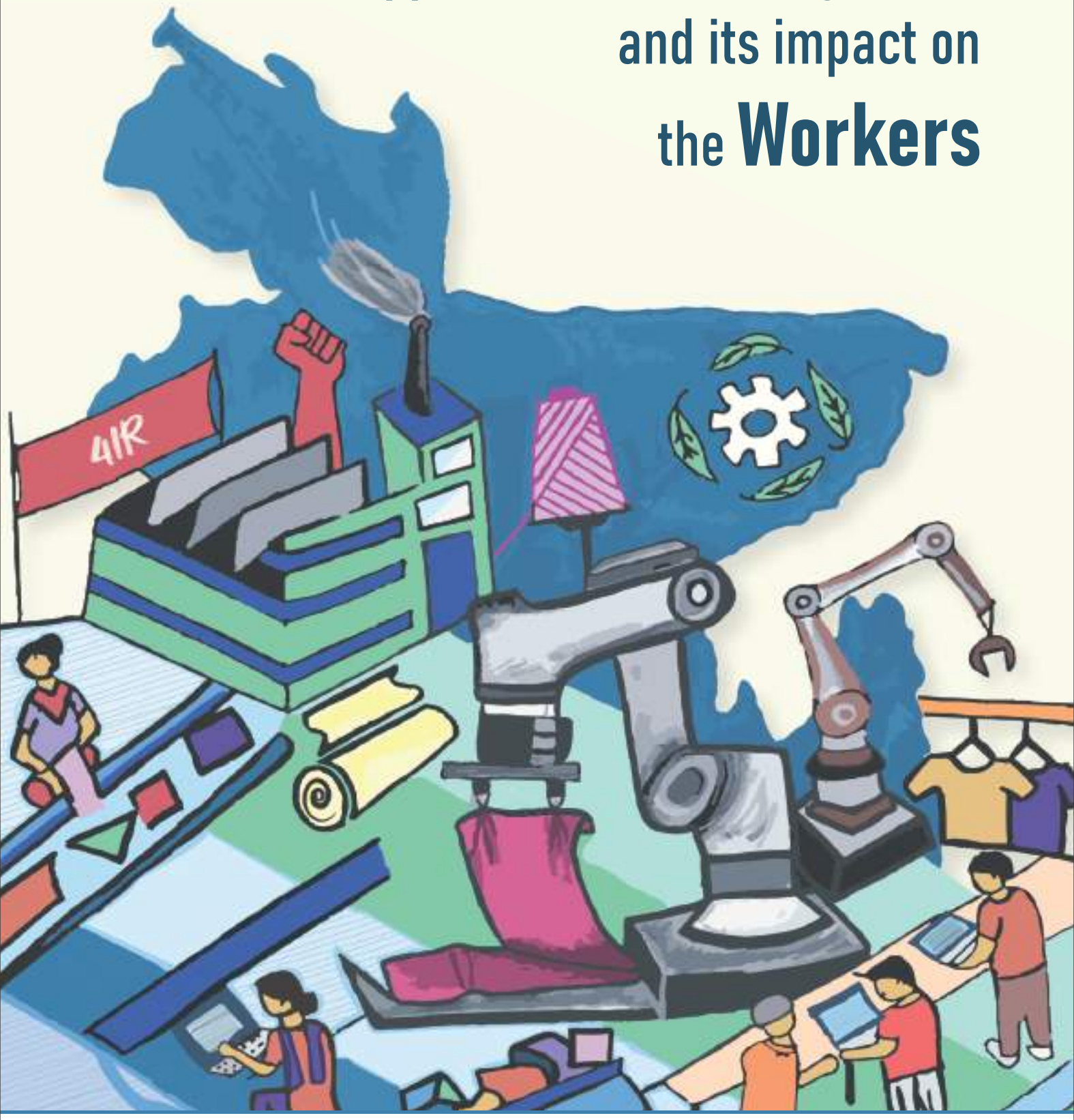
Technological Transition in Apparel Sector of Bangladesh and its impact on the Workers



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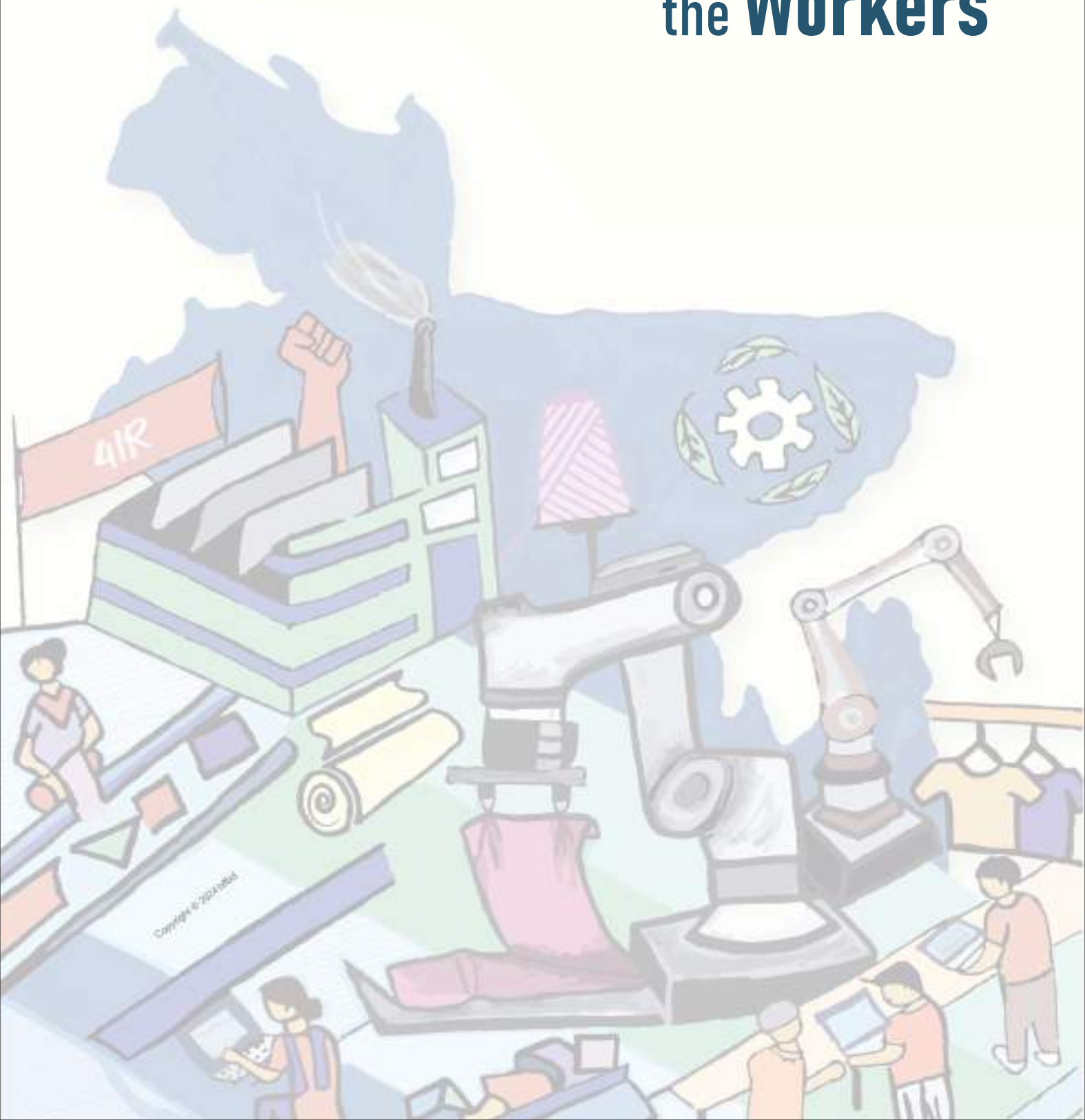

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Preface

As the global apparel industry increasingly adopts new methods and technologies to boost efficiency, productivity, and competitiveness, the integration of automation has become essential for Bangladesh to maintain its position in the global market and drive further growth. Understanding the ongoing transformations within the country's apparel sector and addressing the challenges associated with implementing automation are crucial. In this context, the following study on automation in the Bangladesh Apparel industry, based on data collected between August and October 2024, has been conducted by BRAC University, funded by the Bangladesh Labour Foundation (BLF) with the support from Solidaridad Network Asia.

The specific objectives of this project are: (a) to explore the current status of technological transition and automation in the apparel industry, (b) to understand the impact of automation on garment workers and its effects on workers' livelihoods, and (c) to evaluate the readiness of the stakeholders towards technological transition and automation. To investigate these objectives, a survey of 429 workers was conducted from Dhaka, Gazipur, and Narayanganj, 26 key stakeholders participated in in-depth interviews, and four FGDs of workers were executed.

In response to the sustainability of the Bangladesh apparel industry through upgrading technology and automation, I hope this study will provide an opportunity for policymakers to understand the status of automation in this sector and its impact on the factories and the workers. By exploring the challenges of automation, the government and other key stakeholders will be able to address these challenges based on evidence and take adequate actions to mitigate the problems. The information on what type of skills is required and how the training structure can be developed will benefit all the stakeholders involved in this industry.

In summary, this study aims to contribute valuable insights to the ongoing discourses on advanced technology, innovation, and sustainable development. We aspire to lay the foundation for a more informed and effective approach to achieving a 'Just Transition' and creating a sustainable and socially just apparel sector that aligns with SDGs 5, 8, 9 and 10.

With Thanks

AKM Ashraf Uddin
Executive Director, BLF

Acknowledgments

The research team would like to acknowledge the Bangladesh Labour Foundation (BLF) for pursuing research on the impact of automation in Bangladesh's apparel industry. The team sincerely appreciates BLF for funding this study and complying with the research team at each and every step. Special acknowledgments must be made to Mr. AKM Ashraf Uddin, Executive Director of the BLF, for his sincere commitment to launch this study. Moreover, the successful completion of this research would not have been possible without the continuous assistance from other key BLF team members, particularly Md. Mohinuddin, Research Lead, and Yasin Arafat, Senior Programme Officer, for their invaluable support in reviewing and providing feedback to finalize the report.

Understanding the production process and application of technology and automated machines in various stages of production was pivotal to designing this research, ranging from the formation of a questionnaire to the execution of the survey. Without constant advice from Mr Shamsul Haque, an experienced and senior factory manager, it would have been incredibly challenging to make progress in the study. His relentless efforts have become a key cornerstone of the project. We remain immensely grateful to Mr Haque.

At the same time, the project team would like to express gratitude to Mr. Hasan Mahmud and Mr. Abdul Wahab Chowdhury for their kind cooperation and support in sharing information relevant to the research and connecting it to the resources. Such a humble and proactive contribution from them is highly appreciable.

We extend our gratitude to the workers for their participation in the survey and FGDs. This project also acknowledges the contributions of our key informants, whose powerful and expert insights into the current state of the industry illuminated our project. A special thanks go to Mr. Sifat Islam Ishty for connecting us to the stakeholders and Shaan for formatting the report. Furthermore, the contributions of brands BGMEA, BKMEA, and DIFE have been integral to our study, for which we are extremely thankful. Finally, the research team acknowledges the survey coordinator, Fahad and Waliullah, and the survey enumerators for their relentless efforts in conducting the fieldwork.

Research Team
Brac University, December 2024

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Abbreviations

4IR	Fourth Industrial Revolution
BLF	Bangladesh Labour Foundation
BGMEA	Bangladesh Garment Manufacturers and Exporters Association
BKMEA	Bangladesh Knitwear Manufacturers & Exporters Association (BKMEA)
CAD	Computer-Aided Design
CBT&A	Competency-Based Training and Assessment
DIFE	Department of Inspection for Factories and Establishments
HREDD	Human Rights and Environmental Due Diligence
JIT	Just-In-Time
MFS	Mobile Financial Services
NSDA	National Skill Development Authority
RFID	Radio Frequency Identification Devices
SAM	Standard Allocated Minutes (inferred from context)
SANEM	South Asian Network on Economic Modelling (full form inferred)
SMV	Standard Minute Values (inferred from context)
SPI	Stitches Per Inch (contextually inferred from CAD usage)
Tk	Bangladeshi Taka
UNGP	UN Guiding Principles on Business and Human Rights
VSM	Value Stream Mapping (contextually inferred)
WIP	Work-In-Progress

Executive Summary

The ready-made garment (RMG) sector in Bangladesh stands at the cusp of a technological revolution, driven by the imperatives of Industry 4.0 and global market competitiveness. This study, commissioned by the Bangladesh Labour Foundation (BLF) and conducted by BRAC University, assesses the current status of automation within the apparel sector and analyzing its multifaced impact on workers' livelihoods, skill requirements, and economic conditions.

Conducted across Dhaka, Gazipur, and Narayanganj, the research examines the automation processes within garment factories. The study identifies a dual impact of automation: while it enhances productivity, efficiency, and global competitiveness, it simultaneously introduces significant worker displacement, increased production targets, gender disparities, and wage stagnation. Notably, women, unskilled, and older workers face heightened vulnerability. Despite some positive outcomes—such as reduced physical strain and increased skill acquisition—automation has led to job polarization, income disparities, and insufficient access to formal training, especially for female workers.

The study concludes that the sector is not adequately prepared for a just and inclusive technological transition, due to structural limitations, financial constraints, digital illiteracy, and the absence of coordinated policies. It calls for a collaborative strategy among factories, brands, trade unions, and the government to ensure ethical automation that protects and empowers workers.

Keywords: RMG sector, automation, technological transition, Industry 4.0, worker displacement, gender inequality, Bangladesh, just transition, digital skills, labour rights, upskilling, wage stagnation, manufacturing innovation, ethical sourcing.

Bangladesh is the second highest RMG exporter in the world after China, contributing 10.35% of the national GDP and 84.58% of the country's exports in FY2023. Bangladesh is now home to 61 of the top 100 highest-rated LEED-certified factories in the world, with 229 LEED-certified green factories. The world is now shifting towards a technological transition like 4IR. However, the technological transition brings out drastic changes in the industries like RMG, textiles, etc., posing challenges for the workers (i.e., job loss, skills, decreased overtime, etc.) as well as manufacturers (i.e., investment, training, productivity, alternative jobs for the workers). Considering this, the Bangladesh Labour Foundation (BLF) commissioned this study on "Assessment of technological transition in apparel sector of Bangladesh and its impact on the workers," with the support of the Solidaridad Network Asia, which was conducted by BRAC University between August and October 2024. The research utilized mixed methods: Surveys of 429 workers from Dhaka, Gazipur, and Narayanganj, Key Informant Interviews (KIIs) with 26 stakeholders and 4 Focus Group Discussions (FGDs) with workers.

Status of Automation: The status of automation is still at a low to medium level, far behind the advanced system seen in any other industries around the world, while the score was 2.5 to 3 out of 5, where 0 means no automation and 5 refers to complete automation. Aligning with this, the study conducted by LightCastle Partners (2024) also stated that Bangladesh is still in the early stages of adopting automation in manufacturing, with a high-tech intensity of just 1.9 compared to China (63.7).

This study explores that out of the 10 stages (from spinning to shipment) only 3 phases are fully automated which are spinning, dying, and finished fabric preparation. It highlights those backward operations, such as spinning, are fully automatic. The advanced level of automation was not found in the manufacturing stage. The sewing section, where the majority of workers are employed, is still semi-automated, and Industry 2.0 dominates this process.

Beyond the production stage, automation has taken place in the system and data management. Technologies in the system have initiated digital IDs, fingerprint scanning, mobile payments, IoT-enabled systems, and streamlined processes such as attendance tracking, quality monitoring, and resource management. Data automation enables manufacturers to track production metrics, energy use, and maintenance schedules in real time, support Just-In-Time (JIT) operations and reduce waste.

Impacts of Automation: Automation brings both positive impacts and challenges for both the workers and manufacturers. It is considered a business case for the manufacturers, but it brings financial burdens as well. This study has explored the impact of automation on factories, such as higher production and less time, better quality, efficient tasks, top-notch design, more accuracy, the increased pace of work, less labour, fulfilment of consumer demand, competitiveness in the global market, survival in the market, maximization of profit, trouble-free operation, scaling up worker performance and mitigate increased wage cost. It is observed that the official capacity of automated machines is about 200 pieces per hour, while a factory using manual machines can only make 50 to 60 pieces per hour.

Based on in-depth interviews with senior management of 10 factories, it is also mentioned that the efficiency was increased by 3% to 5%, optimized production was possible, reduced work in process, attained maximum manpower utilization and saved manpower, achieved better visibility and communication, improved customer service (fast response) and reduced of operator motion time. Regarding spreading fabric, the factory requires only 1 worker instead of 7 (by the manual process), which saves $1020 in labor cost, and the payback time is 4 years. In addition to this, three workers are attaching welt pocket now with new machine which was done by seven workers with manual machine that saved also $850 of labour cost. It is also found that a factory has increased productivity per hour from 90 to 140 and reduced rejection from 10% to nearly 0% after introducing the Back Moon machine to produce knitted polo shirts.

Workers are also trying to adapt to automated and semi-automated machines, and mentioned some benefits; for example, 85% of surveyed workers reported reduced physical strain, particularly in knitting tasks, with notable productivity gains from automated machines. The number of errors has reduced by more than 50% with automation, which is statistically significant. Most of the interviewed workers agree automation has helped achieve production goals (96.74% of the respondents) due to the significant reduction of alteration and rejection and increased safety (97.67% of the respondents) because of the avoidance of using scissors manually.

Automation has simultaneously created opportunities for skilled positions in machine operation, programming, and maintenance. With the advent of automation, workers are increasingly required to operate both basic machinery and more advanced automated systems, making them more versatile and empowered. About 79% of the interviewed workers believe that if they leave now and join another factory, their salary will be increased due to the skills attained after automation. Another significant finding is that workers are having more leisure time by which they

are spending time with family, household chores and child caring etc. Regarding this, most of the women workers work in sewing section where automation has increased their family time (77.71% of the respondents) and they can also spend more time in household chores (75% of the respondents). Most importantly, enhancement of skills by operating non-manual machines have empowered the workers.

Challenges: Although technological transition brings several positive impacts on workers, this also poses significant challenges to workers, especially women, aged, less literate, unskilled, and confident workers. The sweater factory saw the highest percentage of worker decline, with 37.03%, and the woven factories recorded a slightly lower decline of 27.23% worker decline per line of production. On the other side, the cutting production process has seen the highest percent of the decline in workers (48.34% per worker per line), and the sewing process shows a lower reduction (26.57% per worker per line). Overall, the total decline in workers across processes is 30.58% and the majority of them were helpers. Less workers are required in factory due to automation and the study illustrates displacement of workers in the industry which raises question about 'Just Transition.'

Among the displaced workers due to semi and automated machines, some workers lost jobs and some were moved to other sections with new roles and positions and trained to be operators. Replacement in the other sections, is commonly seen in the large factories only while others can't afford. As factories rely on automation, workers are finding that their previous skills are no longer as valuable, creating concerns about job security. In recruitment, technical knowledge and skill are required. Now, to get recruited with a higher level of education, a worker also needs to finish a body or process in 6 minutes on average, regardless of the production type that requires high skill; previously, it was 11 minutes. Another concern is the integration of automated systems comes with higher productivity targets and stricter performance monitoring, which can create an environment of pressure and anxiety. The study found that the production target has increased to 64.21% and the workers have to take more pressure.

In addition, it has greatly impacted livelihood since the workers have limited overtime now, and the wage structure has not upgraded that much considering the competency. It is noted that when a worker changes a machine once, their income increases by Tk. 278 similarly knowing one extra process in a machine can increase the monthly salary by Tk.118 only. This highlights the fact that the more machines or processes a worker can operate, the more they earn monthly, but this amount is not adequate. While automation has enabled workers to operate multiple machines or processes, the increase in responsibility has not translated into proportional wage growth. Male workers who operate more advanced machines and manage several processes, such as Kansai or Jacquard, often earn slightly higher wages (Tk.15,000/month vs Tk.13,500-14,000 per month for others). One connection between income and automation that this study has explored is that the higher the operation of a machine, the higher the income level. One of the most significant impacts of automation has been the reduction in overtime hours. Weekly overtime has dropped from an average of 20 hours to 11 hours, largely due to faster production cycles enabled by automated machines. This directly affects livelihoods and family life, with negative impacts driven by low income and rising inflation rates. While the factories have benefited significantly after the use of advanced technology and machines, there has been no significant rise in the income of the workers after this technological transition.

From the gender context, it is found women workers are more vulnerable due to a lack of technical skill, and 62% of workers stated that women were replaced- either by being reassigned to different roles or, in some cases, losing jobs. Scenario is that, female operators typically know how to operate fewer machines, often sticking to just one, while 50% of male operators know how to operate at least two machines. Male operators also excel at managing multiple processes on the same machine, averaging 3.5 processes compared to 2.91 processes for female operators. Gender inequality is also visible in upper-level production roles like CAD operations which is dominated by male workers. For males, income increases about TK.1,848 for the knowledge of more than one machines, indicating that handling additional machines reflects higher skill level rather than a specific timeline for machine changes.

This transition has also led to job polarization, particularly in mid-level roles. Many tasks previously handled by mid-level employees can now be performed more efficiently by automated systems and software. Limited access to training is another challenge for workers, as 41.28% mentioned that they did not receive any formal training, which is a serious concern, especially as the industry becomes more automated. For those who do get formal training, most of it happens during work hours (46.79%), putting more pressure on them. This lack of proper and consistent formal training leaves many workers feeling unprepared and worried about their job security. It is also evident that female participation in both formal and informal training is comparatively low.

Readiness to Automation: Whether a factory will embrace automation or not, it depends on different critical factors apart from a direct positive impact on productivity. Usually leading factories do a cost-benefit analysis of labour cost versus automation. In most cases, the factories argue that the labor cost, although the minimum wage has increased, is still the lowest compared with Vietnam, the competitor of Bangladesh. The factories that cannot afford expensive machines do not see the use of labor with the manual machines as a major obstacle to doing business. The other determinant factors are design of garment, expectations of brands and the current skills of workers.

It is explored that automation has not been paid attention to at a broader scale compared to factory building safety and environmental sustainability. The factories are not yet ready as the cost of implementation of technologies and automation is quite heavy and access to finance has become a big challenge. This financial strain has been worsened by the long payback periods associated with automation, which only larger factories with more resources can manage. There has also been a shortage of skilled technicians who can maintain and repair these automated machines. Some manufacturers have faced resistance to automation from mid-level management on several occasions. It is the opinion of a few factories that this reluctance could slow automation's implementation. Some staff in mid-level management have been working for many years and do not want any change.

Alongside the automation's financial cost, another crucial factor of attracting educated workers, particularly women, is becoming harder. There are no structured training facilities for the workers to run automated machines. Although the workers believe that they have the skills to operate current machines, which are not difficult to learn, the factory management argues the majority of workers do not have the skills to manage all the processes involved in one machine and lack knowledge of operating multiple machines. They have noticed deficiency in digital literacy, understand apps, basic knowledge on Computer, English, and Mathematics among the workers.

The common practice of training in automation and advanced technology is that a team of machine suppliers come to the factory to lay out and set up the machines and sometimes, if required, offer training to the workers about the operation of the machines. Such type of training is arranged in an informal manner for a very short period of time – one or two days.

This situation indicates that the sector is not ready to adopt automation efficiently and with a longer vision, and the same applies to all rights holders.

Recommendations

A coordinated approach from factories, training institutions, brands, buyers, business associations, government, and development partners are key to ensuring automation benefits everyone in the industry.

Manufacturers/Suppliers

- Develop a strategic plan for sustainability to ensure a just transition for workers and smooth business operations.
- Establish structured training facilities (inhouse or outside the factories) for skilling and upskilling workers and mid-level management, in partnership with training institutes or consultancy firms so that workers can be replaced to other sections.
- Ensure timely information sharing with workers to prevent panic and conduct counselling sessions to reduce workplace stress and fear of adopting new machinery.
- Offer motivation packages to engage workers in the learning process and reward those who enhance their skills with new machinery.
- Introduce internship programs in collaboration with Technical Education Institutes to attract future talent to the industry.

Brands and Buyers

- Ensure responsible business conduct (RBC) and ethical trading practices.
- Conduct impact assessments to evaluate and update the social and economic effects of automation on workers and suppliers.
- Collaborate with suppliers, trade associations, trade unions, and governments on transparent, inclusive automation strategies.
- Design and fund training programs to help workers adapt to new technologies or transition to new roles.
- Ensure fair wages, safe working conditions, and labour rights are maintained throughout the automation process.
- Commit to long-term contracts and adjust pricing structures to offset automation costs for suppliers.
- Work with suppliers to minimize layoffs by focusing on reskilling/upskilling and redeployment within the supply chain.

Trade Unions

- Coordinate and collaborate with employers, employers' associations, brands, Government, and CSOs to initiate structured capacity development program that equip workers with skills for new roles in automated environments.

- Advocate with the government and other right holders to develop and implement policies like a just transition that protects workers during technological shifts.
- Ensure that decisions about automation are communicated openly and that the approaches are participatory, where workers and their representatives are consulted on automation strategies.
- Ensure women are not disproportionately affected by automation, rather provide additional support for women workers during the transitional process.
- Push for stronger social safety nets, including unemployment benefits, pension schemes, access to affordable healthcare and education, etc.
- Engage for greater accountability from global brands to ensure their supply chains remain ethical and comply with global labour and human rights standards amidst automation

Government

- Develop a National Plan of Action on just transition prioritizing workers welfare that includes job creation, skill development, and social security for those affected by the automation.
- Strengthen labour laws and protection to address challenges posed by automation and ensure fair benefits and compensation for displaced workers.
- Provide access to finance for technology upgradation, green infrastructure, and advanced machinery, especially for small and medium factories.
- Strengthen the National Skills Development Authority (NSDA), National Occupational Safety and Health Training and Research Institute (NOSHTRI), and other public and private Technical Training Centres (TTC) and Technical and Vocational Education and Training (TVET) to offer demand-based skills training for workers and mid-level management.
- Develop upskilling and reskilling programs specifically tailored to the needs of female workers, emphasizing technical, digital, and managerial skills to upgrade their current grades, which may further lead them into supervisory roles.
- Foster inter-ministerial collaboration (MOLE, MOI, MOF, MSW) for inspections, job creation, guidelines, social security, and related services.
- Enhance regular inspections through DIFE to minimize job loss and ensure worker benefits.

Chapter 1 Introduction

1.1 Background

The apparel industry began to take shape in the 1960s, with its first significant exports occurring in 1965. Since then, it has evolved dramatically. The "Made in Bangladesh" tag has also brought glory for Bangladesh, making it a prestigious brand across the globe. However, by FY24, the apparel exports experienced a 5.22% year-on-year decline, amounting to $36.15 billion, where woven contributed $16.87 billion and knitwear accounted for $19.28 billion. This sector remains a cornerstone of the economy, contributing 81.29% of the country's export earnings and 7.87% to the GDP. Bangladesh's apparel products are exported to over 150 countries, with key markets including the USA (14.91%), Germany (10.17%), the UK (9.43%), Italy (7.59%), and France (4.56%) (EPB, 2024). This sector alone directly employs nearly four (4) million skilled, semi-skilled and unskilled workers. Around 4000 export-oriented factories are in operation which started its journey in Bangladesh in the early 1980s, whereas the male and female ratio of workers is now 43:57 and 1100+ subcontracting apparel factories support raw materials. However, over 60% of skill gap exists in the RMG sector, ranking 2nd highest (BIDS, 2023) & Bangladesh ranked 123rd in Global Competitiveness Index (GCI, 2023). In addition, Per Hour Labour Productivity Level is $5.9 which is lower than other competitors like Vietnam ($6.4) and India ($7.2) but higher than Cambodia ($3) (Nomura & Kimura, 2022).

The apparel sector is experiencing technological change through the adoption of strategies like Quick Response (QR), which includes Just-In-Time (JIT) activities and Computer Information Usage (Kincade & Regan, 1994) . This transformation is largely driven by the adoption of Industry 4.0 technologies, which include automation such as 3D printing CAD, CAM, RFID, IoT, and AI, which enhance supply chain efficiency, reduce costs, and improve transparency (Z. H. Khan et al., 2023; Mohamad et al., 2022). These technologies facilitate real-time data management, automate production processes, and optimize inventory control (Khan et al., 2023). This shift enables businesses to achieve economics of pace and reach, alongside traditional economies of scale (Itagi, 2024). Since the industry is reliant on traditional manufacturing processes which is being now challenged by the need for innovation and technological upgrading to remain competitive against nations like China and India, which are rapidly advancing their technological capabilities (Khan, 2008; RMG Bangladesh, 2024). However, the skills and expertise required by 4.0 are not present in the current workforce. When the automation takes place many of the works that used manual force will shift to automated machines (Salman et al., 2023). This would affect the workforce who have been largely relying on the traditional method of production. According a recent study, it is projected that by 2041, approximately 5.38 million jobs in these sectors in Bangladesh are expected to be at risk, with the RMG industry being the most vulnerable, facing potential job losses for 2.7 million workers, or 60% of its workforce (a2i, 2019). Several researchers anticipate that unskilled workers might be replaced by workers skilled in operating modern technologies like robotics, AI and the IoT, and thus increasing unemployment (Salman et al., 2023).

Under the current circumstances, we can conclude that the compliance cost has gone up to fulfil the global commitments on labour rights. There has been uncertainty about meeting up this cost because productivity remains low in this sector and the buyers' prices have been declining over time. One way to address this inconvenient situation could be upgrading of initiatives in workplaces. A key aspect of upgrading has been looking at how firms can learn through their participation in value chains (De Marchi et al., 2018) and consider upgrading as a process or an outcome (Khan et al., 2020). The technological transition through automation in factory has been an upgrading model for some of the suppliers. As the apparel sector worldwide is implementing new methods and technologies to increase efficiency, productivity, and competitiveness, embracing automation has become critical for Bangladesh's ability to sustain in the global market and enhance its growth. In this context, what is missing in literature is limited studies on the impact of automation on apparel sector and its effect on the workers. Therefore, with Bangladesh as the world's second biggest garment exporter, it is critical that we understand what transitions are occurring in the country's apparel sector and address the current status, readiness level and challenges of implementation of automation, with its implication on workers and their livelihoods.

1.2 Objectives

The primary objective of this study is to assess the technological transition in Bangladesh's apparel sector and its impact on workers. The specific objectives of this project are:

- To explore the current-status of technological transition and automation in the apparel industry
- To understand the impact of automation on garment workers and its effects on workers' livelihoods
- To evaluate the readiness of the stakeholders towards technological transition and automation

1.3 Importance of the Study

This research study on the impact of automation on workers is crucial in the context of several global and national commitments and obligations. At the global level, the study contributes to the Sustainable Development Goals (SDGs), particularly Goal 5 on gender equality, Goal 8 on decent work, Goal 9 on industry, innovation and infrastructure and economic growth and Goal 10 on reducing inequalities. These global commitments are designed in such a way that they uphold labour rights. Nationally, the study addresses the country's development goals for 2030 and 2041. Ensuring the sustainability of this industry is crucial for Bangladesh to maintain its preferential market access, such as the GSP+ status, and its transition to a Middle-Income country by 2026.Understanding the gendered impacts of automation is important for addressing power dynamics and promoting gender equality in the industry. It is also relevant to gain the goals of National Women Development Policy 2011 (Ministry of Women and Children Affair 2011) as apparel has been portrayed as a wheel of women empowerment model in Bangladesh.

Most importantly, this study is crucial for Just Transition which ensures that the shift to automation and new technologies occurs in a fair and inclusive manner. One of the key components of Just Transition is the upskilling and reskilling of workers to equip them with relevant skills in an increasingly automated industry. A recent study by the World Economic Forum (2023) estimated that by 2025, nearly 50% of all employees worldwide will require reskilling due to technological

advancements. In Bangladesh, the absence of structured skill development programs could lead to increased unemployment, particularly for low-skilled garment workers. This study will provide early insights into industry readiness, existing skill gaps and the impact of automation on workers' livelihoods, which are important for designing an updated and demand-driven skill development curriculum. The findings will support the National Skills Development Authority (NSDA) in its mission to enhance workforce capabilities and ensure that workers remain employable despite technological advancements. It will also help finalize the National AI Policy, which aims to promote innovation, sustainable industrial growth and economic transformation to achieve the vision of a "Smart Bangladesh" by 2041. On the other hand, Just Transition requires strategies for social protection, retraining and fair labour policies to prevent job losses and worsening working conditions due to automation. As automation leads to job displacement, the study will help identify necessary social protection mechanisms, including unemployment benefits, job security, reemployment strategies and creating alternative job opportunities. This research will provide recommendations on how social safety nets can be effectively implemented to safeguard worker welfare and economic stability. This will also help the trade union leaders to prepare themselves and for evidence-based advocacy for workers' rights.

Furthermore, Bangladesh's export market competitiveness is closely linked to labour rights and sustainability. Many global consumers, buyers and policymakers are pushing for stronger labour protections and responsible business practices in supply chains. Ensuring that technological transition does not exacerbate inequalities or worker vulnerabilities is crucial for maintaining preferential trade access, such as the GSP+ status in the European Union where eligible countries have to implement 27 international conventions on human rights, labour rights, the environment, good governance. Thus, Human rights and environmental due diligence (HREDD), which originated from United Nations Guiding Principles on Business and Human Rights (UNGPs) and the OECD Guidelines, is a major concern that the study is relevant with. As companies expand their operations beyond national borders, many exploit weak labour protections in lower-income countries, leading to human rights violations and exploitative working conditions. As automation poses significant risks to employment, wages and working conditions, particularly for low-skilled workers, many garment workers, especially women, are at risk of displacement if they are not adequately reskilled to adapt to emerging technologies, which will eventually lead to business losses and economic decline. With proper planning and intervention, we can reduce existing inequalities and increase job security for millions of workers in the sector. This study is essential in understanding how automation is transforming the sector and assessing whether the current workforce, industry stakeholders and policymakers are prepared for these changes. By analyzing the status of technological transition, its impact on workers' livelihoods and the readiness of stakeholders, this study provides critical insights for policymakers, employers, industry leaders, trade unions and development partners to prepare themselves to align with HREDD standard leading to worker's protection and industry growth.

Chapter 2 Literature Review

2.1 Industry 4.0 and Automation in the Apparel Sector

The fourth industrial revolution, or Industry 4.0, is the broad term used to describe new technologies. This notion was included in many policy packages following the Great Recession. These two notions are sometimes misunderstood as the fourth industrial revolution is an umbrella term for changes that will influence society as a whole through political systems, culture, ways of communicating and living. Rather, Industry 4.0 is a narrower idea that applies only to the industrial sector (Anzolin, 2021).

Industry 4.0, which was officially recognized at the 2011 Hannover Trade Fair, combines industrial processes through networked sensors and equipment, resulting in a seamless merging of the physical and virtual worlds (Kagermann et al., 2016; Mohamed, 2018). Currently, Industry 4.0 refers to a broad spectrum of technology developments aiming at increasing production, efficiency, and process autonomy. As the majority of the supporting technologies are still in their early years, an accurate definition of Industry 4.0 is still conclusive.

Industry 4.0 is significantly transforming the apparel sector through the integration of advanced technologies such as the Internet of Things (IoT), robotics, and big data analytics, enhancing operational efficiency and innovation. The systematic literature review highlights the strategic importance of these technologies, which facilitate vertical integration, flexibility, and supply chain optimization, ultimately leading to reduced operational costs (Monteiro et al., 2024). Industrial robots are increasingly utilized for repetitive tasks, improving productivity while necessitating workforce retraining to mitigate job displacement concerns (Lázár, 2024). In developing economies like Sri Lanka and Bangladesh, the adoption of Industry 4.0 remains limited, with challenges including inadequate infrastructure and low digital integration levels (Kulandaivel & Bandara, 2024; Mim et al., 2024). However, a proposed roadmap for adoption emphasizes workforce development and strategic planning as critical steps for successful digital transformation (Kulandaivel & Bandara, 2024).

Nayak & Padhye (2018) mentioned different types of automation have already arrived and adopted in the apparel sector in their book titled 'Automation in Garment Manufacturing', is shown in the table (Nayak & Padhye, 2018).

Table 1: Different Types of Automation in the Apparel Sector

Automation in Fabric Inspection: Invention of online automated inspection systems has mitigated the major issues related to quality control as human error has often led to inaccuracies and inefficiencies in the inspection process.	**Sewing:** Sewing is mostly manual, but some factories use robots for speed. New robots handle specific tasks, while others aim to sew entire garments. These robots have limitations in fabric types and require special techniques. 3D sewing might be the future for complex, high-quality clothes. **Example:** Sewbo robot, developed by Zornow (which costs $35,000), can make a T-shirt in just 4 minutes.

Design and Prototyping: 3D scanners can help create better fitted clothes using digital models to modify garment designs and quick sampling.	**Use of radio-frequency identification:** Clothes tags with chips (RFID) can track garments real-time. This helps factories manage inventory better by streamlining supply chain management using automated sorting systems. For instance, tags on fabric bundles can show what kind of fabric it is, the style, and colour.
Fabric Handling and Cutting: Automated machines can now precisely spread fabric layers and cut out garment pieces with minimal waste.	**Pressing:** Ironing clothes in garment factories is a tough, manual job usually done by men with high turnover. While some fancy pressing robots exist, most factories haven't adopted them.

On the other hand, another study titled 'Automation in RMG sector: Impact on Employment through a Gender Lens' showed the comparison between Human Labour vs. Automation in the Apparel sector that is illustrated in the following table (Sarwar & Raihan, 2024).

Table 2: Comparison between Human Labour and Automation

Human Labour	Automation
Manual Manufacturing Processes: Production relies on manual skills, especially with the hands of workers for tasks like cutting, sewing, and finishing clothes.	**Increase in productivity:** It is estimated that 40 to 70 percent of labour time can be reduced through automation.
Technical Proficiency: Proficiency in garment manufacturing techniques, such as stitching, embroidery, and pattern-making, as well as knowledge of industry-specific processes and standards.	**Increased inventory turnover:** Rapid production cycle of fast fashion, growing a competitive edge over other manufacturers.
Adaptability: Human labour offers flexibility in responding to changing market demands, fashion trends, and production requirements, adjusting to variations in garment styles, sizes, and specifications.	**Replacement of repetitive and monotonous work:** new machines shape, cut, and attach belt loops simultaneously, saving time, labour costs, and reducing errors.
Emotional Intelligence and Communication: Needed to navigate diverse people coming to work in the industry from different socio-economic backgrounds and age groups.	**Achieving Manufacturing Consistency:** Minimizing product and batch variability, leading to higher quality standards and reducing the need for rework activities.
Cost-Effectiveness: Bangladesh's point of advantage comes from its large production capacity at a low price and acceptable quality.	**Performing jobs beyond human capability:** Advanced sewing machines, such as Juki machines, can automatically sew buttons and create buttonholes.

Human Labour	Automation
Quality Control: Human workers can visually inspect and assess the quality of finished products with precision and accuracy, ensuring that only high-quality garments are shipped to customers.	**Reduction of direct human labour costs and overheads:** Automation has reduced the number of labourers by 50-60% and in some cases up to 90%.
Socio-economic Considerations: Employing human labour in the RMG industry contributes to job creation and poverty reduction in Bangladesh.	**AI can help in predicting fabric properties and fabric fault detection:** A new method breaks down fabric images into “cartoon."

2.2 Technological Transition in the Apparel Sector

The apparel sector, particularly in Bangladesh, is undergoing a significant technological transition driven by the principles of Industry 4.0. This transition is characterized by the integration of advanced technologies that enhance production efficiency, quality, and responsiveness to market demands. The introduction of automation in manufacturing processes has revolutionized the apparel industry. Automated sewing machines and robotics, commonly referred to as "sewbots," are being utilized to perform repetitive tasks with precision and speed. This shift not only increases productivity but also reduces labour costs and minimizes human error in production processes (Saha, 2018). The concept of smart factories is central to Industry 4.0, where interconnected machines communicate with each other to optimize production workflows. This integration facilitates seamless information flow across various stages of production, from design to delivery, enhancing overall productivity and reducing time-to-market (See, 2019). Technological advancements are also promoting sustainability within the apparel sector. Automation and smart manufacturing practices contribute to waste reduction, energy efficiency, and better resource management. For instance, technologies such as 3D printing and digital fabric printing minimize material waste compared to traditional methods (Gökalp et al., 2018).

The current dominance of developing countries in the apparel sector has been due to their comparative advantage, lower labour, and material cost. Because of this renowned apparel brands offshore and reshore their production processes from developing nations. However, widespread technological advancement is lowering labour costs, which may result in developing countries losing their competitive edge and changing the trend of global outsourcing and offshoring (McKinsey & Company, 2018). Moreover, as the textile industry is particularly labour intensive, industry 4.0 and automation has sparked fear among factory employees as they expect to lose their jobs (Withana Appuhamilage, 2022). A key aspect of technological unemployment in the apparel industry is highlighted, stating that computer technology replaces routine tasks but enhances executive roles requiring creativity and problem-solving (Autor et al., 2003).

A study titled ‘Innovation and firm performance in developing countries: The case of Pakistani textile and apparel manufacturers’ reveals that product innovation increases labour productivity and growth, with vertical information flows from overseas clients and suppliers have a substantial impact on a firm's ability to innovate (Wadho & Chaudhry, 2018). On the other hand, Vashisht & Rani (2019) found that 80% of the employment in this industry are routine and theoretically

automatable. Kucera & Barcia de Mattos (2019) presented a situation involving the Italian firm MAICA. The organisation implemented a system in which workers hand-fed the textiles into machines that broke down the shirt, dividing the process into individual parts. This semi-automated strategy may serve as a transitional stage to complete automation, or it may be the most successful gradual method of adopting technology in the industry. A study by the European Commission (Fana et al., 2024) investigated how technological advancement and automation affect employment in the garment and footwear sectors of Germany, Indonesia, Mexico, Romania, and Spain. The findings identify substantial barriers to automation, such as technological difficulties and costs. The literature review indicates that research on the economic and labour market impact of automation technologies have not reached a consensus on the net employment impact of the usage of robots and other technology. Some studies are optimistic about the outcome of automation, while others have a pessimistic or ambiguous outlook towards it.

While Industry 4.0 presents substantial opportunities for the apparel industry, it also poses challenges that require careful management to ensure sustainable growth and competitiveness (Tiwari & Roy, 2024). A recent study shows that 'the overall maturity level for IR 4.0 adoption in the Bangladesh textile and apparel industry is 1.91 on a 5-point scale, indicating a low adoption level' (Mim et al., 2024). Another study stated that Bangladesh is still in the early stages of adopting automation in manufacturing, with a high-tech intensity of just 1.9 compared to China (63.7) (LightCastle Partners, 2024).

About 80% of garment factory owners in Bangladesh plan to invest in automation within the next two years, anticipating over 13% growth in the sector However, this shift raises concerns about unemployment, as only 500 of the average 2,250 workers per factory are expected to engage with automated processes (TBS Report, 2024). It means, less than one-fourth percentage of current workers are expressed to be involved with automation process. Also, 93% of garment factory operators in Bangladesh are willing to work with automated technologies, with 70% of female workers expressing interest in gaining new skills for operating modern machinery (Daily Sun, 2024).

While automation promises increased efficiency and productivity, it also necessitates urgent upskilling initiatives to mitigate its impact on the workforce. According to recent study, it is found that floor supervisors and pattern makers could face the loss of 10,000 positions, with another 10,000 jobs in quality control, production planning and merchandising potentially disappearing as well. Moreover, even high-skilled roles are not exempt from the risks posed by automation. Positions such as fashion designers, CAD-CAM operators, portfolio developers, and production controllers are projected to see an additional 10,000 job losses. In addition, the machine-to-human work ratio, which stood at 44 percent to 66 percent in 2022, is expected to shift to 57 percent and 43 percent, respectively, by 2035 (NewAge, 2025).

Since the first industrial revolution, there have been concerns that automation will replace workers in the textile and garment industries (Parschau & Hauge, 2020). Although technological transition initially causes job displacement however automation historically creates more long-term employment rather than the short-term displacement (Moro et al., 2019). For example, during the first industrial revolution, machines replaced 98% of all human contacts in the textile sector. This greater productivity resulted in lower product pricing, which raised demand for clothing items to the point that total weaver demand outpaced total job displacements (Bessen, 2016).

A recent study titled 'Automation in RMG sector: Impact on Employment through a Gender Lens' mentioned the following status of automation adoption in the apparel industry of Bangladesh (Sarwar & Raihan, 2024).

Table 3: Automation Adoption across the Apparel Sector

Automated Knitting and Yarn Management • **Mohammadi Group:** Their knitting process is fully automated. • **Envoy Textiles:** A denim manufacturer that leverages robotics to boost production and product quality for effective yarn management.
Precision Dyeing and Chemical Dispensing • **DBL Group:** Has adopted automated systems for dyeing and chemical dispensing, ensuring accurate use and minimizing waste. In the sewing lines, they use energy-efficient servo motors rather than conventional clutch motors and an Eco Booster, a cutting-edge heat recovery device that cleans itself automatically. They also use Auto Dosing for controlled measures of chemicals to achieve optimum results.
AI-powered Fabric Optimization • Beximco Group utilizes Thread Sol software with AI to optimize fabric utilization, reducing waste.
Advanced Printing Technology • Robintex Group, a German-Bangladesh joint venture, boasts the world's fastest single-pass digital printing machine for high-quality AOP printing, which has reduced lead time by 2-3 weeks, and the company can ship orders within 4-5 weeks.
Productivity • Team Group, with their LEED-certified factory implemented a semi-automated production line. This approach has resulted in a significant boost of 10-15% in productivity, time management, and cost-effectiveness. • Masco Knitting, part of the Masco Group, utilizes a combination of advanced software-supported circular and rib-knit machines. This ensures their production capabilities remain up-to-date and meet the ever-changing demands of the industry

2.3 Challenges and Opportunities of Technological Transition in Bangladesh

The integration of automation within apparel industry offers a dual spectrum of potential advantages and challenges. Automation holds the potential to replace specific tasks and job roles, potentially resulting in workforce displacement. In response, workers will need to adapt by acquiring new skills and undergoing re-skilling initiatives to align with this evolving landscape. Additionally, the advent of automation threatens to erode the bargaining power of workers, disproportionately affecting women workers (LightCastle Analytics Wing, 2023).

About 62% of the RMG workers in Bangladesh operate machines at work. Financial payback on automation is around five years in Bangladesh (in comparison to around 1.5 years in China (RMG

Bangladesh, 2023). Competitors are significantly ahead, with India utilizing SewBot technology, Vietnam employing Cobots for repetitive tasks, and global brands like Uniqlo adopting robotic cutting technology in Vietnam. Meanwhile, China is advancing with smart clothing, automated manufacturing, and the use of robotic arms (Sarwar & Raihan, 2024). Moreover, the high upfront costs of advanced technologies like 3D printing and Augmented Reality might make them less accessible for Bangladeshi manufacturers compared to competitors with potentially larger budgets. On the other hand, Bangladesh's apparel industry has traditionally focused on being a low-cost producer. This might lead to hesitation in adopting expensive automation solutions (Sarwar & Raihan, 2024).

The transition to automation also demands a workforce with higher skill levels. Many current workers lack the training required to operate advanced machinery or engage with new technologies, resulting in a significant skill gap. Addressing this issue requires targeted training programs to equip workers with the competencies needed to adapt to the automated environment (Khan, 2019; Raj, 2021). A study conducted by BIDS (2023) found that the apparel industry struggles with 60% of skills gaps among the RMG workers, while it ranges from 48% (woven industry) to 69% (knitting industry) (The Business Post, 2023). Also, Workers lack expertise due to continuous advancements in machinery. While 68% of RMG workers received training, nearly half (44%) had only 1 day, and just 13% trained for 6 months (Fibre2Fashion, 2023). While automation offers numerous benefits for the apparel industry, it also necessitates careful management of its social and economic consequences to ensure an equitable transition for workers. Automation is also not strategically planned; new machines are acquired based on immediate needs (LightCastle Analytics Wing, 2023b). However, automation also presents significant challenges, particularly concerning its impact on the workforce. A study by A2i and ILO (2019) projected that 60% of apparel workers are vulnerable to job loss by 2041. The possible number of job losses in the apparel sector by 2041 is shown below. (a2i, 2019).

Table 4: Possible number of job loss by 2041

Occupations	Job Loss
Sewing operators who operate single needle lockstitch machine, double needle lockstitch machine, single and double needle chain stitch machine, Sewing Machine Mechanic (Level 1): Skills which can be acquired with short modular and focused intervention and thereby enhancing the employability of those with minimal education.	500,000
Floor Supervisor, Pattern Maker (Level 2): Skills which require technical training inputs, knowledge of complex operations and machinery, skills of supervision, floor supervisor, pattern maker fall under this category	10,000
Pattern Making for Knitwear, Quality Control, Production Planner, Merchandiser (Level 3): Skills which require long drawn preparation as demonstrated by the acquisition of degrees and involve highly technical capabilities	10,000
Fashion Designer, CAD-CAM Operator, Portfolio Developer, Production Planner and Controller (Level 4): Skills which are highly specialized and require research and design.	5,000

As machines increasingly take over tasks traditionally performed by humans, many low-skilled workers face unemployment or reduced job security. This shift has led to wage stagnation or even declines in some cases, placing additional economic pressure on workers who depend on garment manufacturing for their livelihoods (Textile Focus, 2023). A study reported that automation has replaced human labor in several processes, including pattern making, fabric spreading, lay cutting, and stitching tasks, across woven and knitwear factories. The sweater industry has seen extensive use of automated knitting and lining machinery (Hoque et al., 2022). While automation promises growth in exports, high initial investment remains a significant barrier. Other challenges include top management's lack of awareness about automation benefits and a shortage of skilled workers to operate advanced technologies (Parschau & Hauge, 2020).

A study by the South Asian Network on Economic Modelling (SANEM) and Microfinance Opportunities (MFO) revealed that only a small proportion of workers had exposure to automation, often limited to incremental technological upgrades. A 2022 survey found that 85% of employees experienced increased workloads after receiving new devices, yet 71% reported no change in income, possibly because the new equipment made tasks easier, as workers noted (GWD, 2022). Automation also reduces workers' bargaining power, disproportionately affecting female employees. However, the adoption of automation is expected to generate new job opportunities within the industry.

Large garment manufacturers have been early adopters of automation, leveraging improved efficiency to meet demand swiftly and diversify product offerings. In contrast, small and medium-sized enterprises (SMEs) face significant hurdles in adopting automation, primarily due to financial constraints and dependence on subcontracting. This reliance limits their negotiating power and profitability. A recent study by World Bank (2021) found around 35% of firms and 50% of SMEs are facing difficulties in access to finance, adopting new equipment, machinery, software or processes which is a major constraint for technology adoption in Bangladesh. Without automation, many SMEs struggle to remain financially viable, emphasizing the need for increased financial support and government intervention to facilitate technological upgrades in smaller garment firms (Gu et al., 2021).

Conversely, automation offers the potential to enhance efficiency and productivity, resulting in increased output and shorter production cycles. However, it does not necessarily translate to higher wages or job security, especially for female garment workers, as the majority of workers are at risk of losing their jobs. Given this transforming landscape within the RMG industry, it becomes imperative to prioritize the development of a highly skilled workforce adept at operating and maintaining automated systems. Achieving this goal will necessitate strategic investments in training and skill development to bridge existing gaps and prepare the workforce for evolving roles. Furthermore, market-driven efforts are essential to challenge prevailing perceptions regarding women workers' capabilities and their willingness to engage with advanced equipment (LightCastle Analytics Wing, 2023). Moreover, this transformation is largely driven by the need for efficiency and competitiveness in a global market increasingly focused on quality and speed. Automation technologies, such as robotic systems and advanced machinery, have drastically improved productivity within the apparel sector. Factories can now complete tasks more quickly and with greater precision, significantly reducing lead times and allowing for the fulfillment of larger orders (Posh Garments, 2023; Textile Focus, 2023). For instance, automated cutting machines have reduced the workforce required in cutting sections from 150-200 workers to just

10-12. In addition, the implementation of automation has enabled manufacturers to cut production costs by approximately 30-40% (Raj, 2021). This reduction is crucial for maintaining profitability in a competitive market.

Automation also minimizes errors, leading to fewer defects and waste during production. Automated quality control systems enhance product consistency and quality. Technologies like on-loom imaging allow for real-time assessment of weaving quality, which helps in early detection of issues and minimizes waste (Posh Garments, 2023). The ability to produce high-quality garments quickly has made Bangladesh an attractive sourcing destination for international brands. Automation has allowed manufacturers to meet strict quality standards and respond swiftly to changing consumer demands, thereby boosting exports and attracting foreign investment (BTJ Desk Report, 2024; Posh Garments, 2023).

A recent study titled 'An Overview of the Ready-made Garment (RMG) Sector of Bangladesh: From Origin to the Current State of Pinnacle" highlights that Bangladeshi apparel management anticipates initial financial losses from adopting automation but views it as a long-term investment that could expand business opportunities and create new job roles. Many factories plan to retrain or redeploy displaced workers, sometimes continuing to use outdated technologies. Overall, it is believed that automation will not lead to a net loss of jobs. Automation decisions by factory owners are driven by the desire for cost savings and efficiency, especially in repetitive tasks often performed by low-skilled workers who are more vulnerable to job displacement. Despite recognizing the critical role of training in successful automation adoption, most large apparel companies lack in-house training facilities and depend on external providers (Akter, 2020).

Light Castle Partners in collaboration with policy Exchange Bangladesh, pointed out the following threats and opportunities of Automation in their recent report titled 'Strengthening Bangladesh's RMG Industry for the Future of Work' (Light Castle Analytics Wing, 2023a).

Table 5: Threats and Opportunities of Automation

Threats	Opportunities
Skill Gap: As automation advances, there is a growing need for workers with technical skills to operate and maintain automated systems. The existing workforce may require reskilling to meet these demands.	**Skills Development:** To address job displacement, there is an opportunity for the government and policymakers to invest in skills development, education, and training to prepare workers for new roles in the service sector.
Impact on Working Conditions: While automation can improve safety by automating dangerous tasks, it may also lead to concerns about job quality and the nature of work for garment workers.	**Improved Job Quality:** Even though the quantity of jobs may decrease, automation may improve the quality of jobs in the RMG sector, offering safer and more skilled positions.
Production Efficiency: Automation can enhance efficiency and productivity, but it may not guarantee higher wages or job security for workers, depending on how the benefits are distributed.	**Higher Efficiency:** Automation can lead to higher production efficiency, resulting in increased profitability for businesses, which could potentially benefit workers through improved wages and job stability.

Threats	Opportunities
Potential Unemployment: According to reports by a2i, a substantial proportion of garment workers (approximately 60%) could potentially face unemployment by 2030 as a consequence of automation, which carries severe socioeconomic implications. The introduction of automation is diminishing the bargaining power of workers, with a disproportionate impact on women workers.	**Economic Diversification:** The advantages of automation present an opportunity for economic diversification and expanding our export portfolio into higher value-added industries, including pharmaceuticals and consumer electronics. With a focus on skills development, this diversification effort can also contribute to the creation of more employment opportunities for our workforce.

In summary, while automation presents substantial opportunities for the Bangladeshi Apparel industry, it also brings about several challenges. These include high initial investments, limited training infrastructure, skill gap, and adverse effects on workers. To overcome these barriers, a comprehensive approach involving industry investment, worker upskilling, and supportive government policies are essential to ensure a fair and sustainable transition.

Chapter 3 Methodology

This study employed a mixed-methods approach, integrating quantitative and qualitative data collection techniques to provide a comprehensive understanding of the current status of automation, its impact on workers, and the readiness of the Bangladesh Apparel sector for technological transitions. The methodology was carefully designed to ensure representation from various stakeholders, including workers, factory management, buyers, and trade unions.

Face to Face Interviews: A structured survey was administered to 429 workers across factories located in Dhaka, Gazipur, and Narayanganj. These regions were chosen for their prominence in Bangladesh's APPAREL industry. The survey sample was designed to ensure diversity in:

- Factory Types: Knitwear, woven garments, sweaters, and jeans factories (indicated in table 01)
- Location areas: Dhaka (divided in three regions-inner parts of Dhaka, Ashulia, Savar), Gazipur, and Narayanganj (highlighted by table 02)
- Experience Levels: Less experienced, moderately experienced, and highly experienced workers (highlighted by table 05)
- Gender Representation: Male and female workers to capture gender-specific insights (represented in table 04).

The survey collected data on several key indicators:

- Workers' experiences with automation, including exposure to automated processes.
- Perceived impacts on productivity, job roles, wages, and skill requirements.
- Challenges faced in adapting to automation, particularly for women.

The sampling strategy ensured that responses represented both small and large factories and varied levels of automation adoption. We determined the sample size required for the population 3,006,318 with a margin of error of 5% by using the modified Cochran's formula for finite population (Cochran, 1997). First, we calculate the ideal sample size for infinite population, then we use that to calculate the sample size for finite population.

The formula applied is:

$$n_0 = \frac{z^2 * p * (1-p)}{e^2}$$

$$n_0 = \frac{(1.96)^2 * 0.5 * (1-0.5)}{(0.05)^2} \cong 385$$

Here, n_o = Sample size

Z= z-score (for 95% confidence level)

P= Estimated proportion of the attribute present in the population (0.5 used for maximum variability)

e^2= Desired level of precision (Margin of Error 5%)

$$n' = \frac{n_0}{1 + \frac{z^2 * p'(1-p')}{e^2 * N}}$$

$$n' = \frac{385}{1 + \frac{(1.96)^2 * 0.57'(1-0.57)}{(0.05)^2 * 3006318}} \cong 385$$

Here, n' = Sample size

Z= z-score (for 95% confidence level)

P'= Proportion of female workers in the garments factories (57% female workers)

e^2= Desired level of precision (Margin of Error 5%)

According to Cochran's modified formula for finite populations and considering normal distribution, the sample size required for a population of 3006318 workers with a margin of error of 5% is 385 workers. For this study we have surveyed 429 workers which is above the required minimum worker sample size. Most of the workers were selected from Gazipur (220) followed by Dhaka (181) as these two areas have the most amount of apparel factories and highest density of workers. Dhaka is categorized into three areas: Inner city (which includes Bagan Bari, Khilgaon, Matir masjid, Rampura, Dhaka Uddyan, etc.), Ashulia and Savar. The data was also collected from workers in different processes. 77.39% of workers worked in the sewing, 11.66% in cutting followed by 6.06% in knitting and 4.9% in finishing section which is highlighted by figure-3.

It is also important to note that in the tables and figures in the following sections whenever there is a comparison between manual and automated machines, this study is not indicating that these events are taking place at the same time. All the analysis and statistical tests are done upon the assumption that manual machine era is the worker's responses based on how the events were back in the time of the dominance of manual machines in their factories. While for different workers this time period may vary slightly, but overall, the assumption, based on the KIIs is that manual machine time period is before 2018 and the automated machine time period is post 2018. It is also crucial to note that the impact of automation on worker is analysed by only examining the workers in the production floor.

Key Informant Interviews (KIIs): To gain in-depth insights into automation trends and challenges, 26 key informant interviews were conducted with key stakeholders. The KIIs used a semi-structured format, allowing flexibility to explore each respondent's unique perspective.

Table 6: Stakeholder Groups for KIIs

Stakeholder Groups	No. of KIIs
Government	3
Development Organisation	1
Local and Global Training Institutes	2
Trade Unions	5
Trade Associations	2
Suppliers/ Factory Management	10
Brands/ Buyer	3
Total	**26**

Focus Group Discussions (FGDs): Four focus group discussions were held with workers in Gazipur, Ashulia and Savar to delve deeper into their experiences with automation. Discussions were organized based on gender and skill levels to ensure inclusive representation. The FGDs explored workers' perceptions of automation's impact on their roles and job stability, training availability and challenges in adapting to new technologies.

Case Studies: Four case studies were conducted to provide illustrative examples of automation's impact. One case study was on leading factory with significant automation adoption who shared its experiences, best practices, and challenges in transitioning to automated processes. Three case studies focused on individual worker stories highlighted the personal impact of automation, including job displacement, reskilling, and adaptation challenges. Both male and female workers were included to provide diverse perspectives.

Limitation of the study

While this study gives valuable insight into the impact of automation on the Apparel sector, it has some limitations which are pointed below:

- Worker and management responses relied on self-reporting, which may include biases or inaccuracy.
- Absence of longitudinal factory level data limits the study's ability to access the long-term impact of automation.
- Political instability hindered the data collection process which made it difficult to extract comprehensive data from all region in a limited time frame.

These factors should be taken into consideration when interpreting the results of this sturdy.

The next chapters of this report delve into the key findings of the study, presenting a detailed analysis of the data and insights gathered throughout the research.

Chapter 4 Demographic Profile

In this chapter, a comprehensive overview of the sample size and key characteristics of workers in the apparel industry of Bangladesh, is provided. The sample includes workers from various types of factories, locations, production processes, gender distributions, years of experience, and age groups. The distribution of the sample across different factory types reveals that the largest proportion of workers are from the knitwear (176 workers) and woven (135 workers) factories. Dhaka and Gazipur are the primary locations for jeans and woven factories, with Dhaka having the highest concentration of woven factories (58 workers), while Gazipur leads in jeans production (45 workers). The least number of workers were found in Narayanganj (27 workers), with jeans, knit, and sweater factories being particularly underrepresented in this area.

In terms of factory locations, Gazipur stands out as the most prominent region, housing more than half of the total sample (52.68%). This is followed by Savar, which accounts for 20.75% of the sample, and Inner Dhaka (10.26%). The distribution indicates that Gazipur is a central hub for apparel production, with a smaller but notable presence in Savar and Inner Dhaka. Ashulia and Narayanganj have comparatively lower proportions of the workforce, accounting for just 7.93% and 8.39%, respectively.

Figure 1: Sample Size by Location

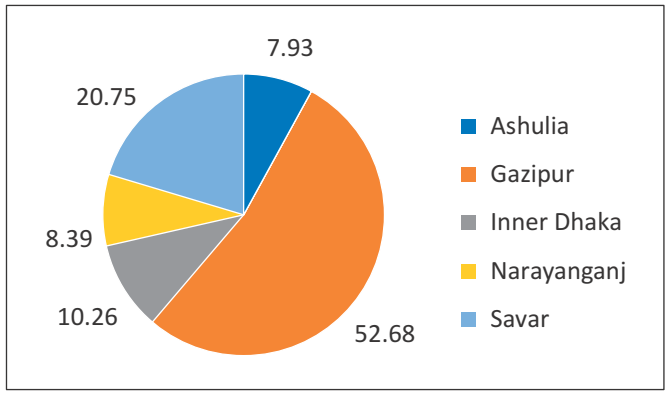
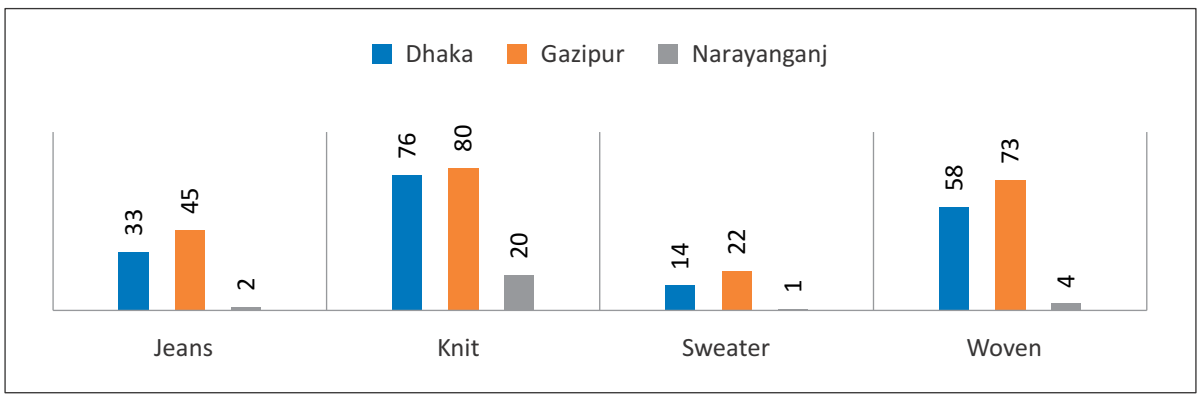
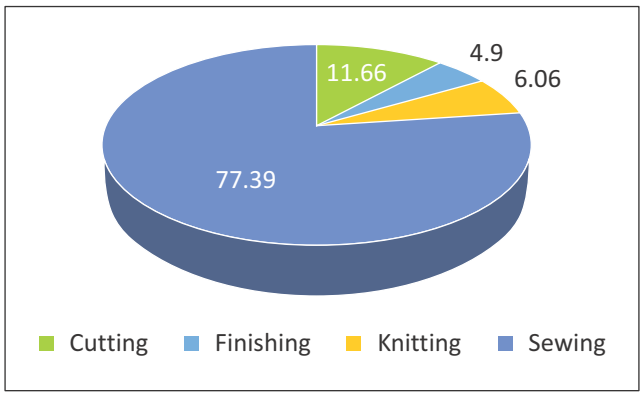


Figure 2: Sample Size by Factory Type



Regarding the production processes, sewing is the most prevalent activity, with 77.39% of the workers engaged in this process. This is in line with the general operations of the apparel industry, where sewing plays a crucial role in garment production. Cutting (11.66%) and knitting (6.06%) are

Figure 3: Sample Size by Production Process



less frequent, while finishing tasks are the least common, accounting for just 4.9% of the workers. This suggests that the workforce is predominantly involved in the assembly stages of production, with fewer workers in the preparatory and post-production processes.

The gender distribution of the sample is nearly balanced, with 50.12% male and 49.88% female workers. This indicates that the Apparel industry in Bangladesh has a fairly equal representation of both genders. However, it is important to note that gender dynamics may vary by specific factory type, location, and role within the production process.

The majority of the workers in the sample have medium-level experience, with 41.96% having 6-10 years of experience. A significant proportion (32.17%) possess over 10 years of experience, which suggests a relatively experienced workforce overall. On the other hand, 25.87% of workers have less than 5 years of experience, indicating a mix of newer entrants and seasoned professionals in the industry. This experience distribution highlights the potential for skill development and the importance of training programs for less experienced workers.

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Table 7: Sample size by years of Experience

Worker Experience	Freq.	Percent	Cum.
(Low) Less than 5 years of experience	111	25.87	25.87
(Medium) 6-10 years of experience	180	41.96	67.83
(High) >10 years of experience	138	32.17	100
Total	**429**	**100**	

The age distribution of the workers shows that the largest proportion (32.87%) falls within the 26-30 age group, followed by 21-25 years (18.41%) and 31-35 years (22.38%). The younger age groups (15-20 and 21-25) make up 23.07% of the total sample, while workers above 40 years constitute 6.06%. This age distribution suggests that the apparel industry workforce is predominantly young and middle-aged, with a smaller but significant portion of older workers. The concentration of workers in the 26-35 age range could imply a workforce with relatively high energy levels and adaptability, which is essential in an industry undergoing technological transitions.

Table 8: Sample size by Age

Age Groups	Freq.	Percent	Cum.
15-20	20	4.66	4.66
21-25	79	18.41	23.08
26-30	141	32.87	55.94
31-35	96	22.38	78.32
36-40	67	15.62	93.94
Above 40	26	6.06	100
Total	**429**	**100**	

This dataset offers valuable insights into the characteristics of the workforce in Bangladesh's apparel industry. The high concentration of workers in sewing and the prevalence of medium-level and experienced workers suggest that while automation may change certain job dynamics, there remains a robust base of skilled labour. Additionally, the gender balance and the concentration of workers in key locations like Gazipur and Savar reflect the geographical and demographic trends in the sector. Understanding these characteristics is essential for developing policies and strategies to address the challenges and opportunities posed by automation in the industry.

Chapter 5 Status of Automation

In this chapter we explore the state of automation in Bangladesh's apparel industry, and focus on how it is defined and implemented. Automation currently is task-specific, with semi-automated processes being the norm in across production process, while full automation is still rare. The findings of this chapter discuss key factors that drive automation such as cost, product design needs, and buyer demands. It also highlights challenges like mismatched worker skills, poor planning, and limited advanced systems.

5.1 Conceptualization of Automation

In reflection of the scholarly conceptualization of automation, one of the brands simplified that automation means that the work which is done today by hand, might have to be done tomorrow by machines. When we say the task will be done by machines, what does it mean? To clarify this idea, a garment factory owner has referred to using robots instead of manpower. When Industry 4.0 was introduced, there was a lot of debate in 2018 and 2019 that the garment sector had been becoming fully automated, and robots were being purchased, leading to the loss of 1 million jobs because of this automation, a significant claim. Explaining the background of automation, this entrepreneur shared his experiences in the following way.

> *"Around that time [2018-2019], a team from Harvard University came to study the issue. One of the team members was from Bangladesh, and they visited my factory, which is a green factory. There was a lot of discussion about robots being bought and the potential dark future for Bangladesh. The Harvard team told me they did not have a study on cost-effective analysis of robot. So, I asked them, without any studies, you cannot know how much it will cost to build a robot like that or how productive it will be."*

Echoing this factory owner, a machine procurement officer of a Bangladeshi garment company has agreed with the factory owner adding that advanced levels of automation, like those used in car manufacturing, are unnecessary for the garment industry, which primarily requires machine-based automation tailored to its specific needs. Supporting the views of the factory owner, the CEO of Shimmy Technology, a global training centre focusing on the use of technology, has made a difference between automated and advanced machine. An automated machine is highly automated, whereas an advanced machine may have one to two automated features. According to the CEO of a global training on technology, the practical definition of automation in the apparel sector in Bangladesh is a very task-based process. Agreeing with this conceptualization of automation, a buyer argues that in terms of automation, there is not much change in the machines but changes in tools. For example, the modifications within a sewing machine, maybe a better model, from analogue to digital, etc. Based on this argument, one of the buyers believes there has been a technological transformation in the sewing section which cannot be called automation. According to scholars such as Hoque et al. (2021), task-specific automation that makes incremental changes has occurred in the Bangladesh apparel industry.

The workers define automated machines by differentiating them from 'Bangla machine' which is actually a manual machine. The factory operators call them Bangla Machine since they lack thread-cutting equipment, a digital display, and other features. This is a basic and simple sewing machine. The upgraded sewing machines are known as automation to the workers because the the machines are more up-to-date and have a display where they can see the daily target. New

features have been added to these sewing machines, such as thread cutters, for which less helper is required in the line after the introduction of such automated machines. Although the workers consider these sewing machines to be automated, they are actually not completely automated as human labour has not been fully or significantly replaced. To the other key stakeholders, the current sewing machines that are operating now in the Bangladesh apparel industry could be referred to as semi-automated machines.

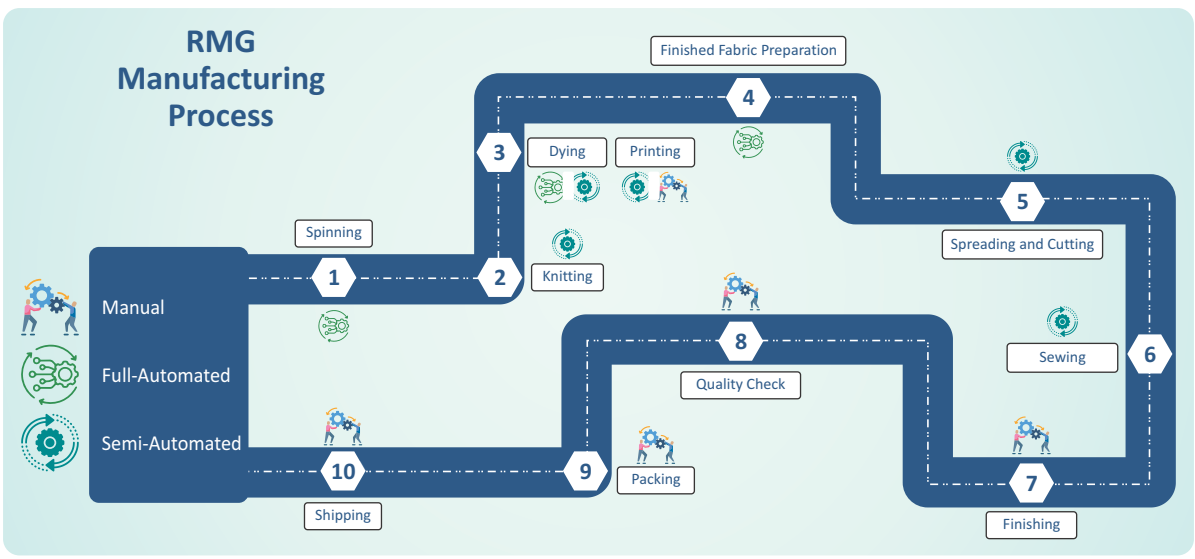
5.2 Nature of Automation

Automation in Bangladesh's apparel sector began with sweater factories in 2010, particularly in the knitting section. Automated knitting machines allowed for computer-generated designs like crisscross patterns that cannot be created manually. Jeans factories have also adopted significant automation, often using a single machine for multiple processes. In contrast, knit and woven factories are less automated due to their varied production processes, which do not always require full automation.

Automation varies by production stage. Backward operations, such as fabric dyeing, knitting, and spinning, are now fully automated. Tasks like handwashing and drying have been replaced by advanced machines, improving efficiency. Spreading and cutting is semi-automated, with most factories using Computer-Aided Design (CAD) software to optimize fabric usage and minimize waste. Smaller factories with low production volumes may still rely on manual cutting, but CAD-designed patterns have become the standard.

Sewing, however, remains semi-automated. Electrically powered sewing machines dominate this stage, reducing the need for helpers but still relying heavily on manpower. While some managers consider sewing largely manual, the use of tools and automated machine features qualifies it as semi-automated. Having more than one automated feature can be considered as a semi-automated machine. So, automation behaviour in the Bangladesh apparel sector is task-based. The way concept of automation is used in global workplaces, such as in a car factory, where industrial robots are working with automated layers, this level of autonomous automation is not evident in the Bangladesh apparel industry. In finishing tasks like ironing and packaging, partial automation has been introduced, but it is still considered as manual. The level of automation discussed in the production process has been highlighted in the figure-5 below.

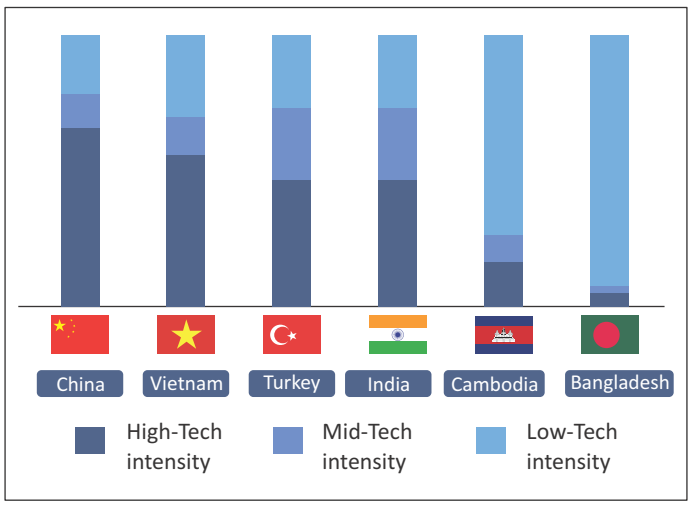
Figure 4: Technological Transition Level in Different Process



Source: Based on the KIIs

It is interesting to note in the above figure that only 3 out of the 10 stages (from spinning to shipment) are fully automated which are spinning, dying, and finished fabric preparation. Most of the other production process are largely semi-automated. Beyond production, system automation has transformed operational efficiency in leading factories. Technologies like digital IDs, fingerprint scanning, mobile payments, and IoT-enabled systems streamline processes such as attendance tracking, quality monitoring, and resource management. Data automation enables manufacturers to track production metrics, energy use, and maintenance schedules in real time, supporting Just-In-Time (JIT) operations and reducing waste.

Figure 5: Bangladesh's position in technological adoption compared to other countries

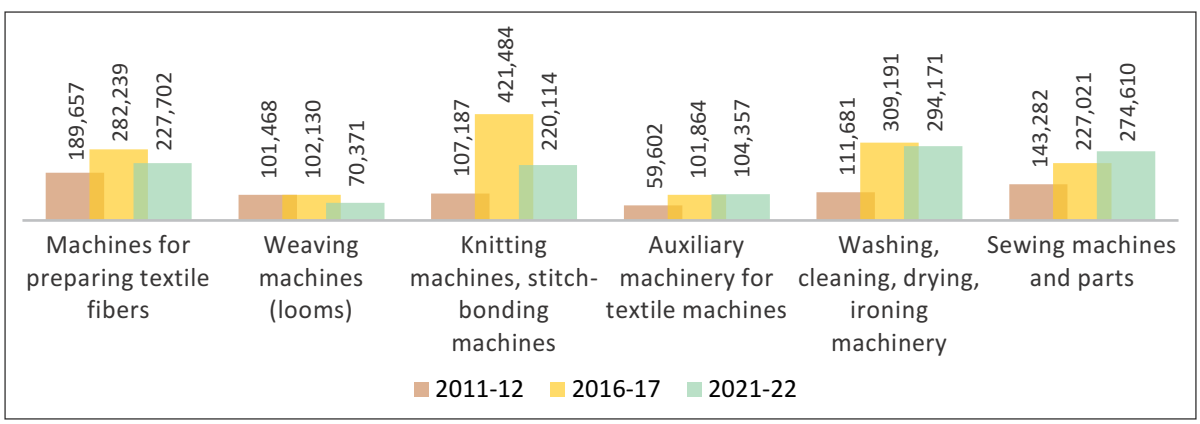


Source: Light Castle Partners, 2024

The overall status of automation is not overwhelming due to the need for various processes. When the factory management was asked to score the current status of automation in the Bangladesh apparel industry, the score was 2.5 to 3 out of 5, where 0 means no automation and 5 refers to complete automation. According to senior factory management, at least 30 to 40 factories in our country have advanced levels of automation. According to a recent report by Light Castle (2024), Bangladesh is still in the early stages of adopting automation in manufacturing, with a high-tech intensity of just 1.9 compared to China's impressive 63.7 (figure 5). This supports the findings of our study.

Regarding the time-frame when automation started, the above machine import data (figure 6) shows that the 2016-2017 level of automation was the highest. Except for sewing machines, the import of other machines dropped after 2016. This study cannot say exactly from when the automation process started as different factories mentioned various years such as 2000, 2007, 2015. Based on their views and the trend of import of machinery, this study assumes that manual machine was used mainly before 2018 and automated dominated after 2018. As the sewing process is the dominant aspect of this industry, the import of sewing machines and parts continues to grow.

Figure 6: Automation Import Data



Source: Prepared by the authors from the data of Bangladesh Bank

The table 9 below presents the type of machines used by different type of factories in Bangladesh which was provided by the factory management during the interviews. There is identified 26 Automated and Semi-automated Machines in the Sewing, Cutting, Knitting and Finishing sections.

Table 9: Automated Machine Distribution based on Production Process

SL.	Production Process	Observations	Percentage (%)
1.	Cutting	Auto Cutting Machine	10
2.	Cutting	Jacquard Cutting Machine	13
3.	Cutting	Km Cutting Machine	5
4.	Cutting	Scissor	2
5.	Cutting	Spider Machine	1
6.	Cutting	Van Knife	1
7.	Cutting	WS Machine	1
8.	Finishing	Dice Machine (Common Name)	1
9.	Finishing	Folding Machine	1
10.	Finishing	Heat Stress	13
11.	Finishing	Iron	1
12.	Finishing	Kanchi	14
13.	Finishing	Overlock	70
14.	Knitting	Jacquard	19
15.	Sewing	Bartack	3
16.	Sewing	Brother Machine	2
17.	Sewing	Button Hole Machine	2
18.	Sewing	Chain Stich	1
19.	Sewing	Cover Stich	1
20.	Sewing	Eyelet Hole Machine	3
21.	Sewing	Flatlock	27
22.	Sewing	Fit Off the Arm	14
23.	Sewing	Hikari	1
24.	Sewing	Hixel	1
25.	Sewing	Plain Machine	131
26.	Sewing	Two Needle Auto Machines	12

Source: Based on KIIs

5.3 Critical Determinant Factors for Embracing Automation

In addition to a clear positive impact of automation, there are other critical issues that determine whether a factory will embrace automation or not.

Cheap labour supply vs expensive machine: Usually leading factories do a cost-benefit analysis of labour cost versus automation. In most of the cases, the factories argue that the labour cost, although the minimum wage has increased, is still the lowest compared with Vietnam, the competitor of Bangladesh. The supply of labour is also not an issue for Bangladesh. The factories who cannot afford expensive machines, do not see the use of labour with manual machine is a major obstacle for doing business.

Basic vs Complicated design: The group of factories that have opted for automation have done so to produce complicated and diverse garments with updated designs. Since they work with leading buyers, they must go for automation to make new garments with top-notch quality to satisfy consumers. However, the majority of exported garments are basic garments with low-value addition. Producing these low-value basic garments does not push factories to install advanced technology with automated features, as the return on investment is negative. One of the suppliers argued,

> *"Getting the return on investment remains one of the biggest challenges for the industry. For instance, using an AI enabled machine saves up 1.38% of fabric which is estimated to save 130 ton of fabrics annually having market value of almost Tk.4 crore. Also, the outcome of value stream mapping (VSM) indicates improved productivity in the workers with automated machines. It seems logical for the factories to invest in such AI enabled machines. However, the cost of setting up the machines and accounting for depreciation of these machines, it is difficult to get production returns of these capital investments accounting for the fact that the buyers are not getting expensive high value garments from us."*

Brand's demand for quality garments: Sometimes, the choice to adopt automation depends on the specific features and quality standards demanded by brands and buyers. A factory manager explained that while common machines suffice for producing basic garments like T-shirts, more advanced machines are often necessary for items like polo T-shirts, which require pockets and other intricate designs. Recently, automated machines for tasks like pocket-making have become available. For example, making a shirt collar manually involves folding, sewing, and pressing, which is time-consuming. Automated machines simplify and speed up this process. Factories producing shirts for buyers with strict quality standards and tight deadlines are more likely to invest in such automation

By sharing another case, a supplier said,

> *"It used to take four workers to make a pocket. Now, a machine does the pocket-making process entirely. There is a specific machine for setting the pocket and making a placket, which includes the buttoning. In the past, it required at least four workers to align the pocket and placket, which was a tricky job. Now, the machine ensures the alignment is perfect every time, eliminating the margin for error."*

However, automation is not always necessary. Senior factory management pointed out that investing in automated machines depends on the buyer's quality requirements. For instance, if

buyers are satisfied with garments ironed manually, there is no need to purchase expensive steam ironing machines. Factories often weigh the cost of automation against the price they receive from buyers. Some buyers prioritize low prices over high quality, making automation unnecessary for factories working with such clients. Thus, the decision to automate ultimately hinges on balancing buyer expectations, product quality, and cost considerations

Convenience process: Sometimes, factories consider the convenience of producing a particular garment before going for automation. Although the highest level of automation is observed in Bangladesh in some stages of production, few factories have not brought any automated cutting machines for shirts. For instance, cutting fabrics with printed patterns, remain manual due to convenience and precision. For plain fabrics, automation is more feasible, but specific production requirements often dictate whether factories adopt automation.

Vision of the supplier: To stay competitive in the global market, suppliers must adopt advanced automation. In the past, buyers accepted imperfect products like manually made plackets, but with automated machines, expectations have changed. Today, flawless quality is non-negotiable, and factories without automation risk falling behind. Automation is not just an option; it is essential for meeting evolving standards and remaining relevant in the industry. As one supplier noted, investing in such technology may not happen immediately, but in the long run, it is a necessity to survive in this competitive landscape.

Following others without assessment: Suppliers often face the challenge of purchasing automated machines without proper need assessments. Many invest in machines simply because neighbouring factories have done so, sometimes as a show of status. These machines often come with features that are unnecessary for their operations, leading to wasted resources. A BGMEA representative noted that factories rarely analyse cost-benefit or potential savings, missing opportunities to invest in worker education or tailored technology. One factory owner shared an example of buying a machine to save water and chemicals, only to face operational issues that required local and foreign technicians to resolve. Despite these problems, other factories bought the same machine without consulting the owner about its effectiveness. As a result, these factories struggled to operate the machine due to a lack of understanding about the required processes, highlighting the pitfalls of unplanned automation investments.

Mismatch between existing workers' skill and automation: The choice of automation depends on the skill level of workers in a factory. Suppliers sometimes purchase machines that are too complex for their workforce, leading to inefficiencies. A factory manager explained the importance of matching machines to production needs, such as choosing specific machines for thin fabrics like georgette to avoid wrinkling. Skilled workers can handle various fabrics on the same machine, but not all workers have the necessary expertise, making automation a practical solution. However, automated machines come with drawbacks, including higher maintenance costs and a need for specialized parts. Automation also requires more than just purchasing machines—it demands skilled personnel. For example, using an automated cutting machine efficiently requires knowledge of CAD software like Auto-CAD, as well as expertise in fabric handling. Simply knowing the software is not enough; an operator must understand fabrics to create accurate designs that the machine can execute effectively. Without skilled people and proper investment, automation can fail to deliver its intended benefits.

Chapter 6 Dual Impact of Automation

6.1 Positive Impact of Automation on Factories

Automation in the apparel industry of Bangladesh has significantly transformed the operational and social landscape, bringing about numerous benefits for both factories and workers. While the transition to automated processes has not been without challenges, its positive outcomes underscore the potential of technology to drive productivity, quality, and improved working conditions. This section highlights the various ways automation has positively impacted workers and factories.

Automation has significantly boosted productivity, efficiency, and competitiveness in the apparel industry by optimizing various stages of production. Processes that previously required extensive manual labour have been streamlined with automated tools and machinery. For instance, automation tools like Fast React make production planning more adaptable, allowing manufacturers to quickly adjust to changes in order volumes or deadlines. This flexibility reduces delays and supports just-in-time (JIT) production, improving overall efficiency. A senior manager highlighted that automation has streamlined processes, reduced labour costs, minimized errors, and improved working conditions, leading to faster cycles, higher output, and less waste. Similarly, a supplier noted that automated machines, capable of producing 200-300 pieces per hour, far outperform manual processes, which only achieve 50-60 pieces per hour. Tasks like adding back pockets or belt loops, previously done by multiple workers in assembly lines, are now completed on a single automated machine operated by one person, saving time, space, and manpower.

Data from different surveyed factories highlights the positive impact of automation. According to KIIs, efficiency increased by 3-5%, production became more optimized, and manpower utilization improved, saving both time and resources. For example, automated fabric spreading reduced the need for workers from 7 to 1, saving $1,020 in labour costs with a four-year payback period. Another factory using a Back Moon machine for knitted polo shirts increased hourly productivity from 90 to 140 and cut rejections from 10% to near 0%. This is presented in the tables 10, 11, and 12 below:

Table 10: Business Case of a Factory

Process	No. of Workers required		Finances of Current Machinery		
	Old machine	Current machine	Cost	Labour Savings	Payback time
Attach Welt Pocket	7	3	$19,800	$850	2.0 Yrs
Auto Elastic Tack	5	2	$15,000	$510	2.5 Yrs
Attach Back Pocket	9	2	$38,000	$1,190	2.7 Yrs
Attach Waistband	5	3	$12,000	$340	2.9 Yrs
Template Quilting	7	4	$7,000	$510	1.2 Yrs
Auto Loop Attacher	2.5	1	$18,000	$255	5.5 Yrs
Attach Front Pocket Facing	2	0.5	$15,000	$255	5 Yrs
Attach Coin Pocket	2	0.5	$16,000	$255	5 Yrs
Spreading Fabric	7	1	$49,500	$1,020	4 Yrs

Table 11: Knitted Polo shirt production by Back Moon attaching machine

	Automated machine	Conventional Machines
No of machines required	01	04
Price of machines, USD	20,000	2,000
No of workers required	01	04
Productivity, piece/hour	140	90
Quality Rejection	0%	5% to 10%

Source: Based on KIIs

Table 12: Benefits of Automation

Benefits	
Operational Benefits: • Efficiency increased by 3% to 5% • Optimized production • Reduced work in process • Maximum manpower utilization and save manpower • Better visibility and communication • Improved customer service (fast response), reduce of operator motion time • Reduce of Machine stoppage duration time. **Financial Achievement:** • Knit Card: Saving 1,17,312 TK per year. • Reduce on-line & off-line Quality Inspection Status.	**Time Savings:** • Officer: 2hr/day/officer • 624 hr/year; • 2hr/day/all knit unit 3120 hr/year • Value in Tk. 287040 Tk./year **Operator:** • 50 Min/Day/Operator 260hr/year • 50Min/Day/All knit unit 45240 hr/year • Value 1458990Tk/Year

Source: Based on KIIs

6.2 Positive Impact on Workers

6.2.1 Reduction of Errors

One of the most widely recognized benefits of automation has been its impact on product quality. Automated systems ensure consistency and precision in tasks such as stitching, cutting, and quality control, which were previously subject to human error. This reduction in defects has not only boosted buyer confidence but also improved the profitability of the sector by minimizing material wastage and alteration costs. One of the workers in FGD indicated that automation has saved time and has had a direct impact on production. According to this worker,

> *"It takes five to six minutes to fix one alter, we can make another five to six pieces in that time. We cannot unpick a stitch with the machine, we need to do it manually. So, it takes time. Since the number of altered pieces has reduced, productivity has increased a lot."*

FGD participants highlighted the benefits of automation, comparing older "Bangla" single-needle machines to modern Juki auto machines. They noted that the older machines had

frequent needle breakages and higher defect rates, while the auto machines reduced defects to just 4-7 pieces per 100 and eliminated needle breakages. Regarding rejection rates, they shared, with the Bangla machine, 2-3 pieces per 100 were rejected; now, with the auto machine, there are no rejections.

Data from table 13 confirms these improvements, showing significant reductions in alterations (57.26) and rejections (7.40) with automation. The statistically significant results ($p < 0.01$) and high t-values highlight automation's role in boosting productivity and ensuring consistent quality, helping factories meet targets with fewer errors.

Table 13: t-test of Piece Alteration and Piece Rejection

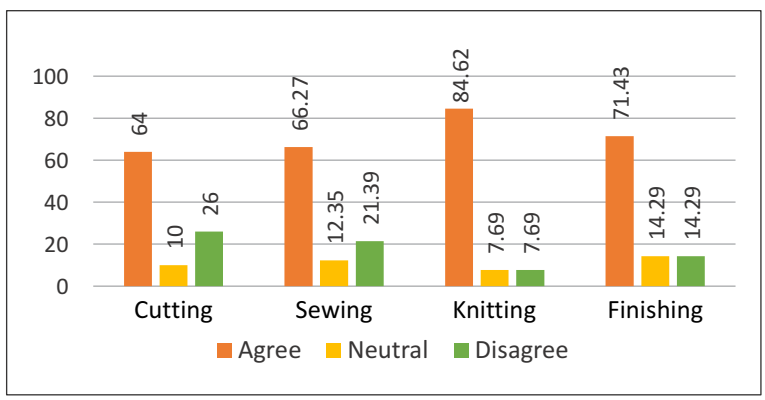
Variable name	Observation	Manual machine	Automated machine	Diff	t-value	p-value
Piece Alterations	318	140.757	83.502	57.256	3.778	0.000
Piece Rejected	318	9.875	2.478	7.397	2.904	0.004

Note: p-values < 0.05 indicate statistically significant differences, only workers with medium to high work experience responses analyzed

6.2.2 Less Physical Pain

Automation has brought notable improvements in workplace safety and comfort, particularly by reducing the physical strain of repetitive and labour-intensive tasks which is highlighted in Figure 7. Workers in roles such as fabric spreading and knitting, which historically involved heavy manual labour, now benefit from machines that handle these tasks efficiently. This has significantly reduced the risk of injuries and chronic health issues, such as musculoskeletal disorders, which were common among workers in manual production processes. The biggest change can be noticed in the knitting process with almost 85% of worker agreeing that they have experienced less physical pain since the introduction of automated machines. It is important to note that by physical pain this study indicates discomforts caused by a specific task related to the manual machine such as strain in eyes while putting thread in a needle, or cuts in fingers while using scissors. Interviewed workers have vastly admitted that this physical pain has reduced since their respective factories have implemented advanced machines regardless of the year of introduction as highlighted in figure 7.

Figure 7: Workers' Perception about Physical Pain (%)



6.2.3 Improved Work Environment

The introduction of automated systems has also improved the overall work environment by incorporating features such as better ventilation and ergonomic designs. Workers have expressed increased satisfaction with these changes, noted by table 14. It shows worker's perspectives on productivity after automation. Most agree automation helps achieve production goals (96.74%), improves ventilation (93.01% reported), and increases safety (97.67%). As automation has not

only occurred in production machines, but also in form of fire safety tools, announcement systems and cooling fans, it keeps the work environment safe and comfortable for workers. Additionally, Fewer workers (58.51% of the respondents) feel less tired, indicating mixed views on its impact on physical strain that is due to the different production stages needing different levels of physical effort. Overall, perceptions are largely positive.

Table 14: Worker's Perspective on Automation

Worker's Perspective on Automation	Agree	Neutral	Disagree
Automation has made it easier to achieve my daily production goal	96.74	1.86	1.4
Automation has improved the temperature and ventilation of my workplace	93.01	5.13	1.86
Automation has increased the safety of my workplace	97.67	1.63	0.7
I feel less tired when I go home after using the automatic machines	58.51	26.57	14.92

Note: The values are expressed as percentages

6.2.4 Creation of Skilled Job Opportunities

While automation has reduced the demand for unskilled labour in certain roles, it has simultaneously created opportunities for skilled positions in machine operation, programming, and maintenance. The shift from manual labour to technology-driven roles has encouraged workers to upskill and reskill, opening up pathways for career advancement. This is supported by the table 15. For instance, multi-skilled workers trained to operate automated systems have reported earning higher wages compared to their peers in traditional roles.

Table 15: Worker's Perspective on Automation

Worker's Perspective on Automation	Agree	Neutral	Disagree
Due to automation, workers performing technical duties are more respected in factories	65.97	30.3	3.73
Salary will increase if you leave the job and go to another factory	79.02	9.56	11.42
I have sought additional training or skill development to reduce the risk of losing job due to automation	50.82	20.51	28.67

Note: All responses are in percentages

This demand for skilled labour has motivated several factories to invest in training programs, equipping workers with the knowledge and expertise needed to thrive in an automated environment. These roles provide a more secure and sustainable source of income for workers. According to the above table 18, 79% of the workers believe that if they leave now and join another factory, their salary will be increased due to the skills attained after automation. The advanced machines have made them concerned about losing their jobs in the future, but exposure to the machines and adapting to them is reducing their vulnerability to job displacement which can be

observed from the worker's perception table above. So, automation and the advancement of technology can increase the skills of the people involved. About the adaptation of workers to new types of machines, a labour representative said,

> *"If you think about a new machine, just like with a mobile phone—your phone is getting smarter. The mobile phone you used 10 years ago, you would not use it anymore, right? You have adapted, and so have the workers. They adapt to new technologies, and their skills grow."*

Moreover, automation has created new opportunities in managing, maintaining, and programming automated systems. Jobs in machine maintenance, software management, and data analysis have emerged, offering career paths for workers with technical skills. This shift encourages the workforce to develop advanced technical abilities, paving the way for technology-focused roles in the apparel industry.

Case study: Ayna Begum's Dream

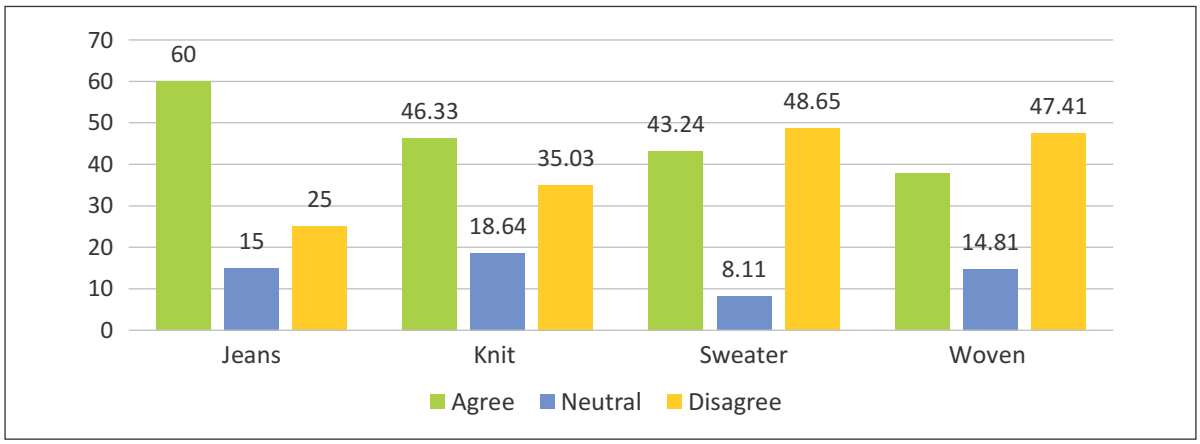
With 18 years of experience in the Apparel sector, Ayna Begum's story reflects the struggles and resilience of female garment workers. Coming from a poor background and relocating to Gazipur for work, she began her career as a helper, cutting threads and performing basic tasks. The factory used "Bangla Machines," lacking advanced features like thread cutters or digital displays. Ayna learned how to operate these machines by observing others, despite accidents and scolding from supervisors. Over the years, her factory transitioned to automated machines, reducing the need for helpers and offering better working conditions. Although initially hesitant and untrained, Ayna adapted to the new technology, eventually mastering advanced machines like the two-needle system. Inspired by a friend's formal training experience, Ayna wished for better training opportunities within her factory to ease her struggles. Her perspective shifted when a close friend left for a higher-paying job abroad, citing better facilities and job security. Ayna realized that while automation had improved working conditions, insufficient training and limited career growth opportunities could push experienced workers like her to seek opportunities elsewhere.

6.2.5 Increased Worker Satisfaction

Automation has made work less repetitive and physically demanding for many workers, bringing a sense of relief. Those trained to use automated systems often feel proud of learning new skills and technology, which has encouraged a culture of growth and learning in factories. Instead of seeing automation as a threat, workers are beginning to view it as a chance to grow and improve their careers as highlighted in the above table 18. Better communication between workers and management has also been a positive outcome of automation. Factories that involved workers in the transition process and offered training programs created a more supportive environment. This helped workers feel valued and see the changes as a win-win situation for both sides.

As shown in the figure 8 below, workers who learned to operate multiple machines felt their bargaining power with management had improved, especially in jeans factories which has highest levels of automation among the production process, 60% of the respondents agreed their skills gave them more leverage. In woven factories, the increase was less noticeable, with about 47% agreeing, showing there's still room to provide more training and opportunities in certain areas. This indicates that the more automated is a production stage the more the factory managements want to hold onto the workers, as a skilled worker is considered an asset.

Figure 8: Worker's Perception on Bargaining Power due to Automation



6.2.6 More Time with Family and Household

Another benefit of modern machines is their ability to automatically count production. Previously, workers spent four to five minutes manually counting how many pieces they had completed, but advanced sewing machines now handle this task automatically, displaying the count on a screen. This feature saves time and has increased production rates.

Automation has also allowed workers to finish tasks faster, giving them more time to relax at work and spend with their families. Tasks that previously required an additional hour on older machines now take an hour less on advanced machines. Workers shared,

> *"Before, reaching a target of 150 pieces was difficult, but now we can easily hit 200 or even 220 pieces. With the older machines, cutting thread by hand wasted time, and we couldn't take breaks or even drink water without reducing our output. Now, with automated machines, we work more relaxed."*

Survey results reflect these improvements, showing that automation has positively impacted workers' family time and their ability to complete household chores highlighted by Figure 9 and 10. Agreement is highest in sewing and finishing, where 77.71% of women workers report having more time with family, and 75% say they can handle household tasks more easily. However, mixed responses in sections like knitting suggest that the impact of automation on personal time can vary depending on the nature of the production Process.

According to the data from table 15, 75.52% of the workers' agreed that automation has allowed them to spend more time with their family, and 58.51% agreed that they are less tired due to the reduction of physical effort. A majority of them (72.49%) find more time to do household work. It also happened because of the less time required to use machines.

Figure 9: Workers perspective on increased family time due to automation

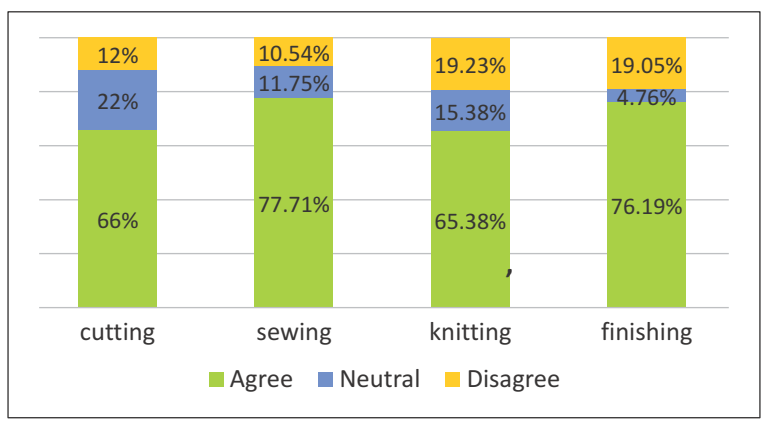
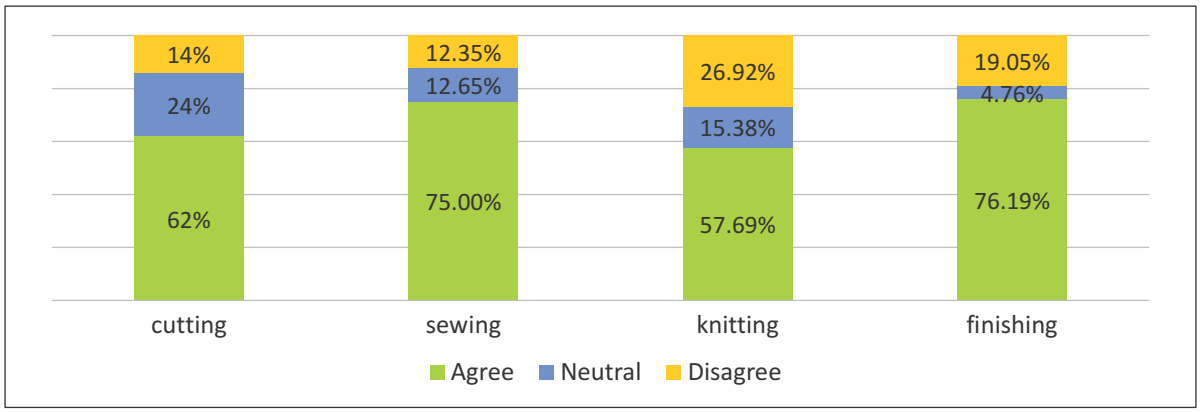


Figure 10: Worker's perspective on increased time in doing household chores due to automation



6.2.7 Improving worker's livelihood

Apart from increased time to stay with family members and do household chores, the workers feel less tired (58% of the respondents), able to afford education and learning materials as desired trough salary (72% of the respondents), shifted to a better house (59% of the respondents), has stable income (60% of the respondents) and more time to pray (46% of the respondents).

Table 16: Worker's perspective on their livelihood after the introduction of automatic machines

Worker's Perspective about Automation	Agree	Neutral	Disagree
Automation has allowed me to stay more time with my family	75.52	12.82	12.82
I feel less tired when I go home from work after using automatic machines	58.51	14.92	26.57
I have more time to do household chores (cooking and shopping)	72.49	13.75	13.75
Since automation my income has been stable/ I get paid on time	60.68	9.11	30.21
I have more time for religious prayers in the factory because of automation	46.09	12.5	41.41

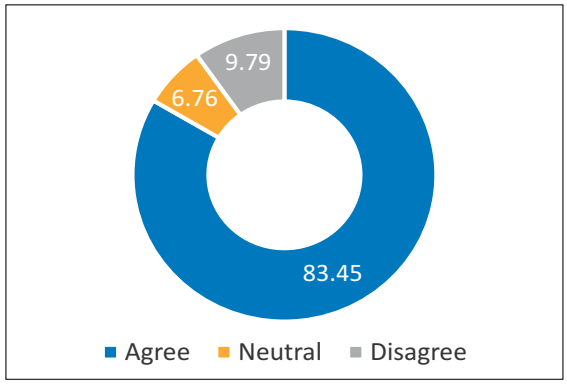
Note: all the values are in percentages

6.2.8 Secure Digital Payment

Automation has introduced systems like fingerprint attendance, which have made tracking working hours more accurate. Workers no longer need to bargain or justify their overtime with supervisors.

According to the data from table 15, 75.52% of the workers' agreed that automation has allowed them to spend more time with their family, and 58.51% agreed that they are less tired due to the reduction of physical effort. A majority of them (72.49%) find more time to do household work. It also happened because of the less time required to use machines.

Figure 11: Worker's opinion about mobile payment being better than cash-in-hand



Manual to MFS: Story of an Apparel company

We are the first factory in Bangladesh to offer mobile financial services. The workers receive their salary by mobile. In the past, we paid salaries manually. We had to carry a huge amount of cash, let's say, BDT 5 crore, on the salary payment day. It was risky. We asked for the services of a Security Company, which added another cost. Finding it difficult to operate, we contacted Dutch Bangla Bank to affiliate with us in 2017. We opened bank accounts for all our workers back then, but it was challenging for workers to pay extra bank charges. To remove the burden, the company took responsibility for paying extra bank charges for the workers. However, on the day of my salary, the system/machine sometimes did not work due to technical issues. Then they said they would give mobile ATM, but it did not work either. Then came Rocket and Robi's mobile banking became a payment-sending process. Robi opted for giving us free sims. Then we gave them the incentive to get their wages 2 days earlier through mobile banking. We are still giving the service. We told the bank to cut the charges off. They agreed. Now we have 100% mobile banking. One of the preconditions of joining our factory is mobile banking.

6.3 Challenges of Automation on Workers

While automation has brought several advantages to the apparel sector in Bangladesh, its adoption has also led to significant challenges, particularly for workers and other stakeholders. The negative impacts of automation manifest in various forms, including job displacement, widening gender disparities, psychological stress, and systemic barriers that hinder equitable adoption. This section explores these issues in detail.

6.3.1 Displacement of Workers and Job Loss

Automation has significantly changed the workforce dynamics in the apparel industry, reducing the demand for unskilled helpers while creating both opportunities and challenges for skilled and mid-level positions. Tasks that were once handled by unskilled workers, such as fabric folding, sorting, or monitoring specific production steps, are now managed by machines. As a result, factories have shifted

towards hiring fewer, more skilled workers who can contribute to higher-value processes. This shift has decreased the availability of low-paid, repetitive roles, pushing the industry to prioritize a more technically adept workforce.

In the context of understanding Just Transition in the Bangladesh apparel industry, semi-automation in sewing operations has significantly reduced the need for unskilled helpers. Previously, each "Bangla machine" operator had a helper for tasks like moving bundles, handling thread, and cutting excess thread. With semi-automated machines, these roles are now handled by auto trimmers and sensors, eliminating helper jobs industry-wide. According to a leading factory owner,

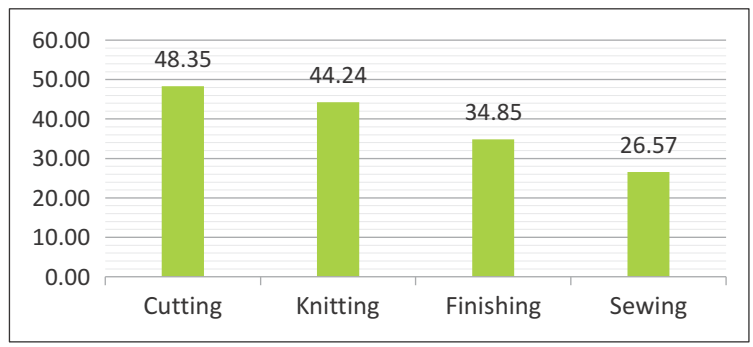
> *"So, in Bangladesh, if there were 500,000 machines, there were 500,000 helpers—500,000 jobs. Today, there is hardly any factory in Bangladesh with that number of helpers because machines have become automated. Tasks that were once*

done manually by helpers are now handled by machines. For example, auto trimmers have replaced the need for manual thread cutting. After the sewing is completed, the machine trims the excess thread, and sensors check for quality. These helpers, who were once on the other side of the machines, are no longer needed. In fact, around 4 to 5 lakh (400,000 to 500,000) jobs are no longer required because of the advanced development of sewing machines."

FGD participants noted that helper numbers per line dropped from 20 to 5, and for 60 machines, only 5-6 helpers are now needed compared to 40 before. For instance, in the sweater industry, automated flat-knit machines now run 24 hours, with only 1 hour break time. In this factory, as mentioned by an owner, one worker can control 6 to 7 machines, whereas it was one worker per machine previously, and production that once required 3,000 operators now needs only 300, cutting the workforce by 90%.

In the survey the workers were asked about the number of workers per line in the period of manual and automated machine. From the figure 12 below it can be observed that the cutting production process has seen the highest percent of decline in workers (48.35%) per line and the sewing process shows lower reduction (26.57%). Overall, the total decline in workers across processes is 30.58%, based on 429 observations from the worker's survey. Overall, while the highest percentage of job losses occurred in cutting and knitting, the total impact is felt across all stages, with sewing representing a substantial portion of the workforce despite its lower decline percentage.

Figure 12: Percentage decline in worker by production process



If we were to look closer into this decline in terms of the location of the factory, the tables 17 and 18 below highlight some key factors. The tables reveal variations in worker decline based on factory location and factory type. Worker per line decline rates is highest in Narayanganj (34.57%) and lowest in Inner Dhaka (21.55%), with Gazipur contributing the most observations.

Table 17: Worker percentage decline by factory location

Factory Location	Worker decline (%)
Ashulia	32.45
Savar	28.47
Inner Dhaka	21.55
Narayanganj	34.57
Gazipur	29.47
Average Decline	29.12

Table 18: Worker percentage decline by factory type

Factory Type	Worker decline (%)
Sweater	37.03
Knit	29.19
Jeans	28.67
Woven	27.23
Average Decline	29.15

To verify the data on worker decline, information was gathered from several large factories through Key Informant Interviews (KIIs). Table 19 summarizes these findings. Upon comparison, the data reveals that the discrepancy between the worker survey results and the observations made by factory management (via KIIs) is approximately 10%. This indicates a relatively close alignment between the two sources of data. In addition, we explored any secondary literature that presents any figure of worker decline due to automation. According to an article published in the World Economic Forum on January 20, 2020, nearly 30% of the workers have been displaced from the sweater factory because of automation. Our study argues that 30% of workers are less required in the apparel industry after changes in technology and automation. From both sources – we can say that our data validates the exciting findings.

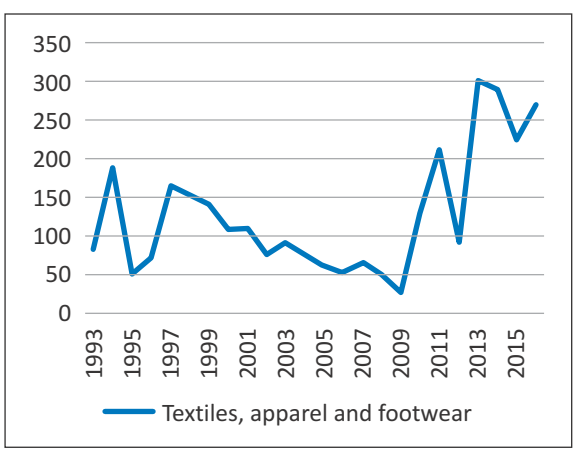
Table 19: Percentage of worker decline according to KIIs

Production Process	Worker Decline (%)	Factory type	Worker Decline (%)
Cutting	33	Sweater	29
Knitting	36	Knit	26
Finishing	24	Jeans	20
Sewing	16	Woven	20

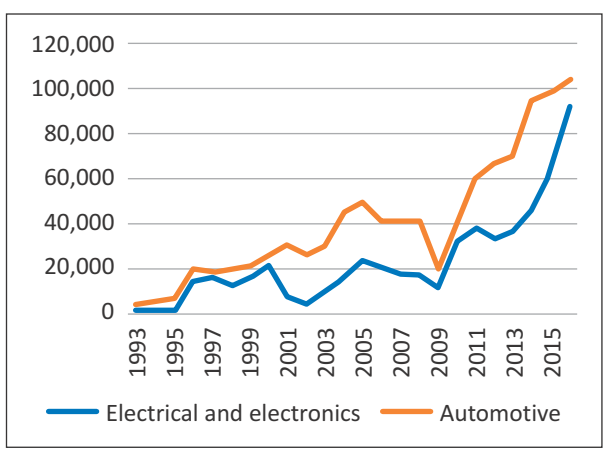
Despite these changes, stakeholders like factory management and trade associations argue that large-scale unemployment in the apparel sector has not occurred and is unlikely in the near future. Senior factory management clarified that automation has increased productivity by enabling multitasking, where one worker can perform multiple roles. However, this shift affects specific processes more than others. For example, the sewing section—where most workers are women—could see significant job losses if sewing robots were introduced. Currently, the widespread use of sewing robots remains unlikely. Global data shows that while robot sales in the automotive industry reach about 100,000 units, only 200 have been sold in the apparel sector, highlighting their high costs and limited feasibility in garment production.

Figure 13: Annual unit sales of Industrial Robots 1993-2016

Panel A. Textiles, apparel and footwear industry



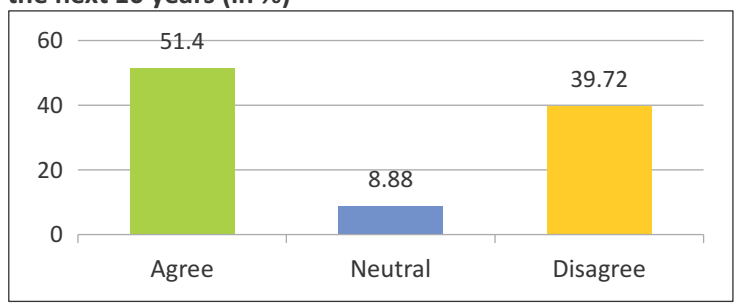
Panel B. Electrical and electronics and automotive industries



Source: International Federation of Robotics (2017)

The figure below illustrates that a majority of workers (51.4%) agree that automation poses a threat by reducing employment opportunities in the apparel industry. In contrast, nearly 40% of workers disagree with this perspective, while only a small proportion (8.88%) remain neutral on the issue.

Figure 14: Worker's perception of technological change over the next 10 years (in %)



Case study: Anowar, Influence of modern machines on the rise and fall of a life

Anowar Hossain's life is a testament to the challenges posed by automation. Born into poverty, his family relocated to Gazipur in search of better opportunities. After years of working odd jobs, Anowar joined a knitting factory and learned to operate manual machines. He quickly became a skilled operator, earning a stable income and supporting his family. However, his golden period ended when his factory replaced manual machines with automated Jacquard systems. Lacking the educational background to understand the new technology, Anowar lost his job and struggled to adapt. Efforts to find work in other factories were futile, as most had transitioned to automated systems. Eventually, Anowar took up work in a poultry farm, reflecting on how automation had displaced many workers like him. He lamented his lack of education, which could have helped him adapt to modern machines and secure a better future. Despite his challenges, Anowar remains content with his current life but highlights the need for better training and support for workers affected by automation.

6.3.2 Uncertain Lives of Displaced Workers

Automation in the apparel industry of Bangladesh has significantly reduced the need for helpers in many processes. Advanced machines now handle tasks that previously required extra hands, such as moving materials or assisting operators. This decline in labour demand has raised concerns among workers, particularly about job security. A labour representative stated that while automation moves the country forward, laying off workers due to automation leaves them with nowhere to go.

Even though automation might lead to some job loss, some factories prefer to keep their workers and train them for new roles instead of letting them go. Experienced operators are hard to find, so it is more practical and cost-effective to teach helpers or displaced workers how to use the new machines. According to factory managements, automation does not automatically mean losing jobs. Instead, workers who are displaced by semi-automated systems are often reassigned to other tasks or trained to become machine operators. A supplier summed it up, stating that automation does not mean complete job loss. Workers usually find new roles in other parts of the factory.

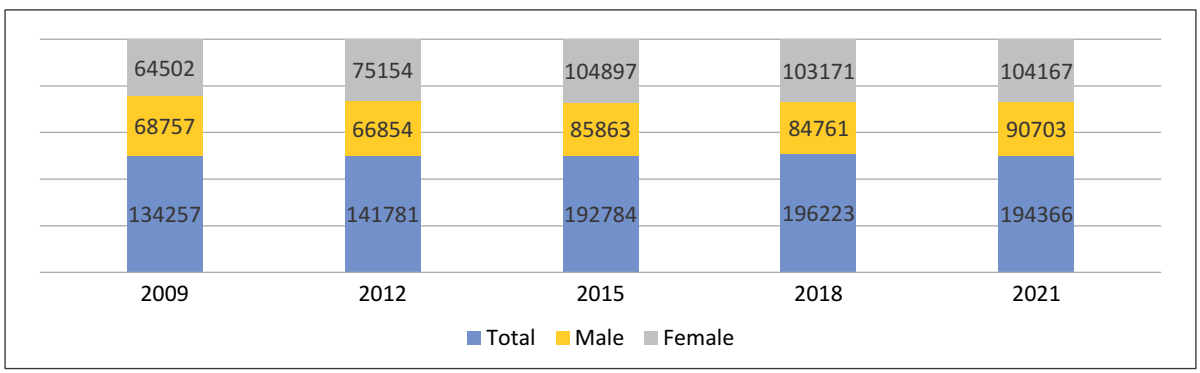
In the KII, factory managers and workers both agree that job loss has been minimal. FGD participants shared that they were taught other tasks and eventually became machine operators. In spite of FGD views, labour federations do not have sufficient evidence to agree with the claim of factories that all workers who lost jobs were moved to another section or position. From the context of workers, as union leaders and senior members of labour federations argued, the goal

should be integrating workers with new machines instead of replacing workers with automation. They expect *"Just Transition"* in the process of transformation like work as a trade union leader argued, *"The biggest concern from the labour side is to provide fair job security to the workers. We refer to this as 'just transition' or fair transformation. Will the social safety net provide coverage for the workers? Will they receive rehabilitation, or will they receive training and qualifications to handle this automation or new technology? The main question is whether the owners will make them fit in all the above places. We propose a just transition."*

6.3.3 Slower Pace of Worker Hiring

As the factories claim that displaced workers were given new roles and positions and they did not lose jobs, the consequence of this action could be slower pace of recruitment of new workers in the industry. Their approach has reduced the need to hire new workers, which is reflected in a study by Rahman et al. (2023). The research highlighted in the figure-15 shows that worker recruitment increased steadily from 2009 to 2015 but has since levelled off as automation became more common

Figure 15: Apparel industry labour entry



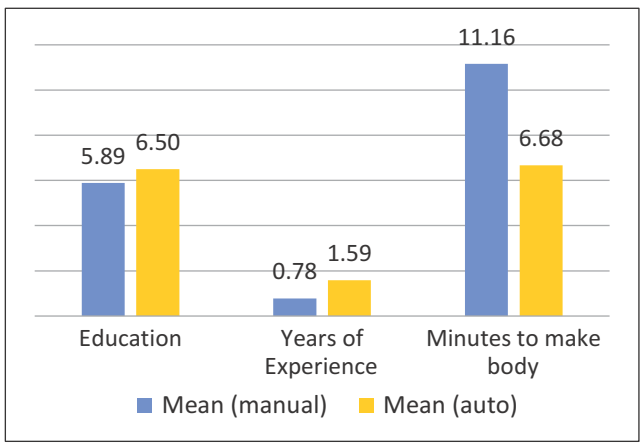
Source: Rahman et al. (2023)

6.3.4 Rising Barriers to Entry

Automation has reshaped the apparel industry, shifting the focus from traditional sewing skills to operating machines. Tasks that once required expertise, like sewing pocket joints, are now done automatically, reducing the demand for skilled workers. As factories increasingly rely on automation, workers are finding that their previous skills are no longer as valuable, creating concerns about job security.

To adapt to this shift, workers need to learn new technical skills. Automation has made technical literacy and basic digital knowledge, like understanding machines and software, essential for staying employed. Unlike 10-15 years ago, when manual labour and basic machinery skills were sufficient, today's workforce is expected to have a higher level of technical knowledge and adaptability. Current recruitment emphasizes technical literacy, as workers need to understand and operate

Figure 16: Changes in recruitment criteria



automated systems. Basic digital skills, such as data entry and navigating software interfaces, are now essential. In contrast, previously, such skills were not typically required, as manual processes dominated production lines.

Not much change is visible in terms of education and experience. However, technical knowledge and skill are reflected in workers' productivity. Now, to get recruited, a worker needs to finish a body/ process in 6 minutes on average, regardless of the production type; previously, it was 11 minutes. This is highlighted in the figure-16.

6.3.5 Psychological Stress and Increased Workload

For workers who have retained their jobs, automation has introduced new forms of psychological and emotional stress. The integration of automated systems comes with higher productivity targets and stricter performance monitoring, which can create an environment of pressure and anxiety. Worker's report feeling overwhelmed by the need to meet unrealistic expectations while adapting to new technologies. The increasing production target per hour is highlighted by the figure 17. Due to the introduction of automation production target for workers have increased by 64.14%.

Figure 17: Production target before and after automation

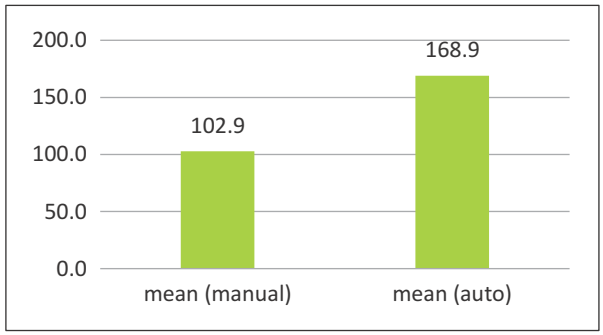
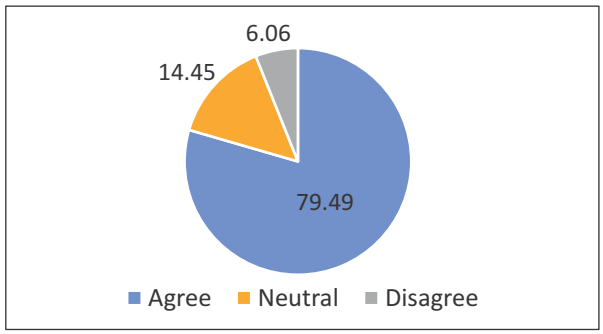


Figure 18: Worker's perception onyoung workers ability to operate automated machines



Additionally, while automation has reduced the manual workload for some tasks, it has increased the intensity of others. Workers operating automated machines in knitting are required to maintain constant vigilance to ensure smooth functioning, which can lead to fatigue and mental strain. Figure-18 illustrates that younger workers find it easier to operate automated machinery compared to older workers, with about 80% of workers agreeing with this statement. This disparity, coupled with the fear of being replaced not only by machines but also by younger employees, exacerbates job insecurity, ultimately eroding workers' morale and motivation.

Moreover, the worker survey has revealed that automation has increased external monitoring of the workers as 79.71% of the highly experienced workers reported it which has been confirmed by the other level of workers as well (table 20). As for the breaktime among the most experienced workers (more than 10 years), the agreement is highest at 43%, while 26% are neutral, and about 31% disagree. This shows that dissatisfaction with breaks is a common concern across all experience levels, with a slight increase in agreement as workers gain more experience, possibly reflecting heightened expectations for better work conditions over time. A notable percentage of workers have also reported that night shift has increased since the introduction of automated machines, which also contributes to the increased workload.

Table 20: Challenges faced by workers of different levels of experience

Challenges	Low experienced (<5 years of working)			Medium Experienced (6 to 10 years of experience)			Highly Experienced (>10 years of experience)		
	Agree	Neutral	Disagree	Agree	Neutral	Disagree	Agree	Neutral	Disagree
Nightshifts	24.32%	4.50%	71.17%	25.00%	7.78%	67.22%	30.43%	6.52%	63.04%
Less breaks	39.64%	31.53%	28.83%	41.11%	28.89%	30.00%	42.75%	26.09%	31.16%
External monitoring	76.58%	8.11%	15.32%	79.44%	3.89%	16.67%	79.71%	3.62%	16.67%
More abuse	26.13%	18.92%	54.95%	21.67%	14.44%	63.89%	23.19%	10.14%	66.67%

While factory management claims that physical and verbal abuse has been eliminated, many workers feel otherwise. In fact, 26% of less experienced workers, 21% of moderately experienced workers, and 23% of highly experienced workers reported that verbal or physical abuse has actually increased since automation was introduced.

6.3.6 Job Polarisation

This transition has also led to job polarization, particularly in mid-level roles. Many tasks previously handled by mid-level employees—such as data management, quality control, and routine decision-making—can now be performed more efficiently by automated systems and software. This change has reduced the need for such positions, leading to job losses or reassignments in these areas. While automation has opened new opportunities for highly skilled roles, the gap between high- and low-skilled positions has widened, leaving fewer opportunities for workers in the middle tier. These shifts highlight the dual challenge of leveraging automation for efficiency while ensuring an inclusive workforce transformation.

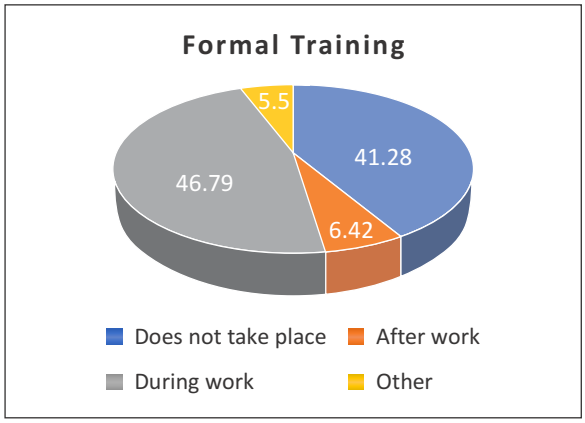
6.3.7 Limited Access to Training

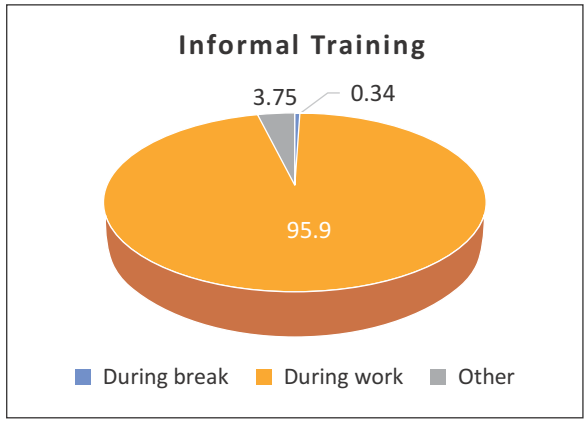
The transition to automation requires workers to acquire new skills, but many faces significant barriers to accessing training programs. Factories often prioritize short-term productivity gains over long-term investments in worker development, resulting in inadequate or poorly designed training initiatives. Workers frequently report that the training provided is insufficient to prepare them for the demands of automated roles.

From the data in figure 19 below almost half of the workers (41.28%) say they do not receive any formal training, which is a serious concern, especially as the industry becomes more automated. For those who do get formal training, most of it happens during work hours (46.79%), with very few opportunities after work (6.42%) or in other settings (5.5%). Informal training is far more common, with 96% of it happening during work hours, but it only lasts an average of 1.75 hours compared to 5.62 hours for formal training.

This lack of proper and consistent formal training leaves many workers feeling unprepared and worried about their job security. Without structured efforts to help them keep up with the increasing technical demands of automation, workers are left relying on shorter, less effective informal training, which adds to their anxiety about staying relevant in the industry.

Figure 19: Formal Training and Informal Training time





Note: The segregation between formal and informal training has been done by the authors to better explain the data. Here, formal training indicates the kind of training which is done outside of working hours and workers are compensated for receiving the training. This formal training can last for a week or month depending on the need and is conducted by the factory or some other organization. Informal training denotes training done in between work in an informal way for few hours. This usually includes a worker or a supervisor demonstrating the use of a machine and worker's just trying it few times.

6.3.8 Gender Disparities in Job Loss

It is already evident in this study that fewer workers were required in the factory after automation. In the survey, the workers were asked who was replaced more – male or female. According to the following table-20, 62% of the workers said more women were replaced-either by being reassigned to different roles or, in some cases, fired. As is evident in this study, there has been a smaller number of helpers after the emergence of new machines. While larger factories often have the capacity to reassign these workers, smaller factories may be forced to let them go. The FGD discussions have explored that women were mainly affected as most helpers were women. In this context, one of the FGD participants said, "Before the automatic machines came, a large number of women worked as helpers…Now that the automatic machines have come, we no longer require many helpers. As a result, a lot of women lost their jobs."

Table 21: Replaced workers by gender

Replaced worker	Freq.	Percent	Cum.
more men	98	22.84	22.84
more women	267	62.24	85.08
no noticeable difference	64	14.92	100
Total	**429**	**100**	

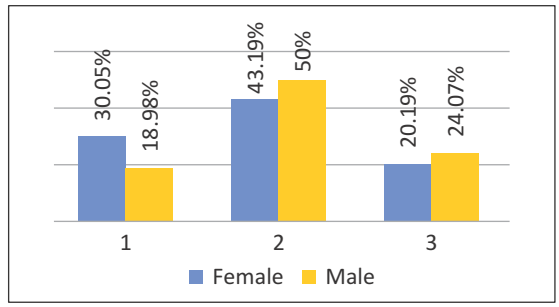
Studies show a decline in the number of women workers in the apparel industry, partly due to difficulties in adjusting to new machines. Some believe this is because men tend to have higher education levels, physical advantages, and more time to focus on training. There is also a perception that women are hesitant to handle advanced machinery. A study by Rahman et al. (2022) found that management often favours hiring men, prioritizing qualities like adaptability, long working hours, and the ability to handle automation—traits they perceive women as lacking.

However, labour unions disagree, arguing that the issue is not a lack of skill but biased perceptions. They believe women can handle advanced machines if given proper training, though balancing

household responsibilities makes it harder for them to participate. Learning speeds vary, and slower learners—regardless of gender—need more focused attention. A union representative pointed out that women are just as capable of handling automation, emphasizing that it is not as complicated as some make it seem. This underscores the need for fair opportunities and better training support for women in the industry.

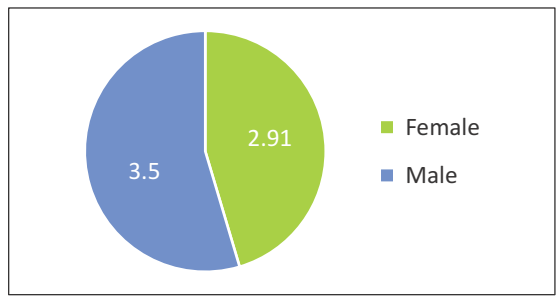
The figure 20 highlights the differences in average machine usage between male and female operators in the garment industry. Female operators typically operate fewer machines, often sticking to just one, while 50% of male operators can handle at least two machines. This trend continues with three machines, where male operators are more likely to specialize. Male operators also excel at managing multiple processes on the same machine, averaging 3.5 processes compared to 2.91 processes for female operators which is highlighted by figure 21.

Figure 20: Average machine user by gender



However, overseeing multiple processes presents significant challenges for female workers. The added responsibility and complexity can be overwhelming, particularly in environments that may not provide adequate support or training. This skill gap not only reflects on their income but also highlights the additional barriers female workers face in adapting to these demands, further contributing to disparities in opportunities and earnings.

Figure 21: Number of processes known by workers



6.3.9 Gender Inequality in Upper level of Production

In Bangladesh's apparel industry, gender inequality is starkly visible in upper-level production roles like CAD operations. While most garment workers are women, they remain concentrated in lower-level sewing roles, with men dominating digital jobs in CAD departments due to technical education or internal promotions. This disparity leaves women behind in a rapidly evolving industry. Stakeholders must prioritize providing women with access to CAD training, as their understanding of clothing construction offers a solid foundation for upskilling.

Physical demands also contribute to inequality. Women often avoid training for processes like denim production, which require physical strength, and focus on sewing tasks instead. Machines with complex mechanisms, like Jacquard and Kansai, are predominantly operated by men, leading to higher salaries and additional benefits for male workers. Women, by contrast, earn less and receive fewer privileges, further widening the gender gap.

Social structures and cultural norms, including religious restrictions, also discourage women from pursuing advanced training. However, women who do attend often adapt as well as their male counterparts. Despite these barriers, automation has provided some benefits, like reduced working hours and better work-life balance, allowing women more time for household responsibilities. Still, the industry must address these inequities to ensure women are not left behind in the push for modernization.

Chapter 7 Income Dynamics

Automation has reshaped income structures in the Bangladesh's apparel sector, creating a mixed picture for workers. While some have benefited from increased productivity and new opportunities, many faces stagnant earnings and widened income disparities, especially across gender and skill levels. The income of a worker is primarily decided at the time of recruitment. The production manager or the supervisor asks about the process worker. After knowing the process, the recruitment team assesses the applicant for a practical interview by finding out the time a worker takes in the machine to complete that process. After that, by seeing the capacity per hour or process, the factory management set up the salary and grade - A, B, or C. According to a worker, "In the interview, they [The hiring body of the factory] basically see our accuracy, hand speed, production per hour, etc. If an operator knows all of the processes of a body, he/she is selected for A grade operator, and the salary could be Tk.14,000 – Tk.15,000". Therefore, it is pivotal to examine any significant impact of automation on income.

7.1 Average Income with Shades of Complexity

The below table-22 shows that workers in automated processes across all factory types (jeans, knit, sweater, and woven) consistently earn more than their manual counterparts, with income differences ranging from approximately Tk.5,167 to Tk.6,108. Although this suggests a clear trend where automation is linked to higher earning, it mainly happens due to revised minimum wages.

Table 22: Income difference due to automation by factory type

Factory type	Difference (avg)
Jeans	5962.225
Knit	6108.104
Sweater	5167.24
Woven	6091.081

To find the relationship between income and automation, we have analysed other variables that influences monthly income. The regression analysis indicated that gender has a negative value of Tk.335.3 in the monthly salary keeping all other things equal, which means that female workers, on average, regardless of the machine/ process, earn Tk.335.3 less than their male counterparts.

Machine changes show a positive association with income, where each additional machine a worker learns to operate increases their monthly income by approximately Tk.278.14 Similarly, learning more processes (total process) is associated with a monthly income increase of Tk.118.28 per process. However, none of these are statistically significant as the p-value is greater than 0.005.

Years in the factory appear to have a positive impact, with each additional year contributing to a monthly income increase of Tk. 102.92. The p-value of 0.104 suggests this relationship is approaching statistical significance but is not definitive. The number of pieces produced per hour due to automation has a very small positive effect, with an increase of Tk.0.18 per additional piece. However, this result is not statistically significant as well. Similarly, the impact of machine years

under automation on monthly income is minimal (Tk.33.19 per additional year), with a p-value of 0.673 showing no significant effect.

The constant term, representing the baseline monthly income when all other factors are zero, is Tk.10,925.6 and is highly significant, with a p-value of 0.000. This suggests that other unexplored factors such as revision of minimum wage play a significant role in determining income. Overall, while some variables show positive trends, the lack of statistical significance for most of them indicates that the observed effects may not consistently influence monthly income.

It is evident in the study that the factory has gained a positive economic impact after the transition as automation is considered as a business case. For example, three workers are attaching welt pocket now with new machine which was done by seven workers with manual machine. It has become a business case for factory because three workers are doing the work of seven workers which has saved workers' salary of $850. However, there has been no proportionate rise of income of workers after the automation. When a worker changes a machine once their income increases by Tk.278, similarly knowing one extra process in a machine can increase the monthly salary by Tk.118. This highlights the fact that the more machine or process a worker can operate the more they earn monthly. Although the income has increased, this study has not found this increase as statistically significant and also very low considering doing the work of several workers with increased target.

7.2 Reduction in Overtime Earnings

One of the most significant impacts of automation has been the reduction in overtime hours. Weekly overtime has dropped from an average of 20 hours to 11 hours, largely due to faster production cycles enabled by automated machines which is supported by table-23. While this gives workers more time for personal and family responsibilities, it has significantly reduced their take-home pay, as overtime bonuses often made up a large portion of their income.

Table 23: Overtime hours before and after automation

Variable name	obs	mean (manual)	mean (auto)	diff	t-value	p-value
Overtime	318	19.9654	11.2138	8.7516	16.1774	0.0000

Note: Only workers with medium to high work experience responses analysed

This observation is also supported by the worker's survey where 88% agreed that since the introduction of automation they needed to less hours of overtime as compared to before. There has been an average of 8 hours of overtime reduction across all production process. But fewer overtime opportunities mean less financial security for those who rely on extra hours to support their families. This trade-off between income and work-life balance remains a key concern.

7.3 Limited Income Growth Despite Increased Responsibilities

While automation has enabled workers to operate multiple machines or processes, the increase in responsibility has not translated into proportional wage growth. Male workers who operate more advanced machines and manage several processes, such as Kansai or Jacquard, often earn slightly higher wages (Tk.15,000 per month compared to Tk.13,500-14,000 for others). However, this pay gap is not significant given the added workload and skills required to handle complex machines.

Female workers face even greater challenges, with limited access to these roles and no major income improvements for mastering additional processes. This lack of significant wage growth for increased responsibilities highlights a disconnect between productivity gains and worker compensation.

One connection between income and automation that this study has explored is that the higher the operation of a machine, the higher the income level. When a worker has only ever used one machine or has the knowledge of just operating one machine their income is lower compared to when they have the knowledge of using two different machines. Income increases by almost 9% when a worker has used two different machines compared to one regardless of their gender.

The data presented in the below table-24 shows a significant difference in performance incentives between manual and automated processes. Workers in automated processes receive higher performance incentives on average (449.29) than those in manual processes (256.40), with a difference of -192.89. This difference is statistically significant, as indicated by a t-value of -10.99 and a p-value of 0.0000, suggesting that automation is associated with considerably higher performance incentives for workers. However, according to the workers, wages have not increased due to automation. Even after many years of service in the same factory, they only receive the standard 5% increment. The yearly increment typically ranges between Tk. 500-600.

Table 24: t-test of incentives based on performance

Variable name	Observations	Mean (Manual)	Mean (Auto)	Diff	t-value	p-value
Overtime	318	19.9654	11.2138	8.7516	16.1774	0.0000

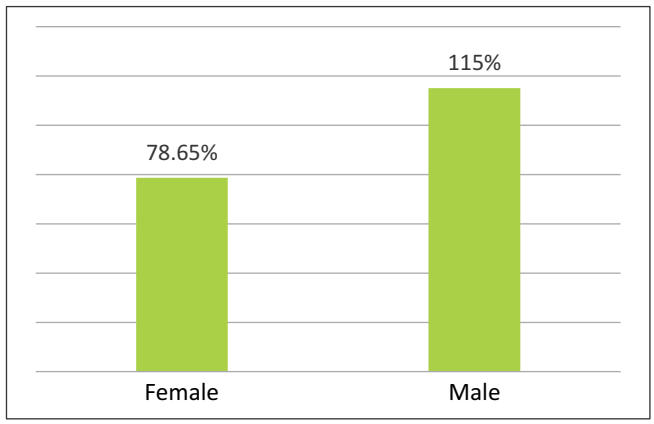
Note: Only workers with medium to high work experience responses analysed

7.4 Gender Pay Gap

This study does not find a significant gender pay gap between males and females as indicated in the regression table in the appendix. Females earn a little bit more than male workers. Whereas the average monthly income of females was Tk.13752, it was Tk.13371 for male workers. We have also compared percentage increase in monthly income by gender across four apparel factory categories: jeans, knit, sweater, and woven. Female workers earn more than males in knit production (females:

+9.47%), while males show higher earnings in jeans (males: +1.9%), sweaters (males: +9.32%), and woven apparel (males: +5.81%). It is important to note that income is not reflecting the minimum wages of current times, rather it is a broader comparison of two different eras (manual and auto). In the figure 19 below, it can be observed that female income increased by less percentage than male income after the adoption of automated machines. It is noted that about 36.35% has been increased for the male workers compared to female workers. It also based

Figure 22: Increase in percentage income by Gender by changing manual to auto machines



on manual timeframe before 2018 and automation after 2018. However, this captures the fact that male and female workers use different type of machines and work in different type of factories.

7.5 Barriers to Higher Earnings for Women

Women in the RMG sector face significant obstacles to earning higher incomes. Limited access to education and training, combined with societal expectations, often prevents them from taking on advanced roles or participating in technical training programs. This lack of opportunities means they are less likely to transition into higher-paying positions, even as the industry moves toward automation.

The preference for men in roles involving physical strength or complex machines further limits women's earning potential. Machines like Kansai or Jacquard are predominantly operated by men, who receive higher salaries for these roles. This systemic bias not only perpetuates gender disparities but also undermines women's ability to benefit from the industry's modernization.

This study highlights the percentage monthly income increase by gender with one and two machine changes throughout their career. It is important to note that this machine changes have happened though out their career so the incomes are averages of before and after 2018. Hence, income is not reflecting the minimum wages of current times. For females, income rises modestly at +3.79% when they have changed machines twice. This change of machine indicates how many different machines the workers have worked with in their time of working in this sector. For males, income increases sharply with a +15.67%, indicating a more significant income gain when handling additional machine changes than females. This suggests potential differences in task complexity or productivity associated with machine changes across genders. It can be also inferred that males handle more complex machines like Jacquard than female workers, which makes their income increase more sharply when they are given a new machine to work with in the factory. Income progression varies by gender and machine usage, with males benefiting most at two machines while females see steadier growth.

Chapter 8 Readiness to Automation

The readiness of factory and workers to changes in technology and machines has been analysed by evaluating the challenges they have encountered. The challenges of automation in the context of the Bangladesh's apparel industry can be analysed from the perspectives of two key stakeholders – factory and workers. Although different stakeholders' welcome automation, the concerns have varied from one another. Whereas affordability is the main challenge for the factories or the suppliers, job loss has become a crucial concern for the trade unions.

8.1 Less Priority

Automation has not been a priority for the factories as well as the government. Although it has triggered recently – some argued, after 2007 and others after 2018 –, compared to building safety and climate change, automation has not paid the attention at a broader scale. From 2013 to 2018, the Accord and Alliance was the key of attention of the factories, trade associations, buyers, and the government. Without ensuring building safety, it was impossible to get orders from the buyers. For the survival, everybody was concerned about getting the approval from the Accord and Alliance. After that, the priority was shifted to environmental sustainability from 2019 after the appearance of various legislations in the EU and the US which demanded commitment from the suppliers to reduce the level of carbon dioxide. This target is still going on and will be vital for Bangladesh in the post-graduation regime from the LDCs the continuation of business depends on the actions taken by the factories to the goal of net zero by 2050, a global commitment set by the UN. Compared to the building safety and environment, automation has never been a priority for the government of Bangladesh, BGMEA, BKMEA and the factory management. Despite less focused, the suppliers have transformed technology and machines as per the requirements and the process of production to remain competitive in the market. The automation has evolved over the time without paying a major attention.

8.2 Affordability to Investment and Payback time

The high cost of automation is a significant hurdle for factory owners in the apparel sector. Decisions about adopting new technologies often depend on whether they add value, reduce running costs, and deliver a fast return on investment (ROI). However, arranging the necessary funds remains a challenge for many. Access to financing is a major barrier, with funding options often being too expensive for smaller factories. As a BGMEA member pointed out, access to affordable finance is a persistent issue for investment in automation.

For factories exporting to the EU, meeting GST+ eligibility adds another layer of expense, requiring investments in backward linkages like fabric, spinning, and yarn. A factory manager explained that while funding from EU sources exists, the high cost makes large-scale automation unfeasible for most factories at present. This financial strain is worsened by the long payback periods associated with automation, which only larger factories with more resources can manage. Immediate impacts are often expected, but the reality is that most automated systems take years to show significant returns.

The cost of fully automated systems, such as IoT-enabled machines, remains prohibitive for the majority. It has been reported in the KII that only about 20% of Bangladeshi factories have adopted

such devices, partly because the depreciation of the dollar has driven up the cost of imported technologies. For example, transitioning from manual to automated knitting can cost around $8million, while implementing ERP systems requires an upfront cost of Tk.50 lakhs and monthly expenses of Tk.1.5 to 2 lakhs.

Although there are rare success stories, such as a factory earning $7 million in profit after a $45 million investment in automation, such cases are exceptions. Most factories in Bangladesh lack the financial capacity to make similar investments. Without more accessible financing options and shorter payback periods, automation remains out of reach for many, leaving the sector divided between those who can afford to modernize and those who cannot.

8.3 Capacity of Small and Medium Factories

Automation is not equally accessible to all factories in the apparel sector. While large-scale factories with substantial financial resources have successfully implemented automation, SMEs face significant barriers to adoption. The high cost of acquiring and maintaining automated systems, coupled with the long payback period, makes automation an unfeasible option for smaller factories.

This disparity has created a competitive imbalance within the industry, where smaller factories struggle to match the productivity and quality standards of their automated counterparts. Workers in SMEs are particularly disadvantaged, as they are more likely to face layoffs or stagnant wages due to the inability of their employers to invest in automation. This uneven distribution of technological benefits threatens the overall stability of the sector and raises questions about equitable growth.

8.4 Limited Supply of Technicians

A major hurdle in adopting automation in the apparel sector is the lack of skilled technicians to maintain and repair advanced machinery. When a sensor or key component of a machine breaks down, factories often cannot rely on local technicians and are forced to bring in specialists from the machine's manufacturer. This process is both costly and time-consuming, leaving machines idle for long periods. As one factory owner explained, their faulty machine sat unused until the next new machine arrived with a foreign instructor, highlighting the delays and inefficiencies caused by this skill gap.

This problem is compounded by the practices of machine providers, who often withhold complete technical manuals and encourage factories to rely on their teams for maintenance. This forces factory management to spend additional money on foreign technicians rather than empowering their own workforce. As one supplier noted, this dependency creates an unnecessary financial burden for factory owners, who feel exploited by these companies.

The lack of investment in local technical capacity further exacerbates the issue. Factory owners admit that while the industry has expanded, little has been done to build a local talent pool capable of handling advanced technology. This oversight has left factories reliant on external expertise, with one owner reflecting, *"We grew as entrepreneurs, but we never invested in capacity building, and now we are paying the price."*

Additionally, the absence of skilled local technicians leads to other complications. Workers, fearing job loss due to machine breakdowns, often attempt to fix issues themselves without management's knowledge. These unauthorized repairs can cause further damage, making the

machines even more expensive and complicated to fix. This highlights the urgent need for investment in local technical training to support the sustainable growth of automation in the apparel sector.

8.5 Resistance in the Mid-Level Management

Training mid-level managers and operators to adopt new technologies is a significant challenge in the apparel sector. Many views changes to traditional processes as a threat, fearing job loss or diminished credibility, rather than recognizing the potential benefits of automation in simplifying tasks and enhancing production efficiency.

Resistance is particularly common among middle-aged managers who have worked in the same way for decades. Some supervisors and managers, having risen through years of experience, are hesitant to embrace training programs, fearing they will lose their authority or be replaced. Younger managers, however, are generally more open to adopting automation.

A consultant noted that mid-level managers' resistance often undermines training efforts, while their cooperation ensures success. Some managers oppose training workers, believing trained employees will leave for other factories, ignoring factors like delayed salaries or supervisor mistreatment that drive turnover. As one development partner pointed out, even if a few trained workers leave, the industry as a whole benefit.

An additional challenge is the mindset of some managers who rely on outdated methods like verbal abuse to achieve productivity, rather than adopting organized and data-driven approaches. This attitude hinders the adoption of systems like ERP at the factory floor level, as many managers prefer to "firefight" problems instead of following standard operating procedures. Changing these entrenched attitudes is critical to successfully implementing automation and improving workforce efficiency.

The supervisors, production managers and other mid-level management closely monitor workers to raise productivity by smother transition to technology. But sometimes, this group of upper-level staffs lack technological skills, which is another challenge for the factory owners. In this case, a factory has faced difficulties in implementing IoT due to a shortage of skilled workers in both production and management. Mid-level management must be skilled to effectively train workers and maximize the benefits of system and machine automation. However, Bangladesh's garment industry lacks formal training or education for this management level from the government, buyers, or development partners. The disappointment of factory management is reflected in this statement, *"The contribution of workers in the total value chain is 15%, so there is no way to improve the production efficiency if the factory only focuses on the workers and not the management."*

8.6 Absence of Cohesive Systems within Factory Operations

For the maximum utilization of automation, it is important to install a governance system in factories that can present the whole picture of the factory. The leading factories usually have such mechanisms, but a majority of factories do not realize the necessity of such an idea. One of the major challenges highlighted by trade associations is the absence of cohesive systems within factory operations. While the factories themselves are mechanized, the critical aspects behind the scenes such as salary disbursement, calculation of technical requirements, and other operations

unrelated to production, are not effectively connected together into the operation. This lack of cohesion greatly diminishes the potential for maximizing efficiency from the automated machines and advanced technology

8.7 Finding the Right Fit

The key challenges faced in implementing automation is finding the right fit for requirements as technology is ever evolving this sometimes becomes infinite. There are multiple promising options form variety of machine, software and IOT manufacturers globally. Choosing the right fit for your particular need is quite challenging. To choose the right fit one has to do rigorous research and find best options catered to the needs by making comparison based on adaptation for the future, customization, finding ease of use, cost of investment and longevity of the technology. Once the right technology is known, it is important to understand how the technology implementation plan will transform existing production dynamics making a good synergy between man and machines. In a country like Bangladesh, where more than half of the people are yet to explore and learn about adaptation to new technology, it is always important not to select complicated technologies and operations that might disrupt the current ways of work that the people are used to.

8.8 Availability of Educated Workforce

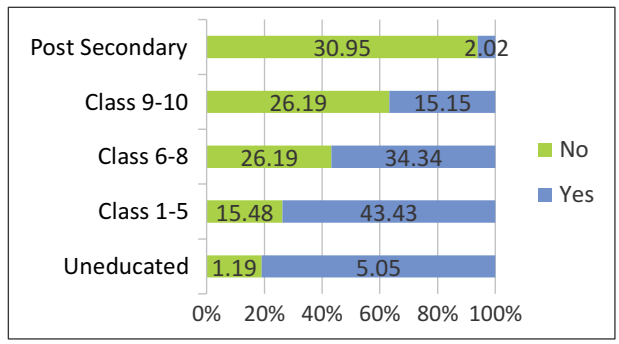
The recruitment criteria in the apparel industry have changed with the rise of automation. In the past, factories hired illiterate workers who could handle basic sewing tasks. Now, with semi-automated machines, workers are expected to have at least secondary or SSC-level education to read instructions, which are often in English, and operate the machines effectively. While some experienced workers argue that skills gained over time are enough, younger workers and factory managers believe that basic literacy, numeracy, and digital knowledge are key for adapting to modern technology and advancing in their careers.

Many workers feel that higher education is not always necessary, as machines now come with easy-to-understand labels and symbols. Surveys show that six years of education is generally enough for most tasks, similar to what was required for manual machines. However, factory managers note that workers with higher education tend to learn faster, require less supervision, and provide better feedback, making them more productive overall.

Despite these benefits, low productivity remains a concern for factory management, and they often link this to the limited educational backgrounds of workers. The broader challenge is helping workers improve their understanding of technology through better education and training.

For the future, stakeholders agree that having more educated workers is critical, especially as automation continues to grow. However, attracting educated workers, particularly women, is becoming harder. Another study conducted by Rahman et al. (2023) shows that only 2% of those with post-secondary education want to work in apparel, citing high production targets, stress, and the demanding nature of the work as reasons to avoid the industry that is presented in the figure-23. This reluctance highlights a growing challenge for factories as they seek to build a more skilled and educated workforce.

Figure 23: Education level of potential workers



8.9 Insufficient Capacity to Multi-Process and Multi-Machine

Another challenge the factories encounter is skill deficiency in operating multiple processes. Semi- and automated machines come with more than one process in a machine. Although the workers argue in FGDs that machines are easy to learn, one needs to practice for a few hours or days, some factory managements disagreed with this view. From the experiences of senior managers, informal training may be required for some machines, but it is not the case for all machines. Some machines are difficult to operate without formal training. Some workers do not have the skills to manage all the processes involved in one machine. In this way, all machine features remain unused, and in terms of cost-benefit analysis, it is not worth purchasing those machines. Having these skills also benefits workers. As a factory manager said,

> *"One machine can facilitate multiple skills, and if a worker can do all of them, then they can get higher salaries or better increments."*

The BKMEA, BGMEA, and factory owners who participated in this project as KIIs have stressed the need for workers to learn multiple processes to remain relevant in the evolving industry. As automation takes over specific production sections, workers with knowledge of various processes can move between roles and stay employable. This recommendation underscores the growing importance of adaptability in the workforce as automation reshapes the industry. Workers who can perform various tasks will be better positioned to avoid job loss and contribute to the changing production landscape.

According to FGD participants, factory management prefers workers who have done critical work and know more than one process. Knowing different methods, such as how to do pocket join, pocket bond, bond toxin, and level toxin, would place a worker in a better position to grab a job. In this regard, one of the workers shared her experiences, saying,

> *"In Bangla machine, if we know one process, we were selected for the job, but now, in the era of the auto machine, we have to capture at least two processes; otherwise, we are not selected for the job."*

Multitasking training ensures that workers are not limited to one specific task but can handle multiple functions, making production lines more resilient to staff shortages or sudden increases in demand.

Misunderstanding of workers about skills advancement through training: Evaluation by a factory

Every machine has a control panel, whether a sewing, knitting, or dying machine. They all have a control panel or dashboard. You can see all the information on that dashboard, how long it has been running, the rotation of the motor per hour, and even, in some cases, you can see the product's qualities on your dashboard. A machine has multiple software features, but the operators only learn the basics. They only learn how to turn on and off the machines, which button to push to run the machine, or changing the needle, or which lights will blink if there is an error. However, in a single machine, you can have multiple functionalities; for example, you can get different types of sewing performance by reprogramming the same machine. This is where you need skills. We have seen the transformation from manual to semi-automatic to automatic technologies. But you can quickly run those machines only with basic skills. We have this kind of basic skills. However, our workers do not have that much skill to utilize the full functionalities of these machines

for further expertise. Our current skill level is limited to the worker's efficiency level. But if you consider the technological skills, for example, as I have mentioned before, utilizing multiple functionalities of the machines, we are far behind. Our workers don't even know that these functions exist, they don't know that by setting an IOT they can quickly get a productivity report, and if anyone lags behind, we can assist them or add quality control attributes. Our workers are never being trained on these things. This is one kind of loophole for automation. What happened in our country is that the owners spent some money to buy automated machines and gave those to inexperienced or unskilled workers, who only learn the basic operations but don't have any interest in learning advanced use of those machines, nor do they have the time or opportunities to learn them. If we had small factories, like a factory with only ten machines, wherewith those ten machines you are doing multiple things, or if we had fashion makers in our country then it would be possible. Since we are a country that only exports essential products, we aren't required to explore the advanced use of these machines. However, in some cases, we will find some people who have learned advanced skills. What kind of advanced skills are we talking about? Today, the most important thing is to develop AI skills because we are gradually shifting to AI-driven technologies. For example, in the case of CAD, Marker, or patternmaking software, we must learn how to use AI. Especially in the sample section, these skills are the most important things.

8.10 Digital literacy: Understanding Apps, Tabs, and basic Computer

In an article, Sarah Krasly, CEO of Shimmy Technology, and Rubana Huq, former President of BGMEA, argued that digital literacies should centre around digital models: reading, changing, evaluating, troubleshooting, and, at the top skill tier, creating. Education is required to understand digital literacy. The advantages of having educated workers understand quickly the instructions and guidelines of machines, which are written in English, and less dependence on supervisors and others to operate all processes of a machine. It was reported by a few FGD participants that many workers run advanced machines by intuition, and they memorize the buttons and their functions. They believe that if a worker just studied till class 4-5, they usually do not understand the guidelines. Echoing this argument, another worker argued,

> *"…The new machines from Brothers Company show errors on the display. Even if a needle is broken, you can see that on the display; you don't manually search for everything. Now, if anyone does not understand English, they can't read the display. If I had a better education, I could easily read and understand the functions. Even If I don't have experience, I might learn quickly if I am educated enough. Otherwise, I will have to learn by experience, which will take time."*

To upskill the workers, The Asian University of Women in Bangladesh has taken the initiative to provide primary education in English, Math, and computers to the women garment workers. The former President of BGMEA argues that the objective of this level of education is now essential to participate in digital-based training using tabs, understand the instructions of current and future machines, and absorb the training well. The trade representative also believes that workers with 11-12 education grades are in a better position to utilize changing machines and technologies properly.

Considering the readiness for future work, the use of computers is another area to concentrate on. The work done now manually, might be done in the future automatically by computer. One person will operate multiple machines with just one computer. After doing a need-based assessment of future work, basic computer knowledge is essential. Realizing this necessity, a worker said,

> *"If we want to stay employed in this industry, we must learn the new technologies. We must learn to use advanced computers."*

8.11 Inefficient Training Structure

There are different ways to train the workers according to the needs. The training institutes can focus on the skills required in this industry that have already mentioned in this study. One way to receive training which is also dominant in the industry is the factory in-house training. The leading garment companies have training academy who do the need assessment of their workers and offer training to them in align with the new machines. Another way is to receive training from private organizations as consultant groups and sometimes offered by development partners. The most dominant approach is training provided by government institutions. The National Skill Development Authority (NSDA) oversees skill development policies, strategies, and training standards in Bangladesh. While NSDA does not directly provide training, it monitors over 855 registered institutes, including 100 for the apparel sector, ensuring quality and consistency across public and private training centres. NSDA collaborates with 29 ministries and development partners like ADB, World Bank, and GIZ, while working to align training curricula with domestic and international labour market needs. The current problems of training institutions are discussed below.

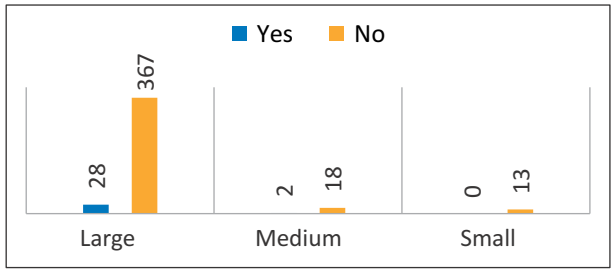
Training Modules and Tools: Most training centres (80-90%) rely on traditional theoretical methods, while only a small portion focuses on Competency-Based Training and Assessment (CBT&A), which emphasizes practical skills. Additionally, there is a shortage of qualified trainers and modern tools, particularly in government-owned centres, which struggle more than factory-owned STPs. While NSDA has developed training modules covering basic to PLC machines, advanced topics like robotics and IoT are absent due to high costs and limited resources. This lack of updated curricula hinders the preparation of workers for 4IR technologies.

Worker Availability and Demotivated Centres: Workers often cannot attend training after work hours, and many training centres lack motivation to fully utilize NSDA's diverse curriculum. To address this, NSDA introduced Recognition of Prior Learning (RPL), enabling workers to study independently using competency-based learning materials (CBLM) and take certification exams at training centres. While these steps aim to bridge the gap, training centres need greater encouragement and market-driven approaches to diversify their programs.

High Cost of Training Tools and Lack of Support: As the training tools are expensive, it is hard to convince the training centres to run specific training programs, for example any modules with Iot. There have been seminars and advertisements to motivate and disseminate the training programs to the broader public. Till now, the government has not taken any bold steps regarding the matter, such as not letting new training centres teach the same modules as the existing ones or limiting training centres on how many same modules they can teach in a period. However, if needed in the future, NSDA is planning to take those steps.

The figure 24 suggests that while more giant factories might have a slight edge in accessing support, organizational engagement across all factory sizes remains minimal. Over the past decade, only four out of 66 training projects in the apparel industry have focused on skill development for workers, with most programs addressing safety and workers' rights after the Rana Plaza tragedy. Barriers like shifting funds to the Rohingya crisis, budget cuts during COVID-19, fears of workers leaving after training, disruptions to production targets, and a lack of emphasis on training by authorities have all contributed to this gap.

Figure 24: Training support from organizations



Workers also face personal challenges. Training costs are often too high, and most programs only cover basic tasks, leaving them unprepared for advanced technologies or roles requiring them to handle multiple machines. Digital training is unpopular because workers feel it doesn't provide the hands-on experience they need. Many believe factory-based training would be the best solution—it's affordable and tailored to meet the current demands of production.

Participatory committees (Pcs), which could address training needs, rarely discuss skill enhancement, focusing instead on workplace issues like leave and conflicts. Factory management also struggles with a lack of foresight, often unaware of future technological trends. Workers suggest that if management and PCs prioritized preparing for upcoming advancements, it would make training more relevant and accessible, ensuring they're ready for the future.

Lack of Blended Training: Training programs primarily focus on technical skills but neglect soft skills, which are essential for holistic development. International consultancy firms have emphasized that blending technical and soft skills leads to better outcomes, but this approach is yet to be widely adopted in Bangladesh.

Outdated Machinery: A significant gap exists between the outdated machinery used in many Technical and Vocational Education and Training (TVET) centres and the advanced systems in modern factories. Some training centres still use equipment from the 1960s, leaving workers ill-prepared for the automated machines they encounter on factory floors. This disconnect highlights the urgent need for updated infrastructure in training centres.

Limited intension to invest in worker: Factory managers often worry that workers leave for better-paying jobs at other factories after being trained, making them hesitant to invest in upskilling. Workers use their new skills to negotiate higher salaries elsewhere, which is seen as a loss for the factory that provided the training. A global training expert suggested a shift in mindset, encouraging factory owners to view training as an investment in the industry, not just their business. *"Show workers they matter—invest in their skills even if they might not stay forever. This builds mutual respect and loyalty,"* the trainer explained. While some workers may move on, their improved skills still benefit the apparel sector and the country's overall growth. Thinking this way could encourage more factories to invest in training, helping advance both the workforce and technology.

Table 25: Workers' views on how to improve training

Worker's Perspective on Automation	Number
Training During work	132
More frequent training sessions	125
Personalized training based on individual needs	42
More hands-on practice	42
Better instructional materials	29
Training after work	12

The above table 25 summarizes worker suggestions for improving training programs. The most common suggestions include training during work hours (132) and more frequent training sessions (125). Suggestions for personalized training and more hands-on practice are equally important (42 each), followed by better instructional materials (29). A smaller number prefer training conducted after work hours (12). These insights emphasize the importance of integrating training into work schedules, increasing frequency, and tailoring it to individual needs to enhance effectiveness.

Shimmy Technology

"Shimmy Technology is a global training provider. The way Shimmy works is innovative in that they look at the large data sets about the behaviour of automation, what machinery is leaving and coming into the sector, and then understand what machine skills will correlate with helping somebody to be successful in the labour market. In their research report, Pulse, the initiator found that Kansai, feet-of-the-arm and automatic pocket settings were three of the types of machinery most of the Apparel factories were purchasing. The training was designed in such a way that labour is optimized along with those shifts in machinery. Explaining the training process, the CEO of Shimmy Technology said, "Every automated machine has a digital screen at some point, and many workers don't have a high level of digital literacy. So, what we do is look at the shapes, the symbols, the buttons, and the elements of those digital controllers, and then build those into games. So, before somebody knows it, they're touching an arrow. The screen is behaving in this way, allowing that person to have the correct digital literacies to be much more successful in completing that machine training when they're sitting in front of the machine."

Absence of Gender Friendly Training: The data from table 26 on training highlights efforts to address skill gaps through inclusive programs aimed at workers with basic education. Among females, 12.67% participate in formal training compared to 17.13% of males, while informal training includes 65.73% of females and 73.63% of males. Although male participation slightly exceeds female participation, the differences are not statistically significant for either formal (Pr = 0.195) or informal training (Pr = 0.076). This suggests that the training curriculum, designed to be accessible to all workers regardless of gender or education, has helped reduce disparities. Using visual aids and simple instructions has made skill acquisition easier for everyone.

Table 26: Formal and Informal Training based on Gender

Gender	Formal training		Informal training	
	No	Yes	No	Yes
Female	186	27	73	140
Male	179	37	57	159
	Pr= 0.195		Pr = 0.076	

However, challenges persist, particularly for female workers. Household responsibilities often prevent women from attending training sessions outside of their shifts. Additionally, lower education levels among women in Bangladesh make adapting to automation more difficult. As noted by a factory manager, some female workers still struggle with basic literacy tasks, such as signing their names, highlighting the need for better support and targeted training to help women adapt to the changing workplace.

Chapter 9 Recommendation

A coordinated approach from factories, training institutions, brands, buyers, business associations, government, and development partners are key to ensuring automation benefits everyone in the industry.

Manufacturers/Suppliers

- Develop a strategic plan for sustainability to ensure a just transition for workers and smooth business operations.
- Establish structured training facilities (inhouse or outside the factories) for skilling and upskilling workers and mid-level management, in partnership with training institutes or consultancy firms so that workers can be replaced to other sections.
- Ensure timely information sharing with workers to prevent panic and conduct counselling sessions to reduce workplace stress and fear of adopting new machinery.
- Offer motivation packages to engage workers in the learning process and reward those who enhance their skills with new machinery.
- Introduce internship programs in collaboration with Technical Education Institutes to attract future talent to the industry.

Brands and Buyers

- Ensure responsible business conduct (RBC) and ethical trading practices.
- Conduct impact assessments to evaluate and update the social and economic effects of automation on workers and suppliers.
- Collaborate with suppliers, trade associations, trade unions, and governments on transparent, inclusive automation strategies.
- Design and fund training programs to help workers adapt to new technologies or transition to new roles.
- Ensure fair wages, safe working conditions, and labour rights are maintained throughout the automation process.
- Commit to long-term contracts and adjust pricing structures to offset automation costs for suppliers.
- Work with suppliers to minimize layoffs by focusing on reskilling/upskilling and redeployment within the supply chain.

Trade Unions

- Coordinate and collaborate with employers, employers' associations, brands, Government, and CSOs to initiate structured capacity development program that equip workers with skills for new roles in automated environments.
- Advocate with the government and other right holders to develop and implement policies like a just transition that protects workers during technological shifts.

- Ensure that decisions about automation are communicated openly and that the approaches are participatory, where workers and their representatives are consulted on automation strategies.
- Ensure women are not disproportionately affected by automation, rather provide additional support for women workers during the transitional process.
- Push for stronger social safety nets, including unemployment benefits, pension schemes, access to affordable healthcare and education, etc.
- Engage for greater accountability from global brands to ensure their supply chains remain ethical and comply with global labour and human rights standards amidst automation

Government

- Develop a National Plan of Action on just transition prioritizing workers welfare that includes job creation, skill development, and social security for those affected by the automation.
- Strengthen labour laws and protection to address challenges posed by automation and ensure fair benefits and compensation for displaced workers.
- Provide access to finance for technology upgradation, green infrastructure, and advanced machinery, especially for small and medium factories.
- Strengthen the National Skills Development Authority (NSDA), National Occupational Safety and Health Training and Research Institute (NOSHTRI), and other public and private Technical Training Centres (TTC) and Technical and Vocational Education and Training (TVET) to offer demand-based skills training for workers and mid-level management.
- Develop upskilling and reskilling programs specifically tailored to the needs of female workers, emphasizing technical, digital, and managerial skills to upgrade their current grades, which may further lead them into supervisory roles.
- Foster inter-ministerial collaboration (MOLE, MOI, MOF, MSW) for inspections, job creation, guidelines, social security, and related services.
- Enhance regular inspections through DIFE to minimize job loss and ensure worker benefits.

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Chapter 11 | Appendices

11.1 Appendix 1: Names of Machines by Types of Factories

Stakeholder Groups	No. of KIIs
Knit	Over Lock, Flat Lock, Plain Machine, Lock Machine
Woven	Button attaching machine, buttonhole machine, feed off the arm, needle lock stitch machine, chain stitch machine, embroidery machine, bar tack machine, zigzag sewing machine, Blind stitch machine, cover stitch machine, Fusing Machine, Kansai machine, two needle vertical machine
Denim	Automated Single Needle Post Bed Tacking Machine, Automatic Jeans Pocket Setter, Belt Loop Making Industrial Sewing Machine, Double-needle Lockstitch, Eyelet Hole Machine (Making Eyelets), Single needle edge cutter, 2 Needle 5 Threads Over locker, Snap Button Attaching machine
Sweater	Jacquard, Cut & Sew, Panel Knitting, Full fashion, knit to wear
Jeans	Spreader, auto cutting, Metal Detection

Source: Based on Survey

11.2 Appendix 2: Case Study of a Garment Company

Established in 1993, SMA is a leading vertical textile manufacturer in Bangladesh. With over 22,000 employees and an annual turnover of over 95 million USD, the company specializes in denim, knitwear, woven garments, and lingerie. Their business portfolio encompasses knitting, dyeing, printing, sewing, distribution, and sports apparel. In 2010, SMA ventured into garment manufacturing with SMA Garments Ltd., and their knitwear project has experienced significant growth over the past 11 years, attracting partnerships with major brands.

Ground-level automation began in Bangladesh in 2010. Since then, garment factories have largely stopped using manual, non-electric machines. The denim sector is the most automated, followed by woven, knit, and sewing. SMA group aims to vertically integrate its operations and become the leading denim manufacturer with the highest quality standards.

The general manager of SMA group stated that the increasing competition from Vietnam, India, and Myanmar in the cotton-dominated basic fashion market forced them to automate their production lines. Automation made production more efficient and cost-effective. SMA Garments now has 1500 automated machines, increasing their daily production capacity to 30,000 pieces. This automation has boosted worker productivity by 25% since 2010. The company uses various automated machines, including the Automatic Snap Button, Feed of The Arm, Automatic Loop Attach, APW Machine, Bottom Hemming, Pattern Sewing Machine, Destroy Stitch Machine, Spreading Machine, Automatic Back Pocket Attach, Double Head Needle Detector, Automatic Back Pocket Rolling, Automatic Cutting, Automatic Loop Attach Vibemac, Pant Finisher, and Auto Edge Cutting. This modernization has helped SMA remain a leading textile manufacturer in Bangladesh.

There are two types of automation in the apparel industry: system and machine automation. Successful automation requires both. SMA group has implemented system automation using digital IDs, fingerprint scanning, a PA system, mobile payment, RFID, IoT, safety hotlines, and more. This system is crucial for efficient production. Digital attendance has improved time management as supervisors no longer need to track workers physically. System automation has also facilitated communication between supervisors, managers, and workers. It has improved the livelihood of the workers as salary is given on time through mobile financial services.

Automation has simplified not only monitoring but also the hiring process. Workers undergo a three-day trial period to assess their skills before being assigned tasks. While most workers are hired based on their ability to operate a specific machine, there are also instances where untrained workers are hired and trained for 15 days to 3 months. SMA group has an in-house training facility for up to 30 workers at a time. Moreover, the SMA group has an in-house research and development team which works relentlessly to develop fresh designs based on consumer preferences and pleasure to draw more attention. The R&D team is eager to meet consumers' demands and provide unique products.

Machine automation has had a nuanced effect on the workers. While it has boosted productivity and improved working conditions, it has also resulted in a change in the male-female ratio, notably in the denim and woven sectors. These industries need greater physical strength, which makes them less enticing to female employees. This is because to the heavy denim fabrics and lengthy, physically difficult shifts which lasts up to 12 hours in the woven sector. The sewing business remains primarily female-dominated. SMA Group recognises the impact of automation on worker well-being, particularly among female employees. To address these issues, they have created nurseries and fatigue rooms. On the other hand, second-generation garment workers are more at ease with high-tech machinery and less concerned about being displaced. SMA group's management feels that job security is not a worry while the garment industry of Bangladesh is still expanding and seeks additional people.

With increasing competition from neighbouring countries such as China, Vietnam and India, Bangladesh’s longer lead time than the rest of the countries creates a competitive disadvantage. To gain the buyer's confidence, factories have automated their production process. Bangladesh holds a relatively small market share in the global apparel industry; it specializes in fast fashion and streetwear designed for short-term use 4-5 times. Bangladesh's slower production capabilities than its competitors underscore the urgency of adopting more automated machines to meet the demands of this market segment.

Getting the return on investment remains one of the biggest challenges for the industry. For instance, using an AI-enabled machine saves up 1.38% of fabric, which is estimated to save 130 tons of fabric annually, having a market value of almost Tk.4 crores. Also, the outcome of value stream mapping (VSM) indicates improved productivity among workers with automated machines. It seems logical for factories to invest in AI-enabled machines. However, with the cost of setting up the machines and accounting for depreciation of these machines, it is difficult to get production returns of these capital investments accounting for the fact that the buyers are not getting expensive high-value garments from us.

The cost of implementing fully automated systems with IoT-enabled machines remains a barrier. The dollar depreciation has further exacerbated this challenge by increasing the cost of imported technology. Only 20% of Bangladeshi apparel factories have adopted IoT-enabled devices. SMA Group, despite having the necessary physical infrastructure, faces difficulties in implementing IoT due to a shortage of skilled workers both in production and management. To effectively train

workers and maximize the benefits of system and machine automation, mid-level management must be skilled. However, Bangladesh's garment industry lacks formal training or education for this management level from the government, buyers, or development partners. The contribution of workers in the total value chain is 15%, so there is no way to improve production efficiency if the factory only focuses on the workers and not the management.

On several occasions, workers have removed pieces of the machines and repaired them on their own without management notice, highlighting the need for better management skills to monitor worker performance. The lack of accountability on the worker's side also poses a threat to the adoption of full automation. There is no system to track worker skills, efficiency, or training, which will help in the hiring or additional training facilities. Moreover, the government offers no incentives for automation, even when factories invest in new technology.

The government may significantly contribute to the garment industry's technological shift. Delays in the ports and customs increase the lead time, which is a disadvantage for garment manufacturers. The government can address this issue by implementing stricter regulations and improving efficiency at these facilities. Additionally, introducing curriculums to train management of the apparel industry can enhance the usage of the existing automated machines. By 2030, the SMA Group hopes to establish a male-female ratio of 50-50 in management, which presents a significant challenge given the industry's low percentage of female managers. Therefore, if the government, NGOs, and other development partners promote working for the apparel industry in management and provide appropriate training and workshops, it will immensely benefit the apparel industry.

11.3 Appendix 3: Case study of Altaf: Competition with Jacquard Machines

Altaf has been working in the apparel industry from the inception of manual machines. He works as a senior operator for Slace Sweater Ltd., which is based in Konabari, Gazipur. His employment experience is roughly 15 years. He has two children and lives with his parents in a little home. He is not a well-educated person, but he completed Higher Secondary School with great enthusiasm. Due to familial obligations, he was unable to continue his academic studies.

Altaf resided in a small village near the border in Sherpur. This hamlet lacked food and job possibilities. As a result, Altaf's parents moved from Sherpur to Ashulia. The days were really difficult and painful for them since his parents earned a small amount of money, and with that money, his family struggled greatly. Altaf was just 10 years old at the time, and he began to accomplish something, but he lacked the necessary skills. A garment factory was being developed in Ashulia during the time. As a result, their only alternative is to rely on the income of his parents, and it was claimed that his father was a rickshaw puller and his mother was a day labourer on a small ship. After some time, they decided to relocate to Gazipur after hearing from relatives that there were job opportunities available in the area. After moving to this neighbourhood, they spent their days nicely, although Altaf's father is currently unable to pay for his studies. Altaf then began looking for work, but nothing suited him. When he was 17 years old, he discovered that one of his cousins worked in a sweater factory that was focused on production. Then he became interested in the job and began to learn it. He stated that he received no formal instruction from the factory and instead learned by observing other workers. Because it was a sweater factor, they used a machine called the Raw Machine. At the time, the garment machine was manually controlled. One person operates one machine at a time. They worked at this factory on a per-day production basis, which meant he would be paid based on how many sweaters were produced. He continued for three to

four years after that, and he noticed that the manual machine was being replaced by an automated one. At the time, Altaf was fired because the factory owner had begun to build up automated machines, and the factory owner needed only a few operators to operate the Jacquard machine. Altaf started looking for work as a helper in sweater manufacturing.

After a few months, he landed a job as a helper at a sweater factory. Then he realized that in order to operate an automatic jacquard machine, he needed to follow certain instructions. He explained how he operates a machine.

> *"In a factory, the customer first selects a product design, and the factory authority follows that direction. Our programmer set the design, and they stored it on a pen drive. Following that, the operator installs the program on their PC according to the instructions. Following that, our supervisor inspected the entire system of our queue. I believe that is a type of robotic work."*

According to his opinion, nowadays, a single person can operate 5 to 8 machines at a time with no physical struggle, whereas in the past, manual machines caused a lot of pain in the body because they were run by body. Nowadays, computers are used to program the machines.

Altaf eventually began learning Jacquard programming. He eventually realised that this programming job was not readily available at the moment. Then he began to use the machine day and night. He was obsessed with the robotic operating machine. The proprietor runs this machine 24 hours a day, seven days a week for the benefit of the factory. As a result, Altaf had to work nights two weeks every month. Because of the change in routine, he was unable to sleep properly. On the other hand, he no longer received a high salary. He worked at a factory but only earned a tiny amount of money to support his family. He began to consider leaving his work and starting a small business. It is a common thread in the apparel sector that they cannot pay the most experienced operator a fair rate.

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