial intelligence. The majority of workers are afraid of new technologies and are tans about losing their jobs. We are worried about our job lasting. As a result, it may have an impact on our mental and physical health."*

Automated technologies accomplish a particular work more efficiently, correctly, cost-effectively, and reliably than human operators and are projected to eventually replace at least the majority of them. Automation entirely replaced the human component in certain systems, but just partially in others. However, given varying degrees of automation and value addition in industries, the concept of a clean sweep replacement of human operators is disputed (Parasuraman, 1997).

Evidence found from FSV1

> *"Technological implications lead to layoffs and job cuts because workers are replaced by technology and robots. They agree that automation has the potential to replace certain tasks and jobs traditionally performed."*

ORM3 and LNM2 added

> *"We create new jobs in the service sector and divert some of the workers to the service sector that reduces losing the job of our employees."*

5. Implication, Limitation, and Future Research Agenda

The study highlights the impacts of 4IR on the factory management of the RMG industry in Bangladesh emphasizing the potential for improved efficiency, flexibility, and customization. This transition is characterized by the adoption of digital technologies and automation to enhance productivity and quality while reducing costs.Automation in the apparel industry is leading to a reduction in the demand for traditional labor-intensive tasks. This implies a shift in the required skill set, with a growing need for skilled workers capable of operating and maintaining automated systems. Consequently, unskilled laborers may face challenges in finding employment opportunities within the industry, necessitating

strategies for retraining and upskilling to mitigate potential job losses.Automation has resulted in cost savings for apparel manufacturers in Bangladesh, leading to increased profitability. However, the study underscores the importance of considering the broader socioeconomic implications of automation, including its potential effects on income inequality and job displacement. Policymakers and industry stakeholders need to address these challenges to ensure that the benefits of automation are equitably distributed across society.The impacts of Industry 4.0 especially in the garments industry werelimitedly explored before. The findings of this study will significantly contribute to the existing literature and develop the theoretical perspectives for production and factory management in the high-tech era. Therefore, it will open paradigms for many scholars, researchers, academics, and students in the field of operations management.

The study emphasizes the importance of maintaining competitiveness in the global apparel market, particularly in terms of cost, quality, and time to market. By embracing 4IR technologies, Bangladeshi manufacturers can enhance their competitiveness relative to other major players in the region, such as China and India. This underscores the need for continued investment in technological innovation and process optimization within the industry.The RMG industry has played a crucial role in Bangladesh's economic development, contributing to poverty reduction, job creation, and women's empowerment. However, the shift towards automation poses challenges for vulnerable segments of the workforce, such as unskilled laborers. Balancing the benefits of automation with the need to ensure inclusive growth and social welfare remains a critical consideration for policymakers and industry leaders.The findings of the study highlight the importance of proactive policy interventions to address the challenges and opportunities associated with automation in the apparel industry. This includes investing in education and skills development programs to prepare the workforce for the jobs of the future, as well as implementing supportive policies to facilitate the adoption of 4IR technologies while mitigating potential negative consequences for workers. Additionally, fostering collaboration between government, industry, and other stakeholders is essential to promote sustainable and inclusive growth in the sector.

Acknowledgment

This study was funded by the University of Rajshahi, Bangladesh. The authors are grateful to Md. Shawan Uddin, PhD, Associate Professor, Department of Management Studies, University of Rajshahi for his data collection support.

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